WRIGHT

GL01630

VICTOR ATIYEH
GOVERNOR

Department of Geology and Mineral Industries

ADMINISTRATIVE OFFICE

1005 STATE OFFICE BLDG., PORTLAND, OREGON 97201 PHONE (503) 229-5580

May 1, 1985

Peter Bethe
c/o DOSECC, Inc.
Houston Airport Hilton Inn
Houston, TX 77060

Dear Dr. Bethe:

I am sorry I could not attend the Houston meeting, but a rather severe respiratory infection prevented me. I understand that Dave Blackwell stood in for me and did an admirable job of presenting the Cascades as a candidate for scientific drilling.

Dave called me on Tuesday and indicated that your committee would need some form of proposal with preliminary budget estimates by Thursday or Friday. I have been putting off assembling a final proposal until after the USGS-sponsored Cascades Workshop is held on May 22-23. Nevertheless, our group has been working on this for about two years, and a preliminary outline of the proposal is certainly possible at this time.

Enclosed is a very rough preliminary outline emphasizing the first phase of the investigation, an intensive program of drilling and surface surveys in the Breitenbush-Santiam Pass area of the central Oregon Cascade Range. <u>This proposal is preliminary and subject to modification. It should be used only for generalized planning and should not be widely distributed</u>.

I hope this rough outline will be of help to you. If you need further information please feel free to call me or Dave Blackwell. On Thursday and Friday of this week I will be in the USDOE headquarters at Idaho Falls, Idaho serving on a technical review panel. You can reach me at (208)526-1229 during the day and at (208)523-5993 on Thursday evening. Dave's number at SMU is (214)692-2745.

Best regards,

George R Priest

OUTLINE OF A PROGRAM FOR SCIENTIFIC DRILLING IN THE CASCADES

INTRODUCTION - THE NEED TO DRILL IN THE CASCADE RANGE

For the past two years a group of investigators has been collaborating on a plan for scientific drilling in the Cascade volcanic arc. The group consists of representatives from:

United States Geological Survey
Los Alamos National Laboratory
Sandia National Laboratory
Lawrence-Berkeley National Laboratory
Southern Methodist University
Oregon State University
University of Oregon
University of Wisconsin
Oregon Department of Geology and Mineral Industries
Division of Geology and Earth Resources, Washingtion State Department of Natural Resources

The aim of this group is to develop a quantitative model of the dynamic processes active in subduction-related volcanic arcs. Of particular importance is the need to establish causal relationships between the process of subduction and the rates of volcanism, heat flow, hydrothremal circulation, and crustal deformation. This group of investigators was brought together by a common interest in the Cascades and by the realization that further progress in quantifying the processes of mass and energy transfer in the Cascades volcanic arc would be difficult or impossible without additional data from dedicated scientific drill holes. Problems which have particularly resisted solution by surface surveys are:

1. What is the nature of the pre-Quaternary structure and stratigraphy under the active High Cascade volcanic arc?

2. What are the rates of heat flow and hydrothermal circulation in the main zone of active volcanism in the High Cascades? How is this related to heat flow and hydrothermal circulation patterns in the adjacent Western Cascades and Basin and Range provinces?

3. What is the nature of the heat source for the regional heat flow anomaly which characterizes the Cascades and all other subduction-related volcanic arcs? The half width of the anomaly in the Cascades indicates that the heat source is relatively shallow, at about 7-10 km (Blackwell and others, 1978; 1982). Does this mean that there is a widespread zone of magma accumulation and partial melting at this depth? If so, why is this the case?

4. What is the nature of the pre-Cascade crust in the north-central Cascades? Is it, as postulated by Hamilton and Meyers (1966), chiefly oceanic crust?

The reason that the above problems have not yielded to surface surveys are two-fold. First, the nature of the young volcanic rocks under the active High Cascade volcanic arc has made heat flow analysis and geophysical sounding very difficult. The second problem is that there is really no geophysical technique which can sense the precise composition of rocks and fluids, at least not without extensive calibration to drill holes.

The young High Cascade rocks have very high resistivity, low seismic velocity, and complex structure, attributes which make almost any type of geophysical survey difficult to interpret. The high permeability of the young rocks combines with the high precipitation in the range to wash away heat and hydrothermal fluids in the upper 1 km of the volcanic pile. Drilling.a series of holes to 1 km or greater depth will thus be necessary to characterize the current heat flow pattern in the High Cascades. Drilling to depths of 1.2 to 3 km is generally necessary to reach substantially into hydrothermal systems in most geothermal areas. Given the 1 km of meteoric water "wash out," a depth of 2.2 to 4 km may be necessary to adequately sample the hydrothermal systems in many parts of the High Cascades.

Examination of the pre-Cascade crust and the nature of the source region of the regional heat flow anomaly both require sampling rocks from relatively great depths, about 4 km for the pre-Cascade crust (see calculated gravity sections of Couch and others,1982) and about 7-10 km for the heat source (Blackwell and others, 1978, 1982). Actual samples of fluids and rocks will be necessary to examine the nature of the deep magmatic and hydrothermal system operative in the roots of the volcanic arc. Likewise, samples for detailed chemical and mineralogic analysis will be required to determine the nature of pre-Cascade crust. For example, if the the pre-Cascade rocks turn out to be basalts, analysis of trace element and isotopic signatures will be necessary to determine whether the rocks are from island arc, marginal basin, or mid-oceanic ridge terranes.

Drill hole samples will also be necessary to estimate the volumes of volcanic units, particularly units which are obscured by the Quaternary volcanic pile in the High Cascades. The drill holes can be used to build an accurate subsurface stratigraphy which, when combined with detailed geophysical surveys calibrated to the drill holes, will provide estimates of volumes of volcanic units. Rates of volcanism can then be calculated from known or estimated ages of units. These rates can be compared to contemporaneous rates of subduction estimated from offshore studies (e.g. Engebretson, 1982; Riddihough, 1984) to examine causal relationships.

THE CASCADE GEOLOGIC MODEL

The Cascades consist of two distinct mountain ranges: the Western Cascades, a broadly upwarped, deeply eroded volcanic pile of Miocene and older rocks, and the High Cascades, a still-active volcanic arc composed chiefly of Quaternary rocks (Figure 1). The High Cascade volcanic arc extends from British Columbia to northern California, the approximate extent of the convergent Juan de Fuca-

North American Plate boundary (Figure 1). The proportion of basaltic rocks and the total volume of Quaternary volcanic rocks in the High Cascades increase progressively southward from Washington to Oregon (White and McBirney, 1978). The southward increase in mafic volcanism may be due to a corresponding southward increase in extensional tectonism as the arc joins the Basin and Range province (Priest and others, 1982, 1983). Progressively decreasing rates of convergence of the North American and Juan de Fuca Plates may be the ultimate cause of the increased extension and mafic volcanism which has affected the Cascades over the last several million years (Wells and others, 1984).

Subduction along the Juan de Fuca-North American plate boundary is in the dying phases of activity. The size, and thus the age of the subducting oceanic plate has decreased progressively during the Neogene as the oceanic ridge system contacted the North American plate (Atwater, 1970). The youthful age of the Juan de Fuca plate has resulted in nearly aseismic subduction of thin lithosphere (Atwater, 1970). As the size of the subducting plate shrank, the rate of subduction and spreading slowed (Atwater, 1970; Engebretson, 1982). During the last few million years, the Juan de Fuca Plate has begun to break up into smaller plates, resulting in very little active subduction of the northern and southern ends of the plate (Riddihough, 1984). Active subduction is, however, occurring along the central part of the convergent boundary as evidenced by active deformation of the continental margin (e.g. Kulm and Fowler, 1971; Kulm and others, 1984; Lisowski and Savage, 1984; Savage and others, 1981; Silver, 1972). Permissive evidence for active subduction is indicated by 1) teleseismic evidence for a subducted slab beneath Oregon and Washington (Iyer and others, 1982; Michaelson, 1983; Michaelson and Weaver, 1985), 2) high seismicity of the oceanic ridge-transform fault system (Tobin and Sykes, 1968), 3) the north-northeast trending line of active calc-alkaline High Cascade volcanoes, and 4) heat flow typical of other active convergent boundaries (Blackwell and others, 1978, 1982).

CASCADE HEAT FLOW AND HYDROTHERMAL SYSTEMS

Most hot springs in the Cascades are located on the eastern margin of the Western Cascade Range in Oregon (Figure 2). The majority of these hot springs have estimated reservoir temperatures in the 90-170o C range (Brook and others, 1978; Mariner and others 1980; Sammel, 1978). The hotter springs tend to be closer to the High Cascades, but nearly all are located within the boundaries of the High Cascade heat flow anomaly (Figure 2). Many of the hot springs in Oregon are closely adjacent to faults associated with the Cascades graben of Couch and others (1982) and to the western boundary faults of the High Cascade graben of Taylor (1980, 1981). The faults may have locally channeled the flow of thermal water by providing permeable conduits and by juxtaposing permeable and impermeable units (Priest, 1983). The Location of some hot springs may be controlled by the intersection of the current level of erosion with regional aquifers which dip under the High Cascades.

Two fundamental models are consistent with the regional heat flow pattern of Figure 2. The regional heat flow anomaly could be the result of purely conductive heat flow, little affected by hydrothermal convection. In this case the half width of the anomaly is consistent with a high-temperature (600o C+) heat source at about 7-10 km beneath the highest part of the anomaly in the central Oregon Cascades (Blackwell and others, 1978, 1982). Alternatively, the anomaly could result from conductive heat flow emanating from regional hydrothermal aquifers. Blackwell and others (1978, 1982) favor the former hypothesis, although they outline a number of possible convective models. A zone of high-temperature rock at 7-10 km is also consistent with Curie-Point isotherm studies (Connard, 1980; McLain, 1981), gravity data (Blackwell and others, 1982), electrical surveys (Stanley, 1982), and teleseismic data (Iyer and others, 1982). Iyer and others (1982) interpret regional areas of low seismic velocity beneath the High Cascade heat flow anomaly as "hot rock with pockets of magma." If this zone of partial melt exists at 7-10 km, then fluids circulating to depths of 5 km could routinely reach temperatures of 300o C anywhere within the High Cascade heat flow anomaly in central and probably southern Oregon (Blackwell and others, 1982).

DATA FROM INTERMEDIATE-DEPTH WELLS - NEW DATA FROM SUNEDCO WELL 58-28

Only additional deep drilling will discriminate among the many possible heat flow models. Much of the data in Figure 2 is from shallow (152-600 m) wells. Where wells have penetrated below 600 m there has been evidence of both convective and conductive heat flow. Three wells drilled to between 1,200 m and 1,800 m in the Western and High Cascades at Mount Hood have good conductive gradients and heat flow in excess of 100 mW/m2 (Figure 3; Steele and others, 1982). The Sunedco well No. 58-28, drilled to 2463 m (8,080 ft) near Breitenbush Hot Springs in the Western Cascades, has a gradient in excess of 148o C/km in the upper 782 m (D. D. Blackwell, unpublished data), but this is caused by a warm (minimum of 136o C) aquifer at 752 to 782 m (Figure 3; Waibel, 1985). The 136o C temperature was measured during drilling from a maximum-reading thermometer. Owing to the short time the thermometer was on bottom and the effects of injected drilling fluids, 136o C is a minimum temperature (Waibel, 1985). The thermistor log, taken after the highly sheared aquifer was injected by large amounts of cement, showed only about 115o C in the same part of the well (Figure 3; Waibel, 1985). Temperature gradient surveys in the area indicate that the aquifer dips toward the east where it may reach higher temperatures (Waibel, 1985). The aquifer could probably be reached at depths of 1.5 to 2.0 km by drilling a few kilometers to the east of Well No. 58-28 (Waibel, 1985, personal communication).

Below the aquifer the gradient is low and irregular but increases gradually with depth. Unfortunately the thermistor log of Blackwell (unpublished data) reaches to only 1679 m. However, a Pruett Kuster tool recorded a maximum temperature of 141o C after 50 minutes on bottom (Waibel, 1985). The three recorded temperatures from the Kuster tool (Figure 3) clearly show that the tool had not reached an equilibrium temperature. In fact the three temperatures show a nearly linear increase with time (Figure 4). A minimum overall gradient of about 56o C/km results from drawing a line from 141o C at 2,456.6 m to the ambient surface temperature of 3o C. This is remarkably similar to average conductive gradients of about 60o C/km predicted by the regional heat flow studies of Blackwell and others (1978, 1982) and Black and others (1982, 1983). The data from the Sunedco well and the other three deep wells are thus consistent with the contention of Blackwell and others (1978, 1982) that the High Cascade heat flow anomaly creeps into the Western Cascades and persists to relatively great depths. It remains to be seen whether the gradients continue to the predicted depths of 7-10 km. Deepening the Sundeco well would be a cost-effective way to test the heat flow model.

WHERE SHOULD DRILLING OCCUR?

Given that a number of dedicated scientific drill holes are necessary, what parts of the Cascade Range should be studied? Tables 1 and 2 qualitatively rank various parts of the range in terms of the available data base and geothermal resource potential. Geothermal resource potential was included because understanding the nature of the hydrothermal circulation system in the arc is a major goal, and areas with high geothermal resource potential are more likely to have active hydrothermal systems at relatively shallow depths.

TABLE 1. Qualitative summary of the quality of the data base, access, and geothermal resource potential at possible sites for research drilling in the Cascades (0 = Poor; 1 = Moderately Poor; 2 = Moderate; 3 = Moderately Good; 4 = Good; 5 = Very Good). Soil geochemical surveys in the public domain are only available for Newberry and Medicine Lake volcanoes. Data from wells drilled to depths in excess of 600 m are only available for the Mount Hood area, the Breitenbush area, and Newberry Volcano.

Site	Geologic Coverage	Drilling (Heat Flow)	Geophysics (Non-heat flow)	Access	Resource Potential
		WASHINGTON			
Mt. Baker	3	0	3	3	4
Mt. Rainier	3	0	2	1	4
Glacier Peak	2	0	2	1	4
Mt. Adams	5	0	4	1	4
Mt. St. Helens	5	0	4	1	4
N. & Cent. Wash. between volcanoes	2	0	2	2	0
Southern Wash. between volcanoes	2	2	3	4	2
		OREGON			
Mt. Hood	4	2	3	1	4
Adjacent to Mt. Hood	3	4	3	3	2
Mt. Jefferson area	4	0	3	0	4
Breitenbush area	5	5	3	5	4
Santiam Pass area	5	2	3	4	4
North Sister area	5	0	3	0	4
Middle Sister area	5	0	3	0	4
McKenzie Pass	5	1	3	1	4
South Sister	5	0	3	0	5
Century Drive area	5	0	3	2	5
Newberry Volcano	5	2	5	3	5
Willamette Pass area	4	2	3	4	3
Crater Lake	5	1	3	1	5
Adjacent to Crater Lake	3	0	3	4	4
Oregon passes S. of Crater Lake	3	0	3	4	3
		CALIFORNIA			
Mt. Shasta	5	0	5	1	4
Adjacent to Mt. Shasta	5	3	5	4	3
Medicine Lake	5	3	5	5	5
Mt. Lassen	5	2	4	0	4
Between Calif. stratocones	3	1	3	4	3

Table 2. Ranking of sites based on total scores from Table 1. Parentheses indicate site has poor or moderately poor accessibility. Brackets indicate site has poor resource potential.

Score	Site
22	Breitenbush Hot Springs area, Medicine Lake Volcano
20	Newberry Volcano,
19	Areas adjacent to Mt. Shasta
18	Santiam Pass area
16	Willamette Pass area
15	Areas adjacent to Mt Hood, Century Drive area, (Crater Lake), (Mt. Shasta), (Mt. Lassen)
14	(Mt. Adams), (Mt. St. Helens), (Mt. Hood), (McKenzie Pass), areas adjacent to Crater Lake, areas between northern California stratocones south of Mt. Shasta
13	Mt. Baker, (South Sister), Oregon passes south of Crater Lake, southern Washington Cascades between major volcanoes
12	(North Sister area), (Middle Sister area)
11	(Mt. Jefferson area)
10	(Mt. Rainier)
9	(Glacier Peak)
6	{Northern and central Washington between major volcanoes}

Areas which stand out as good potential drilling sites are:

1. Newberry and Medicine Lake volcanoes
2. The Breitenbush-Santiam Pass transect, central Oregon
3. Areas adjacent to Mt. Shasta, northern California
4. Willamette Pass-Century Drive transect, central Oregon
5. Areas adjacent to Mt. Hood, northern Oregon

The Newberry and Medicine Lake volcanoes, major silicic volcanic centers with large data bases, scored high in the ranking. It is now well known that these volcanoes have a high potential for shallow, high-temperature hydrothermal systems, as shown by the USGS Newberry 2 well (Sammel, 1981). However, the writer is not convinced that further drilling in these areas will tell us much about the High Cascade Range to the west, particularly areas characterized by andesitic to basaltic volcanism. What is needed is an east-west profile of the heat flow in the High Cascade Range and one or more wells deep enough to sample potential hydrothermal systems. Ultimately, it would be of immense scientific and economic interest to penetrate to 7-10 km into the source region for the Cascade heat flow anomaly (Blackwell and others, 1982).

The Breitenbush area, considering that it is in the volcanically inactive Western Cascade Range, ranks very high relative to other sites (Table 2). The abundance of geological, geophysical, and drilling data and the presence of a known, potentially exploitable hydrothermal system caused the Breitenbush area to score high. As previously mentioned, Sunedco Energy and Development released much of their data for the Breitenbush area including data from their 2.5 km well (Well No. 58-28, Figure 2), the deepest well in the U.S. Cascades. This well can be reentered for deepening and additional scientific studies (Edward Western, personal communication). As noted earlier, this well crossed an east-dipping thermal aquifer which could be sampled at higher temperature by a second well drilled to depths of 1.5 to 2.0 km a few kilometers east of No. 58-28 (Waibel, 1985).

Well No. 58-28 is also close to the western margin of a regional graben structure inferred from gravity studies of Couch and others (1982) and Couch and Foote (1983). Referred to as the "Cascade graben" (Couch and Foote, 1983), this structure apparently extends from Crater Lake to just north of Mount Jefferson (Couch and others, 1982). The structure is inferred to have experienced active displacements since the mid- to late-Miocene (Couch and Foote, 1983). Deepening the Sunedco Well would test the hypothesis that this structure has a down-to-the east displacement in excess of 3 km (Couch and Foote, 1983).

Deepening the Sunedco well to about 4 km will allow examination of the pre-Cascade crust (Couch, unpublished calculated gravity cross section). This will help to resolve whether this part of the Cascade arc is built on oceanic crust, as postulated by Hamilton and Meyers (1966) and others.

If Well 58-28 were deepened to 4.0 km, this would also be an additional test of the regional heat flow model of Blackwell and others (1978, 1982). It would establish whether temperature gradients of 60^{o} C/km or more persist to relatively great depths in the main part of the Cascade heat flow anomaly.

Drilling in the Breitenbush area will help to resolve many questions about the nature of the Western Cascade structure and hydrothermal convection but will not elucidate the structure and thermal regime of the High Cascades. The proximity of the Santiam Pass area to the Breitenbush site, its accessibility, and excellent geological coverage (Taylor, 1967; Taylor, unpublished 1:24,000-scale mapping) make the Santiam Pass area a prime target for a profile across the High Cascades. Santiam Pass is also one of the few easily accessible places in the High Cascade Range where the axis of volcanism can be located with a great deal of confidence. It thus affords an unique opportunity to test the hypothesis that the current axis of mafic to intermediate volcanism may have high conductive heat flow and a high potential for hydrothermal resources. In addition, the area lies in a large Pliocene graben which formed after eruption of voluminous late Miocene to early Pliocene ash flows and lavas from the High Cascades (Taylor, 1980). Drilling could provide quantitative constraints on the amount of displacement on this graben, and the nature of the pre-graben volcanic arc (now buried by Quaternary volcanoes). Drilling would also help to test the hypothesis that the regional residual gravity high under the Three Sisters-Mt. Jefferson segment is caused by a large intrusive complex (R. Couch, 1985, personal communication).

A comprehensive study of the Breitenbush area and the adjacent Santiam Pass area is the most logical and cost-effective first step in a scientific drilling program. This would examine both of the major graben structures, the mid- to late-Miocene Cascade Graben and the Pliocene graben in the High Cascades; it also would take advantage of a wealth of previous studies, including the opportunity to reenter the deepest well in the U.S. Cascades. In future years other east-west transects should be studied to help extrapolate the Santiam-Breitenbush data to the north and south.

Drilling in the areas adjacent to Mount Shasta would be of great value both in terms of geothermal assessment and volcanologic research. Drilling would capitalize on the detailed geophysical and geological data base which has been developed for this area by the USGS. Completing a transect to Medicine Lake would also be of interest to study the transition zone between the two areas.

The Century Drive area adjacent to the South Sister is unique in that it has the only Holocene rhyodacite volcanic centers in the High Cascade Range which are also accessible by a major highway. The area is part of a long-lived silicic highland of regional extent (Taylor, 1980). It would be an ideal place to establish whether hydrothermal resources associated with silicic volcanism are present in the main High Cascade Range. Heat flow and geophysical profiles across the full width of the Willamette Pass-Century Drive area would be of interest, especially in comparison with profiles at Breitenbush-Santiam Pass where mafic and intermediate volcanism prevails. Extending the studies to Newberry Volcano would allow investigation of the relationship between the silicic highland at Century drive and silicic volcanism at Newberry.

Areas adjacent to Mount Hood scored well in the ranking because of the large available data base. However, extensive drilling in the area has not been successful in locating indications of major high-temperature hydrothermal systems. According to some interpretations of the geophysical surveys (Goldstein, personal communication), the drill holes may be too shallow and not in the best locations to intercept the hydrothermal systems. In any case, the gravity data indicate that, unlike many of the large High Cascade volcanoes to the south, Mount Hood may not lie above a large, shallow intrusive complex (R. Couch, 1985, personal communication), although Williams and Finn (1983) concluded that a shallow high density intrusion could be present. South of Mount Hood the regional background heat flow increases to values in excess of 100 mW/m^2 (Blackwell and others, 1982), which would be additive to any local heat flow associated with shallow intrusions. This factor would increase the likelihood of large hydrothermal systems in the Cascades south of Mount Hood even if shallow plutons are locally present in both areas.

A transect of detailed temperature-gradient drilling and surface surveys across the southern Washington Cascades would be valuable. This would help to improve the meager heat flow data base in Washington and allow comparisons between this area of somewhat lower regional heat flow (Blackwell and Steele, 1983) and lower rates of Quaternary volcanism to areas with higher rates in Oregon and northern California. This is important for developing a comprehensive model for the Cascades as a whole.

CONCLUSIONS

Figure 5 shows four recommended study areas in the Cascade Range. The Santiam Pass-Breitenbush area is the best site for the first phase of a scientific drilling program in the Cascade Range. This area has a known hydrothermal convection system, a high rate of volcanism, high background heat flow, and a large existing data base for siting drill holes. It is recommended that Sunedco Well No. 58-28 near Breitenbush Hot Springs be reentered, tested, and deepened to about 4 km. Drilling of an additional well to about 2 km depth east of the Sunedco site might cross the east-dipping hydrothermal aquifer at higher temperatures (Waibel, 1985, personal communication). An east-west transect of at least three, and preferably four, 1 km or deeper slim holes should be drilled across the Cascades at the latitude of Santiam pass to delineate the temperatures and heat flow below the zone of rapidly circulating cold ground water. A 2.7 km or deeper well should be drilled near the axis of Quaternary volcanism to test for potential hydrothermal fluids and to explore the nature of the pre-Quaternary stratigraphy. The drilling should be coupled with a program of detailed surface geophysical surveys and extensive radiometric dating of volcanic units to help site the wells and to allow maximum extrapolation of the drilling data. Detailed geologic mapping of the Cascadia and Sweetholme quadrangles will complete geologic coverage of the full width of the Cascade Range. Stratigraphic thicknesses determined from mapping and drilling should be combined with the lateral extent and age of volcanic units to calculate rates of volcanism. This should then be compared to contemporaneous rates of subduction, heat flow, hydrothermal circulation, and crustal deformation to examine causal relationships.

Drilling programs similar to the Breitenbush-Santiam study should be accomplished in three additional east-west transects as a Phase II of the investigation. These studies should be completed in the southern Washington Cascades, the Century Drive-Willamette Pass area, and the Mount Shasta-Medicine Lake area (Figure 5) in future years in order to develop a comprehensive hydrologic and geologic model of the Cascade Range. The third phase of the program would require drilling to depths of 7-10 km to investigate deep magmatic and metamorphic processes operative under the area of the regional heat flow anomaly associated with the Cascade volcanic arc. No formal proposal for Phase II or Phase III is anticipated until the Phase I work is complete.

PHASE I - PRELIMINARY SCHEDULE OF THE INVESTIGATION

Phase I should take about 3 years to complete. The following is a yearly break down of major tasks.

First Year

1. Complete detailed geophysical surveys of the entire study area.

2. Complete radiometric dating in previously mapped areas and begin geologic mapping in two unmapped quadrangles on the west side of the study area.

3. Finish the permitting, contracting, and site selection phases for drilling in the Breitenbush area and for initial drilling in the Santiam Pass area.

4. Finish four 1.2 km temperature-gradient holes in an east-west profile across the Santiam Pass area.

5. Deepen Sundedco Well 58-28 to 4 km and complete testing and logging.

6. Begin drilling a hole east of Well 58-28 aimed at reaching the hydrothermal aquifer at a depth of about 1.5 to 2 km.

Second Year

1. Complete drilling and testing on the well east of Well 58-28.

2. Complete site selection and permitting for a well 2.7 km deep in the Santiam Pass area.

3. Complete drilling on the 2.7 km Santiam Pass well, weather permitting.

4. Continue geologic mapping of the two quadrangles on the west side of the transect.

5. Complete data generation and analysis from the first year's work.

6. Fill in data gaps in geophysical surveys.

Third Year

1. Complete drilling and testing on the Santiam Pass well.

2. Complete geologic mapping and sample analysis.

3. Publish reports and maps synthesizing the drill hole and surface survey data.

PHASE I - PRELIMINARY COST ESTIMATES

Actual costs, in terms of federal monies, are difficult to estimate because some of the proposed drill holes may be drilled under USDOE SCAP No. DE-SC07-85ID12580, which requires an approximate 50% cost share from industry applicants. The following are rough estimates of total costs assuming no industry involvement.

Drilling, logging, and testing wells

	$\$ \times 10^6$
Deepening Well 58-28 to 4 km (from 2.5 km) -	1.0
One 2.0 km well east of Well 58-28 -	2.0
Four 1.2 km slim holes across Santiam Pass -	1.2
One 2.7 km well near Santiam Pass -	3.0
Analysis of rocks and fluids -	.5
In situ stress measurements --	.5

~~Analysis of rocks and fluids -~~ ~~.5~~

~~In situ stress measurements --~~ ~~.5~~

Surface Surveys

Geophysical surveys (gravity, electrical, seismic) - 1.0

Geological surveys - .5

Total - 10.7

PHASE II - PRELIMINARY SCHEDULE

Phase II would widen the investigation to three additional east-west transects. Each transect would take about two years to complete. All of the transects could be done concurrently, so the total time for Phase II would be about two years.

PHASE II - PRELIMINARY COST ESTIMATES

Cost per transect would vary, depending on the area. The Medicine Lake-Mt. Shasta transect is already the focus of detailed geological and geophysical surveys, so a great deal of time and cost can be saved there relative to the Phase I budget. Only a modest drilling program involving relatively shallow (400 m) temperature-gradient holes is planned for the southern Washington Cascades. Likewise, relative to the Phase I program, less drilling is planned for the Willamette Pass-Century Drive transect and the Medicine Lake-Mt. Shasta transect. Four 1.2 km slim holes and deepening one hole to about 2.0 km will probably suffice for each of the two transects. The total cost for Phase II would thus be approximately the the same as the total cost of Phase I, or about 10 million dollars.

PHASE III - SCHEDULE

There is no way of accurately estimating the time that it would take to drill to 7-10 km in a high-temperature terrane such as the Cascades, but it would probably take at least several years, excluding any time required to develop special drilling and logging technologies.

PHASE III - PRELIMINARY COST ESTIMATES

Cost estimates for drilling to 7-10 km in high-temperature rocks are highly speculative, because this has never been done. Most probably a budget in the range of 50 to 100 million dollars would be necessary.

REFERENCES CITED

Atwater, T. 1970, Implications of plate tectonics for the Cenozoic tectonic evolution of western North America: Geological Society of America Bulletin, v. 81, no. 12, p. 3513-3535.

Black, G.L., Blackwell, D.D., and Steele, J.L., 1982, Heat flow of the Oregon Cascades, in Priest, G.R., and Vogt, B.F., eds., Geology and geothermal resources of the Cascades, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-82-7, p. 152-171.

_____, Blackwell, D.D., and Steele, J.L., 1983, Heat flow in the Oregon Cascades, in Priest, G.R., and Vogt, B.F., eds., Geology and geothermal resources of the central Oregon Cascade Range: Oregon Department of Geology and Mineral Industries Special Paper 15, p. 69-76.

Blackwell, D.D., Black, G.L., and Priest, G.R., 1981, Geothermal gradient data (1978): Oregon Department of Geology and Mineral Industries Open-File Report 0-81-3, 98 p.

_____, Black, G.L., and Priest, G.R., 1982, Geothermal gradient data (1981): Oregon Department of Geology and Mineral Industries Open-File Report 0-82-4, 429 p.

_____, Hull, D.A., Bowen, R.G., and Steele, J.L., 1978, Heat flow of Oregon: Oregon Department of Geology and Mineral Industries Special Paper 4, 42 p.

_____, Bowen, R.G., Hull, D.A., Riccio, J., and Steele, J.L., 1982, Heat flow, arc volcanism, and subduction in northern Oregon: Journal of Geophysical Research, v. 87, no. B10, p. 8735-8754.

_____, and Steele, J.L., 1983, A summary of heat flow studies in the Cascade Range: Geothermal Resources Council, Transactions, v. 7, p. 233-236.

Brook, C.A., Mariner, R.H., Mabey, D.R., Swanson, J.R., Guffanti, M., and Muffler, L.J.P., 1979, Hydrothermal convection systems with reservoir temperatures > 90 C, in Muffler, L.J.P., ed., Assessment of geothermal resources of the United States -- 1978: U.S. Geological Survey Circular 790, p. 18-85.

Carlson, R.L., Hilde, T.W.C., and Uyeda, S., 1983, The driving mechanism of plate tectonics: Relation to age of the lithosphere at trenches: Geophysical Research Letters, v. 10, p. 297-300.

Connard, G.G., 1980, Anaylsis of aeromagnetic measurements from the central Oregon Cascades: Corvallis, Oreg., Oregon State University master"s thesis, 101 p.

Couch, R.W., and Foote, R.W., 1983, Graben structures of the Cascade Range in Oregon: Transactions of the American Geophysical Union, EOS, v. 64, no. 45, p. 887.

Couch, R.W., Pitts, G.S., Gemperle, M., Braman, D.E., and Veen, C.A., 1982, Gravity anomalies in the Cascade Range in Oregon: Structural and thermal implications: Oregon Department of Geology and Mineral Industries Open-File Report 0-82-9, 43 p.

Engebretson, D.C., 1982, Relative motions between oceanic and continental plates in the Pacific Basin: Stanford, Calif., Stanford University doctoral thesis, 211 p.

Hamilton, W., and Myers, W.B., 1966, Cenozoic tectonics of the Western United States: Reviews of Geophysics, v. 4, no. 4, p. 509-549.

Iyer, H.M., Rite, A., and Green, S.M., 1982, Search for geothermal heat sources in the Oregon Cascades by means of teleseismic P-residual technique [abs.]: Society of Exploration Geophysicists, 52nd Annual Meeting, Dallas, Tex., 1982, Technical Program Abstracts, p. 479-482.

Kulm, L.D., Thornburg, T.M., and Carson, B., 1984, Distribution of lithologies and fluid vents from the Oregon underthrust margin: Implications for active subduction of the Juan de Fuca Plate: EOS, Transactions, American Geophysical Union, v. 65, no. 45, p. 1090

_____, and Fowler, G. A., 1971, Shallow structural elements of the Oregon continental margin within a plate tectonic framework: Geological Society of America, Abstracts with Programs, v. 3, p. 628.

Lisowski, M., and Savage, J.C., 1984, Strain accumulation in western Washington: American Geophysical Union, EOS, v. 65, no. 45, p. 986.

Ludwin, R.S., and Crosson, R.S., 1984, The azimuth of regional tectonic compression in the Pacific Northwest from shallow thrust earthquakes: American Geophysical Union, EOS, v. 65, no. 45, p. 986.

McBirney, A. R., 1968, Petrochemistry of the Cascade andesite volcanoes, in Dole, H. M., ed., Andesite conference guidebook: Oregon Department of Geology and Mineral Industries Bulletin 62, p.101-107.

McLain, W.H., 1981, Geothermal and structural implications of magnetic anomalies observed over the southern Oregon Cascade Mountains and adjoining Basin and Range province: Corvallis, Oreg., Oregon State University master's thesis, 151 p.

Macleod, N.S., and Sammel, E.A., 1982, Newberry Volcano, Oregon: A Cascade Range geothermal prospect: Oregon Department of Geology and Mineral Industries, Oregon Geology, v. 44, no. 11, p. 123-131.

_____, Sherrod, D.R., Chitwood, L.A., and McKee, E.H., 1981, Newberry Volcano, Oregon, in Johnston, D.A., and Donnelly-Nolan, J., eds., Guides to some volcanic terranes in Washington, Idaho, Oregon, and northern California: U.S. Geological Survey Circular 838, p. 85-103.

Macleod, N.S., Sherrod, D.R., and Chitwood, L.A., 1982, Geologic map of Newberry Volcano, Deschutes, Klamath, and Lake Counties, Oregon: U.S. Geological Survey Open-File Report 82-847, 27 p., scale 1:62,500.

Mariner, R.H., Swanson, J.R., Orris, G.J., Presser, J.S., and Evans, W.C., 1980, Chemical and isotopic data for water from thermal springs and wells of Oregon: U.S. Geological Survey Open-File Report 80-737, 50 p.

Michaelson, C.A., 1983, Three-dimensional velocity structure of the crust and upper mantle in Washington and northern Oregon: Seattle Wash., University of Wash. masters thesis, 100 p.

Michaelson, C.A., and Weaver, C.S., 1985, Upper mantle structure beneath Washington and northern Oregon from teleseismic p-wave arrivals: Journal of Geophysical Research, in press.

Priest, G.R., 1982, Overview of the geology and geothermal resources of the Mount Hood area, in Priest, G.R., and Vogt, B.F., eds., Geology and geothermal resources of the Mount Hood area, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 14, p. 6-15.

Priest, G.R., 1983, Geothermal exploration in the central Oregon Cascade Range, in Priest, G.R., and Vogt, B.F., Geology and geothermal resources of the central Oregon Cascade Range: Oregon Department of Geology and Mineral Industries Special Paper 15, p. 77-87.

_____, Beeson, M.H., Gannett, M.W., and Berri, D.A., 1982, Geology, geochemistry, and geothermal resources of the Old Maid Flat area, Oregon, in Priest, G.R., and Vogt, B.F., Geology and geothermal resources of the Mount Hood area, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 14, p. 16-30.

_____, and Blackwell, D. D., 1984a, Understanding thermal energy and dynamic processes in subduction-related volcanic arcs: Proposed studies in the Cascades: Oregon Department of Geology and Mineral Industries, Oregon Geology, v. 46, no. 10, p. 122-123.

_____, 1984b, Understanding thermal energy and dynamic processes in subduction-related volcanic areas: Proposed studies in the Cascades: EOS, Transactions, American Geophysical Union, p. 722.

_____, Woller, N.M., Black, G.L., and Evans, S.H., Jr., 1982, Overview of the geology and geothermal resources of the central Oregon Cascades, in Priest, G.R., and Vogt, B.F., eds., 1982, Geology and geothermal resources of the Cascades, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-82-7, p. 5-70.

_____, Woller, N.M., Black, G.L., and Evans, S.H., Jr., 1983, Overview of the geology of the central Oregon Cascade Range, in Priest, G.R., and Vogt, B.F., eds., Geology and geothermal resources of the central Oregon Cascade Range: Oregon Department of Geology and Mineral Industries, Special Paper 15, p. 3-28.

Riddihough, R., 1984, Recent movements of the Juan de Fuca plate system: Journal of Geophysical Research, v. 89, no. B8, p. 6980-6994.

Sammel, E.A., 1978, Occurrence of low-temperature geothermal waters in the United States, in Muffler, L.J.P., Assessment of geothermal resources of the United States -- 1978: U.S. Geological Survey Circular 790, p. 86-131.

_____, 1981, Results of test drilling at Newberry Volcano, Oregon: Geothermal Resources Council Bulletin, v. 10, no. 11, p. 3-8.

Savage, J. C., Lisowski, M., and Prescott, W. H., 1981, Geodetic strain measurements in Washington: Journal of Geophysical Research v. 86, p. 4929-4940.

Silver, E. A., 1972, Pleistocene tectonic accretion of the continental slope off Washington: Marine Geology, v. 13, p. 239-249.

Stanley, W.D., 1981, A regional magnetotelluric survey of the Cascade Range region, northwestern United States: U.S. Geological Survey Open-File Report 82-126, 20 p.

Steele, J.L., Blackwell, D.D., and Robison, J., 1982, Heat flow in the vicinity of the Mount Hood volcano, Oregon, in Priest, G.R., and Vogt, B.F., eds., Geology and geothermal resources of the Mount Hood area: Oregon Department of Geology and Mineral Industries Special Paper 14, p. 31-42.

Taylor, E.M., 1967, Recent volcanism between Three Fingered Jack and North Sister, Oregon Cascade Range: Pullman, Wash., Washington State University doctoral dissertation, 84 p.

_____, 1980, Volcanic and volcaniclastic rocks on the east flank of the central Cascade Range to the Deschutes River, Oregon, in Oles, K.F., Johnson, J.G., Niem, A.R., and Niem, W.A., eds., Geologic field trips in western Oregon and southwestern Washington: Oregon Department of Geology and Mineral Industries Bulletin 101, p. 1-7.

_____, 1981, Central High Cascade roadside geology--Bend, Sisters, McKenzie Pass, and Santiam Pass, Oregon, in Johnston, D.A., and Donnelly-Nolan, J., eds., Guides to some volcanic terranes in Washington, Idaho, Oregon, and northern California: U.S. Geological Survey Circular 838, p. 55-58.

Tobin, D. G., and Sykes, L. R., 1968, Seismicity and tectonics of the northeastern Pacific Ocean: Journal of Geophysical Research, v. 73, p. 3821-3846.

Venkatakrishnan, R., Bond, J.G., and Kauffman, J.D., 1980, Geological linears of the northern part of the Cascade Range, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 12, 25 p.

Waibel, Albert, F., 1985, Summary of data from Sunedco well 58-28, Breitenbush area, Oregon: Oregon Department of Geology and Mineral Industries, Oregon Geology, in preparation.

White, C.M., and McBirney, A.R., 1978, Some quantitative aspects of orogenic volcanism in the Oregon Cascades, in Smith, R.B., and Eaton, G.P., eds., Cenozoic tectonics and regional geophysics of the western Cordillera: Boulder, Colo., Geological Society of America Memoir 152, p. 369-388.

United States Geodynamics Committee, National Research Council, 1979, Continental scientific drilling program: Washington D.C., National Academy of Sciences, 192 p.

Wells, R.E., Engebretson, D.C., Snavely, P.D., Jr., and Coe, R.S., 1984, Cenozoic plate motions and the volcano-tectonic evolution of western Oregon and Washington: Tectonics, v. 3, no. 2, p. 275-294.

Williams, D. L., and Finn, C., 1983, Gravity and aeromagnetic study of the Goat Rocks Wilderness, Washington: Transactions of the American Geophysical Union, EOS, v. 64, no. 45, p. 887.

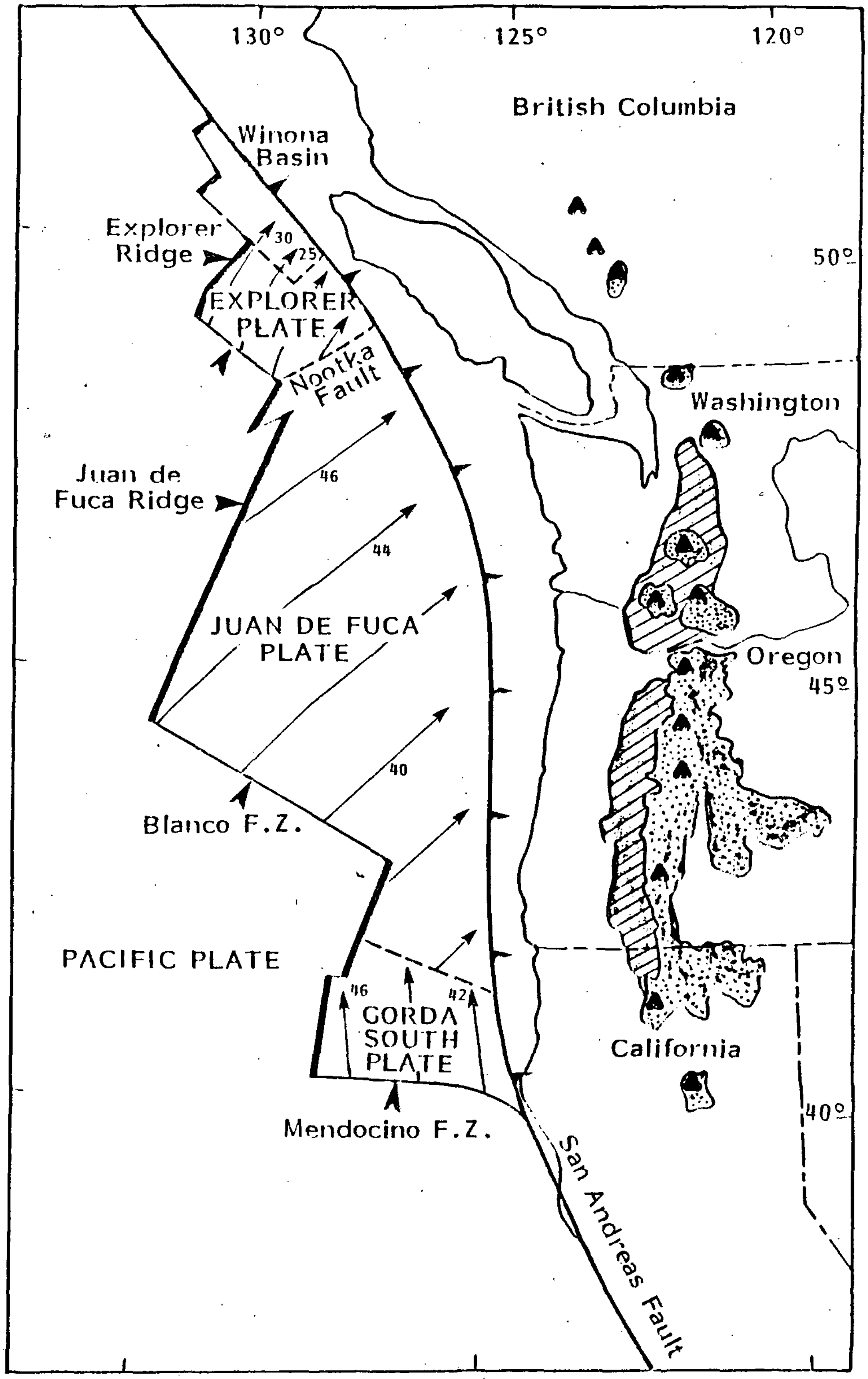


Figure 1. The distribution of Quaternary volcanic rocks of the High Cascades (stippled) and older volcanic rocks of the Western Cascade Range (slant lines) from McBirney (1968) is plotted on a generalized plate tectonic map, modified from Riddihough (1984) Triangles are major composite cones. Arrows on the oceanic plates refer to the motion direction relative to the North American Plate during the last 0.5 my; numbers are velocities in mm/year (all from Riddihough, 1984).

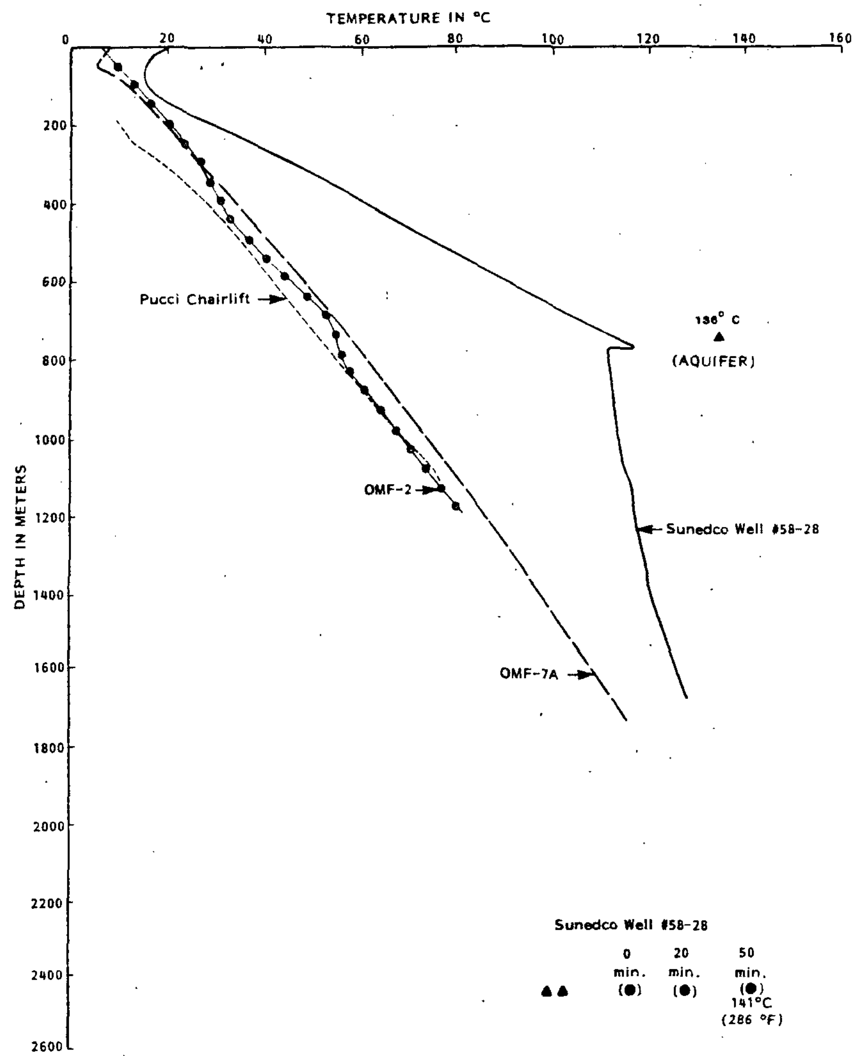


Figure 3. Temperature-depth data from the four deepest Cascade wells in the U.S.

Sources for the data are as follows:

Pucci Chairlift (3s, 9E, 7Ad)-Blackwell, Black and Priest (1982)

OMF-2(2S, 8E, 15Dd)-Blackwell and others (1981)

OMF-7A(2S, 8E, 15Dd)-Blackwell, Black and Priest (1982)

Sunedco Well (#58-28(9S, 7E, 28Dcc)-solid line is a thermistor log (unpublished data of D.D. Blackwell), triangles are maximum reading thermometer values immediately after the end of drilling (Waibel, 1985); dots with parentheses are from a pruett Kuster tool read three times beginning 48 hours after circulation (Waibel, 1985).

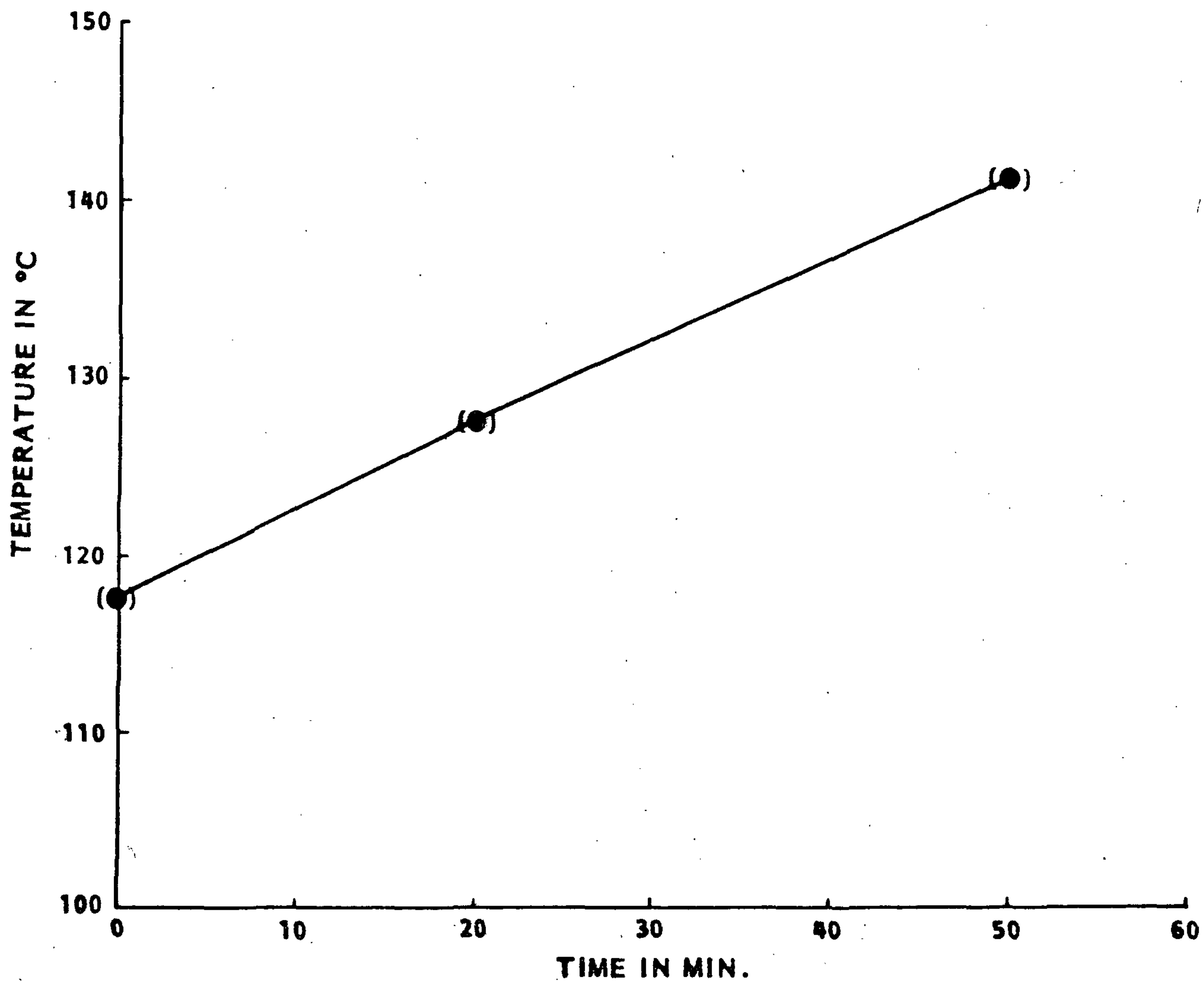


Figure 4. Pruett Kuster tool readings at 2,546.6 m in Sunedco Well #58-28. Starting at 48 hours after circulation (data from Waibel, 1985)

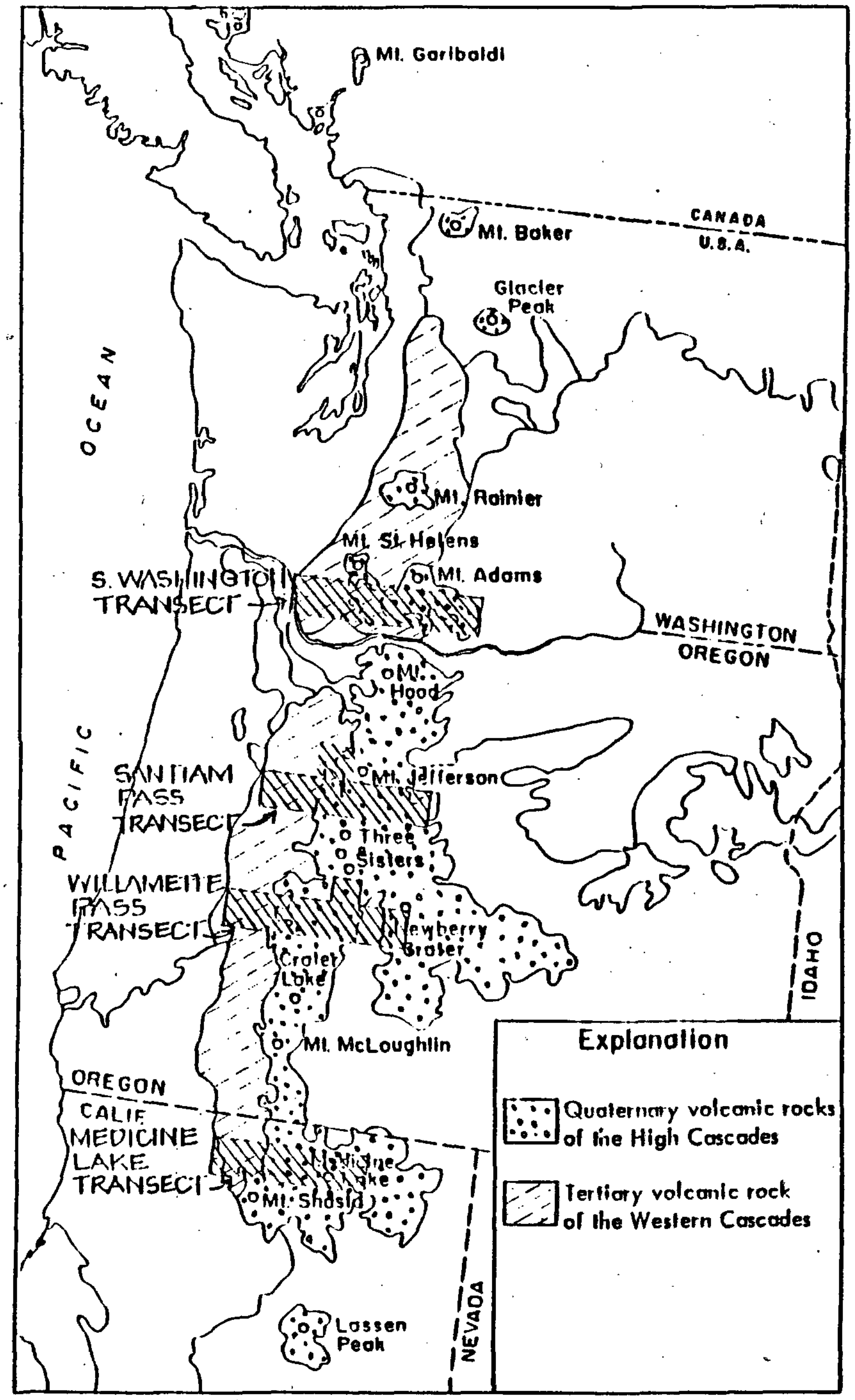


Figure 5. Study areas for scientific drilling programs in the Cascades (base map taken from McBirney, 1968).

WRI 60AT

May 24, 1985
Menlo Park, California

PROGRAM FOR SCIENTIFIC DRILLING IN THE CASCADES

MEETING AGENDA

Summary of results of the April 29, 1985 DOSECC meeting in Houston - Dave Blackwell

Summary of **informal** proposal submitted on short notice to DOSECC - George Priest

Phase I - Three-year study of Breitenbush-Santiam Pass

1. Gravity, electrical, and seismic surveys
2. Map two 15' quadrangles
3. Deepen Sunedco Well No. 58-28 to 4 km
4. Drill a 2 km well east of Well No. 58-28
5. Drill four 1.2 km (4,000') slim diamond core holes across Santiam Pass
6. Drill a 2.7 km (9,000 ') well - Santiam Pass area
7. Estimated cost = 9.7 million dollars (total on p. 12 of the DOSECC proposal is in error)

Phase II - Two-year study of three additional transects

1. Areas = Mt. Shasta-Medicine Lake; Willamette Pass-Century Drive; southern Washington Cascades
2. No detailed description of work elements given
3. Lesser cost per transect relative to Phase I budget stressed with following specific points:
   a. Surface surveys of Mt. Shasta-Medicine Lake are already done or in progress
   b. Modest drilling program consisting of 400 m temperature gradient holes for S. Wash.
   c. Drilling at Willamette Pass-Century Drive and at Mt. Shasta-Medicine Lake will consist of four 1.2 km slim holes and deepening one hole to 2.0 km in each area.
4. Estimated cost of Phase II = 10 million dollars

Phase III - Deep hole

1. Drill to 7-10 km in one of the four transects
2. Special drilling and logging technologies needed
3. Drilling could take several years
4. Estimated cost = 50-100 million dollars

Discussion of final scientific plan for the PSDC

Assignment of specific responsibilities for contributors

STATE OF OREGON

INTEROFFICE MEMO

TO: Interested Persons - Programs for Scientific Drilling in the Cascades

DATE: November 13, 1986

FROM: George P.

SUBJECT:

PSDC meeting on December 11, 1986 in San Francisco; other news.

December Meeting

An informational meeting on the PSDC will be held on December 11, 1986 (Thursday) in Room 378 of the Cathedral Hill Hotel during the AGU conference in San Francisco. The meeting will begin at 6:45 P.M. and last until about 9:30 P.M., if necessary.

The goal of the meeting is to bring contributors and interested persons up to date on progress on the PSDC. The following is a <u>tentative agenda</u>:

1. Recent changes in the organization of the PSDC and new contributors to the science plan.
2. Summary of results of the Rapid City meeting on CSD.
3. The science plan:
   a) Progress to date and estimated time of publication
   b) Significant changes from the first draft
4. Proposals:
   a) Anticipated funding sources
   b) Probable amount of funding
   c) Scope of proposals as determined by funding
   d) Priorities for the initial proposals

Other News

The first steering committee meeting was held in Portland, Oregon on September 23, 1986. Officers were elected in order to split up some of the responsibilities. The following officers were elected:

<u>Chairman, Chief Scientist</u>: David D. Blackwell, SMU
<u>Vice Chairman, Deputy Chief Scientist</u>: George R. Priest, DOGAMI
<u>Coordinator</u>: John Rowley, LANL

Recording Secretary: Norman Goldstein, LBL
Other Official Members:
- Craig Weaver, USGS
- Harve Waff, University of Oregon
- Richard Couch, Oregon State University
- Michael Korosec, Washington Department of Natural Resources

The steering committee members are official representatives of major contributing organizations to the plan. Where possible, they also represent the major scientific and engineering specialties utilized in the science plan, and, as such, represent groups of contributors in those specialties. The final proposals and the final draft of the science plan must have the approval of the steering committee in order to be an official part of the PSDC.

The steering committee made recommendations for changes in wording and emphasis in the science plan aimed at attaining a more realistic, focused format. Initial ideas for proposals based on anticipated funding sources were also discussed. This will be covered in the December meeting at the AGU.

UNDERSTANDING THERMAL ENERGY AND DYNAMIC PROCESSES IN SUBDUCTION-RELATED VOLCANIC ARCS: PROPOSED STUDIES IN THE CASCADES

George R. Priest and David D. Blackwell

It is hard to overstate the importance of subduction-related volcanic arcs in the geologic record and in the record of historic earthquakes and volcanic eruptions. Subduction-related terranes appear to be represented in the geologic record from the Archeozoic to modern times and account for much of the world's volcanic activity. Convergent plate margins stretching for thousands of miles around the circum-Pacific, the Caribbean, the Indian Ocean, and the Mediterranian have some of the most active volcanoes and largest geothermal systems in the world. Many of the world's largest hydrothermal ore deposits are associated with calc-alkaline magmas injected into the crust as a result of the subduction process. The enormous deposits in the Andes, Indonesia, Japan, western North America and other areas around the circum-Pacific are examples.

The Cascade Range is the only presently active subduction-related volcanic arc in the conterminous United States. Active volcanoes related to the arc occur over a distance of over 1,300 km from British Columbia to northern California. The most destructive historic volcanic eruption in the United States occurred in 1980 at Mount St. Helens in the Washington part of the range. Partly because of its unique status, the Cascade Range is also one of the most completely studied volcanic arcs in the world. In spite of the extensive geologic and geophysical data available for the range, the detailed subsurface geology is essentially unknown, because the thick sequences of young volcanic rocks effectively mask over structures. The high porosity, permeability, and resistivity and low seismic velocity of young volcanic rocks in the most active part of the arc make geophysical sounding very difficult.

The only part of the Cascades which has been relatively easy to explore by geophysical techniques is the western part. The Western Cascade Range is Miocene and older volcanic terrane which has been diagenetically and hydrothermally altered, greatly decreasing the porosity and permeability of the rocks. Geophysical techniques have been much more successful in the Western Cascades than in the young volcanic rocks of the High Cascade Range to the east.

One of the most significant findings from studies of the Western Cascade Range is in the area of heat flow. The results of heat flow measurements in numerous drill holes indicate that there is a characteristic heat flow anomaly with a half width of approximately 10 kilometers on the western side extending from northern California to southern British Columbia (Blackwell and Steele, 1983). Heat flow increases by as much as a factor of 2 or more across the western side of this anomaly, and the average geothermal gradients within main part of anomaly in the Oregon Cascade Range are about 65^{o}C/km (Blackwell and others, 1978, 1982). Based on interpretation of these data, it appears that temperatures appropriate for partial melting of granitic material should occur at depths on the order of 7 to 10 kilometers under the easternmost part of the Western Cascade Range in Oregon (Blackwell and others, 1978, 1982) These depths are similar to depths estimated for partially molton granitic bodies under silicic volcanic centers such as the Yellowstone, Long Valley, and Valles calderas. Temperatures at equivalent depths beneath the High Cascade Range may be even higher, but thus far attempts to measure heat flow in the High Cascades have been thwarted by the rapidly circulating shallow ground water which washes away heat flow in the carapace of young volcanic rocks. Lack of reliable heat flow data in the High Cascade Range is one of the principal reasons that it is not generally included in estimates of the accessible geothermal resource base for the United States. If geothermal systems are present in a significant part of this enormous province, they could dwarf the geothermal potential estimated for the largest silicic volcanic centers in the United States.

RATIONALE FOR SCIENTIFIC DEEP DRILLING IN THE CASCADES

The previously mentioned problems presented by the cover of young volcanic rocks in the Cascades can only be solved by drilling. Experience in drilling in areas such as Newberry Volcano in Oregon has shown that drill holes must generally be 1 km or deeper in order to make meaningful measurements of heat flow in the youngest part of the volcanic arc. Drill holes deeper than 1 km are almost completely lacking in the young volcanic rocks of the High Cascades. In order to directly test the hypothesis that temperatures near the melting point of granitic rocks occur at depths of 7 to 10 km, it would be necessary to drill to these depths. Should this hypothesis prove to be correct, it would have enormous consequences for estimates of geothermal potential and for physical models of subduction-related volcanic arcs throughout the world. It would mean that regional zones of very high temperature, possibly molton rock occur at relatively shallow crustal levels under the entire length of active arcs regardless of the presence or absence of single large volcanoes. Measurements in drill holes in the Cascades would allow calibration of the extensive surface geological and geophysical surveys which could then be applied to other, less well-studied areas of the world. The drilling program would thus test a fundamental hypothesis and provide a standard data base for investigating other similar regions throughout the world.

PROGRAM FOR SCIENTIFIC DRILLING IN THE CASCADES

In recognition of the need for deep scientific drilling in the Cascades, a group of scientists who are actively pursuing research in the province have met several times to plan a proposal. A formative meeting was held at the AGU conference in San Francisco last December, and a proposal is now in preparation for submission in early 1985. The essential thrust of the proposed project will be a coordinated program of drilling and surface geological and geophysical surveys aimed at a series of east-west transects across the full width of the Cascade Range. The drilling will occur primarily in the young volcanic terrane of the High Cascades and will be completed in two phases. The bulk of the drilling during the first phase will be aimed at reaching depths of between 1.2 and 2.7 km in two transects of four wells each across two contrasting parts of the arc. Some surface surveys and shallower drilling are also contemplated during the first phase to characterize two lower-priority east-west transects. The four transects are targeted on the southern Washington Cascades, two localities in the central Oregon Cascade Range, and the northern California Cascades. The first phase would allow direct testing and modeling of the hydrothermal systems, measurement of the amplitude of the heat flow anomaly in the High Cascades, and direct sampling of basement rocks to determine the structure, state of stress, and other physical properties. The first phase will also include geologic mapping and a full range of geophysical surveys across both the High Cascades and the Western Cascades to investigate the overall geologic framework of the arc, including the configuration of the subducting oceanic plate and the development of the arc through time. The second phase would be aimed at directly penetrating the source of the regional heat flow anomaly at depths of 7 to 10 km. The second phase would be an extraordinary scientific and engineering accomplishment and would necessarily be preceded by a lengthy period of research and development. Whereas the proposal currently being prepared deals conceptually with the second phase, only work on the first phase will be addressed in the initial proposal.

The extensive knowledge gained from the proposed research in the Cascade Range will, when integrated with similar data from the proposed Trans-Alaska Lithosphere Investigation (TALI), give an accurate representation of the configuration of the major subducting plates and associated volcanism along the western margin of North America. TALI was recently organized by the USGS and other groups to plan for drilling and areal studies along a north-south transect 1,400 km long across the full width of Alaska.

This article is partly intended as an announcement to alert various funding agencies and potential colleagues to the existence of the organizing group for Cascade scientific drilling. We invite participation from other scientists at this time or in the future as the activities become more specific. A proposal submission is planned for January or February, 1985. If you are interested in participating in this project, you can obtain general information and information on Oregon geologic studies from George R. Priest at the Oregon Department of Geology and Mineral Industries (1005 State Office Building, Portland, Oregon 97201: Telephone - (503) 229-5580). The following persons are coordinating other aspects of the project:

Hydrology: Edward A. Sammel, U.S. Geological Survey, 345 Middlefield Road, M/S 39, Menlo Park, California 94025.

Water Chemistry: Robert H. Mariner, U.S. Geological Survey, 345 Middlefield Road, M/S 27, Menlo Park, California 94025.

Hydrothermal Alteration; Geologic Studies in the Northern California Cascades: Terry E.C. Keith, U.S. Geological Survey, M/S 910, Branch of Igneous and Geothermal Processes, 345 Middlefield Road, Menlo Park, California 94025.

All Work in the Southern Washington Cascades: Craig Weaver, U.S. Geological Survey, Geophysics Program AK-50, University of Washington, Seattle Washington 98195.

Heat Flow: David D. Blackwell, Geothermal Laboratory, 253 Heroy Building, Southern Methodist University, Dallas, Texas 75275.

Seismic Surveys: Walter Mooney, U.S. Geological Survey, M/S 77, 345 Middlefield Road, Menlo Park, California 94025.

Gravity and Aeromagnetic Surveys: Richard Couch, Department of Geophysics, School of Oceanography, Oregon State University, Corvallis, Oregon 97331.

Electrical Surveys: Harve Waff, Department of Geology, University of Oregon, Eugene, Oregon 97403.

Electrical Surveys: Norman Goldstein, Lawrence Berkeley Laboratory, University of California, Building 50, Room 1140, Berkeley, California 94720.

Well Logging: Richard Traeger, Sandia National Laboratory, Division 6241, Albuquerque, New Mexico 87185.

In Situ Stress and Related Down-hole Experiments: Mark Zoback, U.S. Geological Survey, M/S 77, 345 Middlefield Road, Menlo Park, California 94025.

REFERENCES

Blackwell, D.D., Bowen, R.G., Hull, D.A. Riccio, J., and Steele, J.L., 1982, Heat flow, arc volcanism, and subduction in northern Oregon: Journal of Geophysical Research, v. 87, no. B10, p. 8735-8754.

Blackwell, D.D., Hull, D.A., Bowen, R.G., and Steele, J.L., 1978, Heat flow of Oregon: Oregon Department of Geology and Mineral Industries Special Paper 4, 42 p.

Blackwell, D.D., and Steele, J.L., 1983, A summary of heat flow studies in the Cascade Range: Geothermal Resources Council, Transactions, v. 7, p. 233-236.

INFORMATION SHEET

PROGRAM FOR SCIENTIFIC DRILLING IN THE CASCADES (PSDC)

OBJECTIVES

1. To determine the geologic history and current volcano-tectonic setting of the Cascade volcanic arc. What is the configuration of the subducting oceanic plate? What is the current state of stress? What is the relationship between the plate tectonic history and the changes in type and rate of volcanism which have occurred?

2. To explore the deep thermal and hydrothermal regime under the young volcanic rocks of the High Cascades. What is the nature of the heat source which has generated the regional heat flow anomaly (Figure 1) and how high is the rate of conductive heat flow? How is the hydrothermal circulation occurring under the arc? Are hydrothermal mineral deposits developing under the High Cascade Range as they have in the older Western Cascades?

A more comprehensive explanation of the scientific issues is available upon request.

SCIENTIFIC PLAN

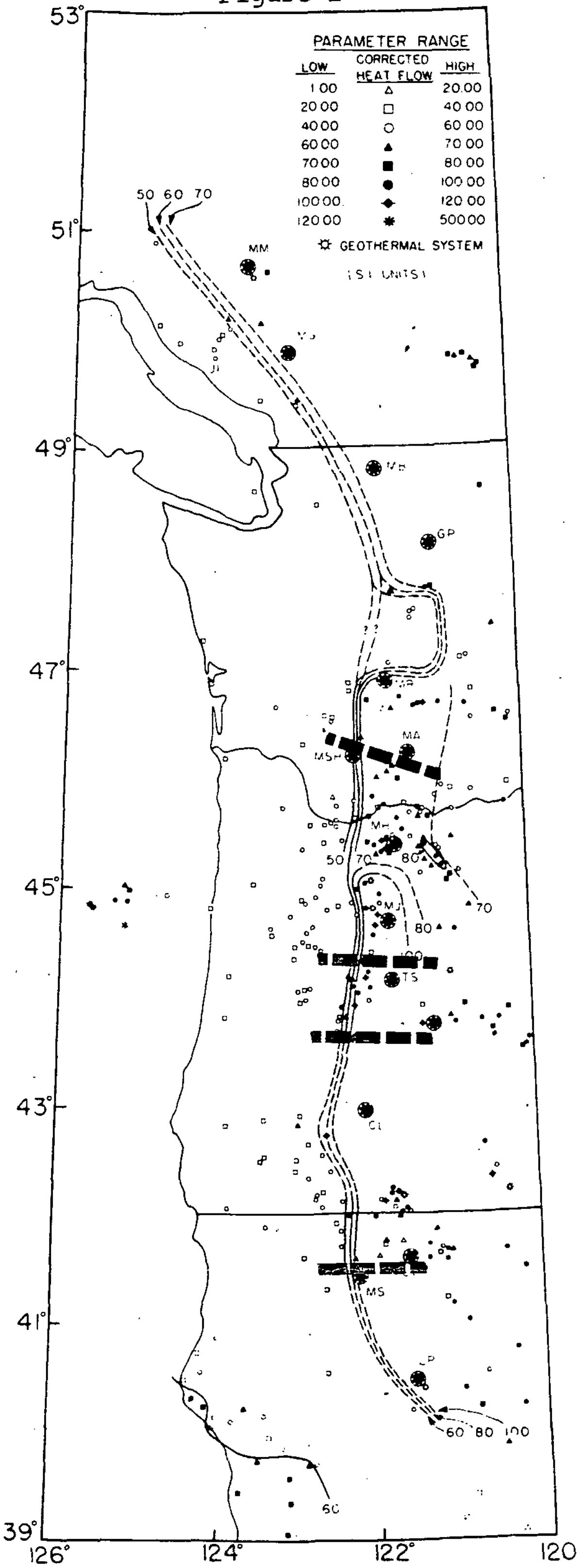
Introduction

The proposed investigation will focus on four east-west transects across the Cascade Range (Figure 1). Intermediate-depth (4,000'-9,000') drilling and areal surveys will occur in two phases beginning with one east-west transect to test and refine the methodology in a well-known, geologically simple area, followed by a second phase which will evaluate three contrasting areas for a second transect of intermediate-depth drilling. The third phase, drilling a deep (7-10 km) well, will not be addressed in the initial proposal except as a general concept.

PHASE I - The Santiam Pass Transect

The Santiam Pass area has been chosen for Phase I because it meets the requirements of being very well studied and possessing an easily interpreted geologic framework. It has a well defined axis of mafic to intermediate volcanism and appears to lie in a graben similar to other volcanic arcs of the circum-Pacific.

Figure I



Heat-flow map of the Cascade Range and adjoining areas (1 Mcal/cm^2 sec = 41.84 mWm^{-2}). From Blackwell and Steele (1983, p. 234). Black dashed lines are proposed transects across the range.

Three wells will be drilled in an east-west profile across the High Cascade Range, and a nearby industrial well in the Western Cascades will be reentered and tested. Geophysical and geological surveys will be completed across the full width of the Western and High Cascade ranges. The wells will consist of two 4,000' wells on each flank of the High Cascades, a 6,800' well on the crest of the range, and the industrial well which is about 9,000' deep. Geophysics will focus on active and passive seismic surveys, gravity, magnetotellurics, resistivity, and heat flow analysis. Geologic mapping of three new 15' quadrangles and publication of six previously mapped quadrangles will complete geologic coverage across the full width of the range.

All wells will be subjected to hydrologic tests and rock mechanics experiments, including in situ stress measurements. Complete lithologic and geophysical logs will be run and extensive laboratory tests will be conducted on cuttings and cores to determine lithologies and physical properties. The well data will be integrated with the areal surveys to build up a three-dimensional hydrologic-geologic model for the study area. The project will take about two years.

PHASE II

Assuming the methodology for Phase I is successful, Phase II will consist of drilling four 4,000' to 9,000' wells in a segment of the High Cascades which is typical of a large part of the volcanic arc but which is also geologically different from the Santiam Pass area. Three transects will be evaluated for this second phase: a transect across the southern Washington Cascades at the latitude of Mount St. Helens, a transect across the central Oregon Cascades in the vicinity of Willamette Pass, and a transect across the northern California Cascades at the latitude of Mount Shasta. Each of these transects will be evaluated by drilling of 8 shallow (3,000' or less) temperature gradient wells and by conducting a series of areal surveys. The initial work will be completed in one field season. This data will be used to pick one transect for an intensive drilling program involving four 4,000'-9,000' wells and additional detailed areal surveys, similar to Phase I. The project will take about three years to complete.

PHASE III - Deep Drilling

Deep drilling will be aimed at reaching the source of the regional heat flow anomaly at predicted depths of about 7-10 km. Temperatures should be near 600°C, if the heat flow model is correct. This hole will be sited in an area where earlier surveys indicate that the regional heat flow is relatively high but not affected by local, high-level magma bodies. It would thus be aimed at testing the main part of the volcanic arc with the highest background heat flow rather than a local young volcanic center.

The intent of this phase is thus quite different from typical thermal regime drilling programs which are aimed at high-level silicic magma chambers.

The deep well will explore the processes associated with the roots of a representative part of an andesitic to basaltic volcanic arc. The results will thus be relevant to a very wide area of similar volcanism throughout the world.

FUNDING STRATEGY

The proposal is about evenly divided in its objectives between purely scientific issues and issues relevant to the production of geothermal energy. Both NSF and USDOE are therefore possible funding agencies. The proposal may be presented to one or both. We will be consulting with both agencies on this matter.

TIMING

The proposal will be submitted in early 1985. If it is successful, field studies could begin in 1986.

VICTOR ATIYEH
GOVERNOR

Department of Geology and Mineral Industries

ADMINISTRATIVE OFFICE

1005 STATE OFFICE BLDG., PORTLAND, OREGON 97201 PHONE (503) 229-5580

MEMORANDUM

TO: Cascade Task Force and Interested Persons

FROM: George Priest

SUBJECT: Results of the Second Task Force Meeting, June 18, 1984, Menlo Park, California

Most of the active contributors to the evolving proposal for Cascade scientific drilling attended the June 18, 1984 task force meeting at the USGS headquarters in Menlo Park. Many others have indicated an interest in participating (see list at end of memo). This second meeting of the task force was very productive and resulted in several substantive changes in the scientific plan and the strategy for implementation of the plan.

The most important change in the plan is a change in the scope of Phase I, intermediate-depth (4,000' - 9,000') drilling. Whereas it is still recognized that parts of the central Cascades of Oregon have some of the highest rates of volcanism in the Cascade arc, the Task Force decided that the project should be enlarged to include the entire Cascade Range from Washington to northern California. The Mount Shasta-Medicine Lake Highlands area and the southern Washington Cascades were considered important sites for scientific studies. In keeping with the wider scope of the project, the project should be renamed "Program for Scientific Drilling in the Cascades" (PSDC), instead of the Central Cascade Drilling Program (CCSDP).

Because of the low regional heat flow and low overall volume of volcanism, the Washington Cascade Range is an unlikely site for Phase II, deep (7-10 Km) drilling. The Washington Cascades are, therefore, a less appropriate target for expensive intermediate-depth (4,000'-9,000') drilling than the other, more active parts of the volcanic arc. Cheaper, shallow temperature-gradient drilling and additional geologic and geophysical surveys in the Washington Cascades would, however, be an appropriate step. This data could be used to compare and contrast the volcanic-tectonic environment in Washington with the rest of the Cascades.

The Mount Shasta-Medicine Lake Highlands area emerged as a top contender for an east-west transect of intermediate-depth drilling, although, because of its high rate of volcanism and well-defined volcanic axis, the Santiam Pass area (Mt. Jefferson-Three Sisters) is still the top priority site. Because of the dispersed nature of the volcanism, hydrologic properties, and contrasting structural style of the Willamette Pass segment, it is also considered a priority site.

The Task Force decided to specify that one east-west transect of four intermediate-depth wells would be located at the Santiam Pass. A second transect of four intermediate-depth wells would be sited at either Willamette Pass or Mt. Shasta-Medicine Lake, contingent upon evaluation of areal survey data. In any case, shallow (500'-3,000'), relatively cheap temperature-gradient holes could be drilled in any areas not receiving deeper drilling to fill critical gaps in the regional heat flow picture.

In terms of short-term goals, the group decided to immediately circulate a short summary of the proposed research. Persons contributing to this summary should have their sections to me by July 2, 1984, so I can get it finalized and sent out before I go into the field on July 5, 1984.

In terms of the long-term goal of preparing a complete proposal, the most incomplete parts of the proposal are the introduction, the down-hole logging and tests, and the geophysics sections dealing with heat flow, gravity, aeromagnetic data, and electrical surveys. All sections must also be revised to reflect expansion of the scope of the proposal. I will expect to receive all of these parts from contributing members before September 14, 1984. All writing should be in formal proposal format, where appropriate. I will collate the sections into a single proposal by September 27, 1984. An internal review among contributors will follow from October 2 to 12, 1984. All contributing members will bring their review copies of the proposal to a meeting of the group on or about October 16, 1984 at Menlo Park (exact date will be arranged later). I will prepare a final proposal by November 1, 1984 and circulate it to outside reviewers.

Persons writing sections of the proposal include:

George Priest	Introductory sections, geologic studies (igneous petrology, geologic mapping, etc.), synopsis, drilling program.
David Blackwell	Short synopsis of the proposal, summary of geophysical studies of the Cascades, heat flow research, geophysical logging.
Walter Mooney and Douglas Stauber	Seismic research, VSP
Mahadenva Iyer	Seismic research, synopsis
Richard Couch	Gravity and aeromagnetic research
Norman Goldstein	Resistivity, controlled-source EMT, I.P.
Harve Waff	SP, Magnetotellurics, introduction and objectives of electrical surveys.

Richard Traeger	Contributor to geophysical logging section, down-hole testing.
Mark Zoback	In situ stress measurements, other down-hole tests.
Edward Sammel, Bob Mariner and Terry Keith	Hydrothermal studies (including flow tests, pump tests, water chemistry, hydrothermal mineralogy, soil-Hg surveys, areal hydrology).

Guidelines to use in rewriting include:

1. Taylor proposed areal surveys to the level of drilling expected in each study area.
   a) Southern Washington Cascades - 500' - 3,000' temperature gradient drilling. Drilling depths will be determined by geologic setting and resistivity soundings. Only a low-level of areal studies are appropriate. No soil-Hg, detailed geophysical, hydrologic, or geologic studies are planned. Regional geophysical studies with relatively low cost will be emphasized.

   b) Santiam Pass - One 9,000' hole, three 4,000' to 6,000' wells; possible Phase II, deep drilling site. Detailed areal surveys aimed at outlining the shallow (0-10 Km) and deep structure.

   c) McKenzie Pass - No drilling; however, this is the site of the COCORP and EMSLAB lines. Detailed areal surveys which are not duplicative of the COCORP or EMSLAB lines are appropriate.

   d) Willamette Pass - Possible site for four 4,000' to 6,000' wells; possible site for deep Phase II drilling. Some shallow (500'-3,000') temperature gradient drilling is appropriate whether or not intermediate-depth drilling is done. Drilling depths will be determined by resistivity soundings. Detailed areal surveys of shallow and deep structure are appropriate.

   e) Mount Shasta-Medicine Lake Highlands - Possible site for four 4,000'-6,000' wells; possible site for deep Phase II drilling. Some shallow (500'-3,000') temperature gradient drilling to measure background regional heat flow is appropriate, regardless of whether intermediate-depth drilling is pursued. Drilling depths will be based on resistivity soundings and geologic setting. Much areal survey work has already been done, so only a modest amount of complementary work need be done.

2. Try to keep the work within a four-year timeline for Phase I. Because intermediate-depth drilling is to be pursued at either Willamette Pass or Mount Shasta-Medicine Lake, but not both, areal surveys and shallow temperature gradient work sufficient to decide between the two areas must be done during the first field season. Drilling and additional detailed surveys will then proceed through the next 3 field seasons only at the winning site.

3. Emphasize the importance of proposed research to larger issues of world-wide significance.

4. Phase II will be summarized only as a general concept at this stage. The proposal will be aimed at Phase I, shallow and intermediate-depth drilling.

5. Only the 8 intermediate-depth (4,000'-9,000') wells will be available for significant down-hole tests, although all wells will be geophysically and geologically logged. Assume about 8 shallow (500'-3,000') wells for the logging and sampling in the Southern Washington Cascades, the Willamette Pass, and Mt. Shasta-Medicine Lake (a total of 24 shallow wells).

It was decided that the most appropriate means of presenting the proposal would be at a half-day special conference at the next AGU meeting in December, 1984. All contributing members would be expected to present a short summary of their proposed research at this conference. The conference should be followed by a meeting with potential funding agencies and members of the CSDP, hopefully, during the AGU.

SCHEDULE

Synopsis due to DOGAMI	July 2, 1984
Synopsis sent out	July 5, 1984
Final proposal due to DOGAMI	September 14, 1984
Proposal sent for internal review	September 27, 1984
Final review meeting at Menlo Park	October 16, 1984
Proposal sent for outside review	November 1, 1984
AGU mini-conference	December 1984
Meet with CSDP, USDOE, and NSF	December 1984

PERSONS INTERESTED IN PARTICIPATING

United States Geological Survey

Mahadeva Iyer - Seismic studies

Terry Keith - Hydrothermal alteration studies

Robert Mariner - Water Chemistry and isotopic studies

Walter Mooney - Seismic studies

Edward Sammel - Hydrology, geothermal assessment

United States Geological Survey (cont.)

Douglas Stauber	Seismic studies
Craig Weaver (Univ. of Wash.)	Seismic studies
Mark Zoback (soon to be at Stanford)	In-situ stress studies

Southern Methodist University

David Blackwell	Heat flow, geophysical logging, geothermal assessment
John Steele	Heat flow, data processing

Oregon State University

Richard Couch	Gravity, aeromagnetic studies
Robert Duncan	Radiometric dating (K-Ar) isotopic geochemistry of igneous rocks
Gary Smith	Volcanic stratigraphy, geologic mapping
Edward Taylor	Volcanic stratigraphy, geologic mapping

University of Oregon

Gordon Goles	Igneous petrology, radiometric dating, trace element analysis (INAA)
Brian Baker	Volcanic stratigraphy, geologic mapping
William Orr	Geologic studies, paleontology
Harve Waff	Geophysics - electrical methods

Portland State University

Paul Hammond	Volcanic stratigraphy, geologic mapping

Boise State University

Craig White	Volcanic petrology, geologic studies

Sandia National Laboratory

Jim Dunn	Geophysical logging
Peter Lysne	Geophysical logging
Richard Traeger	Geophysical logging

Sul Ross University

Dennis Nelson	Isotopic and trace element geochemistry of igneous rocks

Lawrence Berkeley Laboratory

Norman Goldstein	Geophysics - electrical methods

Oregon Department of Geology & Mineral Industries

Gerald Black	Heat flow, geologic mapping, geothermal assessment
George Priest	Geologic mapping, geothermal assessment, volcanic petrology

Columbia Geoscience

Al Waibel	Drilling program- cost estimates and drill site data collection, hydrothermal alteration studies

UURI/WRIGHT

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

June 28, 1984

Dr. George Priest
Department of Geology and Mineral Industries
1005 State Office Building
Portland, OR 97201

Subject: Cascades Geothermal Proposal and Drilling Strategy

Dear George,

Your meeting on the 18th at USGS was most productive. I was impressed with the many Cascade authorities there, and learned a great deal from theie proposal and discussion. Thanks for letting me sit in.

My notes on the meeting are attached in the form of a letter to Susan and Clay. As I was stuffing this in the mail, your Memorandum to the Cascade Task Force and Interested Persons arrived. Hopefully, our impressions are complimentary.

The most significant point I carried from the meeting was that the proposal focussed on the roots of the Cascade Range and deep plate tectonics. The Task Force seemed to exclude geothermal exploration and resource assessment - in the USGS sense. Imagine my surprise on reading the proposal to find an extensive plan for hydrothermal investigations, beginning on page 60. It seems to me that the proposal has two major values, or strengths: scientific understanding, and the preparatory steps for subsequent commercial geothermal development.

These two values are interdependent; I think that neither will survive without the other. Obviously, geothermal development is not feasible until the resource(s) is located and at least one reservoir is successfully drilled by industry. That will require major advances in scientific understanding of the Cascades thermal regime.

Less obvious is the need for scientific research to appeal to geothermal development for support. The sheer magnitude of the funds that you outlined, $16-124 million, will require all the support you can find to succeed in today's national budget priorities.

An obvious answer is to split the proposal in two: forming separate science and applications proposals, which may reference each other. I think that this would be a fatal mistake for two reasons. First, the different sponsors (e.g., NSF and DOE) will say "after you", and neither will act. Second, your strong team of investigators will split, with the geothermal part losing the overall conceptual framework which the science part will work out by interacting together.

So, I would suggest that the single proposal have two distinguishable, but related parts. Each would be addressed to their responsible sponsor(s). The whole would be carried out together, as funding permits.

- - - - - - -

In response to your letter of June 14, commenting on my Cascades geothermal strategy, my lack of knowledge of Cascades research is painfully clear.

On your first point, for DOE to act, it seems to me that we must build on what has been accomplished. After talking to Pat Muffler, it appears that USGS's extensive Cascades work will not be drawn together into a concise summary until a senior person agrees to take on this 1-2 year burden. I am glad to learn that DOGAMI is preparing a similar summary for BPA. Until this distillation is available, and necessary DOE research and implementation tasks identified, if there are any, DOE is acting blindly. Only ID/Clay Nichols and HQ/Marshall Reed are acquaintanted with the past USGS-DOE Cascades actions (primarily near Mt. Hood), as far as I know.

On your second point, regarding quality control of drillpipe, etc., I just finished the Final Report on DOE's Holly Sugar well, in the Imperial Valley. The principal drilling difficulties were twistoffs, caused by used drillpipe. Repeated AMF Tuboscope inspections failed to control this drillpipe quality problem. This problem is also common at the Geysers. Similar difficulties were frequently encountered by Union at Baca, and were a primary cause of loss of critical geological information, as well as lost production wells. Cementing is another procedure which requires proven expertise under conditions comparaable to the specific site. This is not regulation, in the sense of State authority, but certification of bidders qualifications. I've seen too many wells lost, and critical information never acquired, to recommend anything less.

Your suggestion of 2 year propritary rights is welcome. My 6 months was based on LBL's Klamath Basin geophysics data pool experience. I'm glad to learn that drilling projects have established the 2 year precedent.

On Newberry and Medicine Lake, I'm confused by the relation of the Hich Cascades to these eastern geothermal areas. They seem to be included in the Cascades Region by some authorities, and not by others. I assume that they may be related through the major NW fault zones, perhaps as en echelon Cascade volcanic structures. I'd like to be better informed on their relationship, if any. If they are excluded, we lose a substantial chance of extrapolating their proven geothermal activity to the west, into the High Cascades. Perhaps Stauber's and Iyer's mega-seismic probe of Newberry will resolve this question. In any case, I agree that we should not fund industry to pursue commercial interests. Perhaps we can purchase essential proprietary data, if it is relevant to the Cascades.

Once again, experience leads me to a different recommendation on economic interests. Back East, DOE drilled a major geothermal discovery well on the Delmarva Peninsula. Industry would not take it over, because it was not sited near the chicken farmers who could have put it to use.

In fact, Peter House and David Jones of UC Berkeley wrote a book entitled "Getting It Off the Shelf" on the problem of unused government research results. Their work "was motivated by a growing awareness that federally supported R&D ventures frequently fail to produce a technology that is compatible with both the objectives of public policy and the dictates of the technology system which produces, markets, and services products." We shouldn't wait until the bank loan is in place before starting the exploration; but neither should DOE ignore the ultimate problem of industry using the hot water and steam, if they can be found.

Sincerely,

Att: Letter to ID/Prestwich and Nichols, June 27, 1984, same subject.

cc: HQ/Toms, Reed
ID/Prestwich, Nichols
LBL/Goldstein
SAN/Adduci, Crawford, Holman
Stanford/Horne
USGS/Muffler, Sammel
UURI/Wright

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

June 27, 1984

Ms. Susan M. Prestwich
Dr. Clayton R. Nichols
Energy Technology and Conservation
US Department of Energy
550 2nd Street
Idaho Falls, ID 83401

Subject: Cascades Geothermal Exploration Proposal

Dear Susan and Clay,

We've had trouble getting together by phone on the results of the Cascades proposal meeting that George Priest held at USGS on June 18th, so I thought I'd send you that section of my weekly report. (The Apple makes multiple uses of the same information easy to accomplish.)

On June 18th, Dr. George Priest of Oregon State's Department of Mines and Mineral Industries (DOGAMI) held a meeting at USGS, Menlo Park CA. The purpose was to review the first draft of "Proposed Scientific Activities for the Central Cascades Scientific Drilling Program", an 80 page scientific proposal.

In attendance were the following co-authors of sections of the proposal; who represent most of the leading experts conducting field work in the Cascades:

- David D. Blackwell/SMU - heat flow analysis and geophysical logging
- Edward A. Sammel/USGS - geohydrology
- Robert H. Mariner/USGS - fluid chemistry
- Terry E. C. Keith/USGS - hydrothermal alteration studies
- Richard W. Couch/OSU - geophysical studies (gravity & magnetics)
- George R. Priest/DOGAMI - surface and subsurface geology and petrology
- Al Waibel/Columbia Geoscience - drillsite data collection and analysis
- H.M. Iyer & Doug Stauber/USGS - seismology

The proposal defines and justifies a broad, multi-year program for detailed study of the geology, tectonics, and thermal regime of the Cascades. The purpose is scientific, to understand the nature of the Cascades volcanic arc, as a typical circum-Pacific continental-margin volcanic arc.

Their fundamental interest is in plate margin tectonics and associated thermal behavior. The principal thrust is in targeting a transect of test holes across (and probably along) the crest of the High Cascades. These wells would explore the roots of the internal stratigraphy (layers of rock), structure, and heat flow of the Cascade Mountain Range. In the process, major, fundamental advanced would be made in understanding the Cascades as a geothermal province. There might be discoveries of hydrothermal systems, including commercial reservoirs, but that is not the objective of this proposal.

The scope of the proposed program is immense:

- Phase 1. surface geophysics, geology and hydrothermal studies; several 3,600-6,000' wells, one 9,000' well; all with downhole science; est. $16 M; est. 4 yrs.
- Phase 2. 21,000-30,000' well to the partial melting zone, with downhole science; est. $51-124 M; no time est.

The "Central" Cascades limitation has been dropped, and the entire Cascade Range, from Lassen in N. California to the Canadian Border, defines the scope of the proposed investigations. While the current draft, and authors, emphasize Oregon, an open meeting will be scheduled at the next American Geophysical Union meeting (in December ?) to invite ivestigators to add complimentary Washington State and California studies.

Funding support will be sought from NSF, and possibly DOE-BES/Kolstat. The Director of the USGS will be asked to have the USGS lead this effort. It seems to me that a special budget authorization will be required, with multi-State and -agency support and funding. With Senator Hatfield chairing the Senate Appropriations Committee, this is not inconceivable.

Existing deep crustal programs will contribute to Cascades understanding, like COCORP (Consortium for Continental Reflection Profile), and EMSLAB (which will use electromagnetic methods, rather than seismic, to profile the crustal slab).

The heat engine driving the active volcanism along the Pacific Northwest Coast is the Pacific plate, which is being overridden by the continent and "subducted" beneath it. The proposal's ultimate aim is drilling into the plastic zone (or magma) above this descending plate. There are many major points of mutual interest with DOE programs in Continental Scientific Drilling, Magma, Hydrothermal Energy, and Technology Development.

A letter summarizing the meeting and justifying a major Cascades science program is being drafted by Dave Blackwell; it will be reviewed and submitted to EOS for publication. The next steps will be the AGU meeting this winter, submittal of the proposal to the funding agency(s), and reviews with Congress and agency senior management.

Sincerely,

Martin W. Molloy, Ph.D.
Senior Program Manager

cc: HQ/Toms, Reed
DOGAMI/Priest
USGS/Sammel, Muffler
Stanford/Ramey
LBL/Goldstein, Lippmann
UURI/Wright
BPA/Geyer, Seely
File: Cascades Geothermal

VICTOR ATIYEH
GOVERNOR

Department of Geology and Mineral Industries
ADMINISTRATIVE OFFICE
1005 STATE OFFICE BLDG., PORTLAND, OREGON 97201 PHONE (503) 229-5580

MEMORANDUM

TO: Cascade Task Force and Interested Persons

FROM: George Priest

SUBJECT: Results of the Second Task Force Meeting, June 18, 1984, Menlo Park, California

Most of the active contributors to the evolving proposal for Cascade scientific drilling attended the June 18, 1984 task force meeting at the USGS headquarters in Menlo Park. Many others have indicated an interest in participating (see list at end of memo). This second meeting of the task force was very productive and resulted in several substantive changes in the scientific plan and the strategy for implementation of the plan.

The most important change in the plan is a change in the scope of Phase I, intermediate-depth (4,000' - 9,000') drilling. Whereas it is still recognized that parts of the central Cascades of Oregon have some of the highest rates of volcanism in the Cascade arc, the Task Force decided that the project should be enlarged to include the entire Cascade Range from Washington to northern California. The Mount Shasta-Medicine Lake Highlands area and the southern Washington Cascades were considered important sites for scientific studies. In keeping with the wider scope of the project, the project should be renamed "Program for Scientific Drilling in the Cascades" (PSDC), instead of the Central Cascade Drilling Program (CCSDP).

Because of the low regional heat flow and low overall volume of volcanism, the Washington Cascade Range is an unlikely site for Phase II, deep (7-10 Km) drilling. The Washington Cascades are, therefore, a less appropriate target for expensive intermediate-depth (4,000'-9,000') drilling than the other, more active parts of the volcanic arc. Cheaper, shallow temperature-gradient drilling and additional geologic and geophysical surveys in the Washington Cascades would, however, be an appropriate step. This data could be used to compare and contrast the volcanic-tectonic environment in Washington with the rest of the Cascades.

The Mount Shasta-Medicine Lake Highlands area emerged as a top contender for an east-west transect of intermediate-depth drilling, although, because of its high rate of volcanism and well-defined volcanic axis, the Santiam Pass area (Mt. Jefferson-Three Sisters) is still the top priority site. Because of the dispersed nature of the volcanism, hydrologic properties, and contrasting structural style of the Willamette Pass segment, it is also considered a priority site.

The Task Force decided to specify that one east-west transect of four intermediate-depth wells would be located at the Santiam Pass. A second transect of four intermediate-depth wells would be sited at either Willamette Pass or Mt. Shasta-Medicine Lake, contingent upon evaluation of areal survey data. In any case, shallow (500'-3,000'), relatively cheap temperature-gradient holes could be drilled in any areas not receiving deeper drilling to fill critical gaps in the regional heat flow picture.

In terms of short-term goals, the group decided to immediately circulate a short summary of the proposed research. Persons contributing to this summary should have their sections to me by July 2, 1984, so I can get it finalized and sent out before I go into the field on July 5, 1984.

In terms of the long-term goal of preparing a complete proposal, the most incomplete parts of the proposal are the introduction, the down-hole logging and tests, and the geophysics sections dealing with heat flow, gravity, aeromagnetic data, and electrical surveys. All sections must also be revised to reflect expansion of the scope of the proposal. I will expect to receive all of these parts from contributing members before September 14, 1984. All writing should be in formal proposal format, where appropriate. I will collate the sections into a single proposal by September 27, 1984. An internal review among contributors will follow from October 2 to 12, 1984. All contributing members will bring their review copies of the proposal to a meeting of the group on or about October 16, 1984 at Menlo Park (exact date will be arranged later). I will prepare a final proposal by November 1, 1984 and circulate it to outside reviewers.

Persons writing sections of the proposal include:

George Priest	Introductory sections, geologic studies (igneous petrology, geologic mapping, etc.), synopsis, drilling program.
David Blackwell	Short synopsis of the proposal, summary of geophysical studies of the Cascades, heat flow research, geophysical logging.
Walter Mooney and Douglas Stauber	Seismic research, VSP
Mahadenva Iyer	Seismic research, synopsis
Richard Couch	Gravity and aeromagnetic research
Norman Goldstein	Resistivity, controlled-source EMT, I.P.
Harve Waff	SP, Magnetotellurics, introduction and objectives of electrical surveys.

Richard Traeger	Contributor to geophysical logging section, down-hole testing.
Mark Zoback	In situ stress measurements, other down-hole tests.
Edward Sammel, Bob Mariner and Terry Keith	Hydrothermal studies (including flow tests, pump tests, water chemistry, hydrothermal mineralogy, soil-Hg surveys, areal hydrology).

Guidelines to use in rewriting include:

1. Taylor proposed areal surveys to the level of drilling expected in each study area.

   a) Southern Washington Cascades - 500' - 3,000' temperature gradient drilling. Drilling depths will be determined by geologic setting and resistivity soundings. Only a low-level of areal studies are appropriate. No soil-Hg, detailed geophysical, hydrologic, or geologic studies are planned. Regional geophysical studies with relatively low cost will be emphasized.

   b) Santiam Pass - One 9,000' hole, three 4,000' to 6,000' wells; possible Phase II, deep drilling site. Detailed areal surveys aimed at outlining the shallow (0-10 Km) and deep structure.

   c) McKenzie Pass - No drilling; however, this is the site of the COCORP and EMSLAB lines. Detailed areal surveys which are not duplicative of the COCORP or EMSLAB lines are appropriate.

   d) Willamette Pass - Possible site for four 4,000' to 6,000' wells; possible site for deep Phase II drilling. Some shallow (500'-3,000') temperature gradient drilling is appropriate whether or not intermediate-depth drilling is done. Drilling depths will be determined by resistivity soundings. Detailed areal surveys of shallow and deep structure are appropriate.

   e) Mount Shasta-Medicine Lake Highlands - Possible site for four 4,000'-6,000' wells; possible site for deep Phase II drilling. Some shallow (500'-3,000') temperature gradient drilling to measure background regional heat flow is appropriate, regardless of whether intermediate-depth drilling is pursued. Drilling depths will be based on resistivity soundings and geologic setting. Much areal survey work has already been done, so only a modest amount of complementary work need be done.

2. Try to keep the work within a four-year timeline for Phase I. Because intermediate-depth drilling is to be pursued at either Willamette Pass or Mount Shasta-Medicine Lake, but not both, areal surveys and shallow temperature gradient work sufficient to decide between the two areas must be done during the first field season. Drilling and additional detailed surveys will then proceed through the next 3 field seasons only at the winning site.

3. Emphasize the importance of proposed research to larger issues of world-wide significance.

4. Phase II will be summarized only as a general concept at this stage. The proposal will be aimed at Phase I, shallow and intermediate-depth drilling.

5. Only the 8 intermediate-depth (4,000'-9,000') wells will be available for significant down-hole tests, although all wells will be geophysically and geologically logged. Assume about 8 shallow (500'-3,000') wells for the logging and sampling in the Southern Washington Cascades, the Willamette Pass, and Mt. Shasta-Medicine Lake (a total of 24 shallow wells).

It was decided that the most appropriate means of presenting the proposal would be at a half-day special conference at the next AGU meeting in December, 1984. All contributing members would be expected to present a short summary of their proposed research at this conference. The conference should be followed by a meeting with potential funding agencies and members of the CSDP, hopefully, during the AGU.

SCHEDULE

Synopsis due to DOGAMI	July 2, 1984
Synopsis sent out	July 5, 1984
Final proposal due to DOGAMI	September 14, 1984
Proposal sent for internal review	September 27, 1984
Final review meeting at Menlo Park	October 16, 1984
Proposal sent for outside review	November 1, 1984
AGU mini-conference	December 1984
Meet with CSDP, USDOE, and NSF	December 1984

PERSONS INTERESTED IN PARTICIPATING

<u>United States Geological Survey</u>

Mahadeva Iyer - Seismic studies

Terry Keith - Hydrothermal alteration studies

Robert Mariner - Water Chemistry and isotopic studies

Walter Mooney - Seismic studies

Edward Sammel - Hydrology, geothermal assessment

United States Geological Survey (cont.)

Douglas Stauber	Seismic studies
Craig Weaver (Univ. of Wash.)	Seismic studies
Mark Zoback (soon to be at Stanford)	In-situ stress studies

Southern Methodist University

David Blackwell	Heat flow, geophysical logging, geothermal assessment
John Steele	Heat flow, data processing

Oregon State University

Richard Couch	Gravity, aeromagnetic studies
Robert Duncan	Radiometric dating (K-Ar) isotopic geochemistry of igneous rocks
Gary Smith	Volcanic stratigraphy, geologic mapping
Edward Taylor	Volcanic stratigraphy, geologic mapping

University of Oregon

Gordon Goles	Igneous petrology, radiometric dating, trace element analysis (INAA)
Brian Baker	Volcanic stratigraphy, geologic mapping
William Orr	Geologic studies, paleontology
Harve Waff	Geophysics - electrical methods

Portland State University

Paul Hammond	Volcanic stratigraphy, geologic mapping

Boise State University

Craig White	Volcanic petrology, geologic studies

Sandia National Laboratory

Jim Dunn	Geophysical logging
Peter Lysne	Geophysical logging
Richard Traeger	Geophysical logging

Sul Ross University

Dennis Nelson	Isotopic and trace element geochemistry of igneous rocks

Lawrence Berkeley Laboratory

Norman Goldstein	Geophysics - electrical methods

Oregon Department of Geology & Mineral Industries

Gerald Black	Heat flow, geologic mapping, geothermal assessment
George Priest	Geologic mapping, geothermal assessment, volcanic petrology

Columbia Geoscience

Al Waibel	Drilling program- cost estimates and drill site data collection, hydrothermal alteration studies

VICTOR ATIYEH
GOVERNOR

Department of Geology and Mineral Industries
ADMINISTRATIVE OFFICE
1005 STATE OFFICE BLDG., PORTLAND, OREGON 97201 PHONE (503) 229-5580

November 6, 1984

Dr. Marty Molloy
U.S.D.O.E. - F.G.S.
1333 Broadway
Oakland, CA 94612

Dear Marty:

In response to your question about our geothermal charter, we have a duel role within the agency. One is the usual program of geothermal research, dissemination of information, and advice to our regulatory group. The second is a general contribution to the overall goals of the agency which, for the last two years, includes a major program of basic geologic mapping in cooperation with the USGS Oregon map project. The geothermal group, in order to meet both of these goals, has in recent years focused on basic geologic mapping in areas of high heat flow within the central Western Cascades. The project contributes to USGS efforts to complete the Salem 1° x 2° sheet and aids in delineating structures which may control circulation of hydrothermal fluids. It also allows us to do important work in a time of scarce federal drilling funds.

Our interest in the CSDP is also duel in nature. We wish to study overall processes of mass transfer of fluids in response to the heat flux and geologic structure, but we are also interested in the overall geologic framework of the Cascades. After the disappointing results at Mount Hood, we are not as interested in pursuing resources at individual volcanic centers as in looking at the overall, background heat flow and fluid circulation patterns. The current proposal thus emphasizes heat flow and hydrologic measurements relevant to the volcanic arc as a whole. The geologic framework is addressed in part to better understand the relationship between the geology and the thermal and hydrothermal processes, but also to address fundamental earth science issues. The result of this broad scientific emphasis is a program which will be of general interest and applicability to a broad range of similar geologic terranes and a wide scientific and industrial audience.

To address your concerns about the Santiam Pass transect:

1. The road system is east-west (see enclosed map).
2. The area has extensive Quaternary volcanic cover, including a number of Holocene centers.
3. There are excellent aeromagnetic, gravity, and geologic data bases for the area which have been synthesized by ourselves and workers at OSU into a generalized geologic model for the area.

Whereas we recognize that additional surface and shallow drilling data would be helpful in siting the Santiam Pass holes, we feel the current data is adequate. Drilling to 4000' - 6800' in Phase I has the advantages of:

1. Virturally guaranteeing successful penetration of the "rain curtain" effect and thus accurate measurements of deep fluids and heat flow.
2. Allowing calibration of surface surveys to real physical measurements in holes deep enough to offer significant constraints to present theoretical models. This will greatly aid interpretation of surface surveys in Phase II, which is aimed at areas generally less well studied than Santiam Pass.

We were also concerned that the proposal would not be viewed as a CSDP, if the areal surveys were so extensive in Phase I that they dwarfed the drilling effort. Santiam Pass is the only area in the Cascades where the geologic data base and the accessibility are great enough to warrant a large-scale drilling program in tandem with extensive surface surveys. Fortunately, the area also meets the basic requirement of being highly representative of the andesitic-basaltic segments of typical subduction-related volcanic arcs.

If you have any other questions or comments, please feel free to contact me. Your input is a valuable resource for this proposal.

Sincerely,

George R. Priest

George R. Priest
Geothermal Specialist

GRP:ak
cc: Pat Muffler
Mike Wright
Ed Sammel
Don Hull

Enclosure


Toni Lake
Santiam Lake
Forest Camp
Train Lake
Maxwell Lake
Twin Lakes
Maxwell Butte
Three Fingered Jack
Upper Berley Lake
Lower Berley Lake
Summit Lake
First Creek Camp
Martin Lake
Little Lake
Craig Lake
Booth Lake
Jack Shelter
Big Spr.
Cinder Pits
Little Nash Crater
Santiam Junction
Sawyers Cave
AIRSTRIP
Lost Lake
Nash Crater
Potato Hill
Hogg Rock
Gravel Pit
Lodge
Square Lake
Round Lake
Long Lake
Douthit Spr.
Hoodoo
Hoodoo Ski Bowl
Hoodoo Butte
Hayrick Butte
Circle Lake
Sand Mtn
Lookout
Island Lake
Link Lake
Hand Lake
Cache Lake
CORBETT MEMORIAL STATE PARK
Blue Lake
Suttle Lake
Tamarack
Dark Lake
JEFFERSON CO
DESCHUTES CO
Meadow Lake
Big Lake
Four O'Clock Lake
Hortense Lake
Cache Mtn
SANTIAM HIGHWAY
OLD SANTIAM WAGON ROAD
SKYLINE TRAIL
Santiam Pass
FOREST BOUNDARY
NATIONAL FOREST
Santiam Valley
300 000 FEET (NORTH)
T. 12 S.
T. 13 S.
R 7 1/2 E
R 8 E
LAVA