MASTER

GEOHERMAL RESOURCE ASSESSMENT
OF MT. HOOD VOLCANO, OREGON - PHASE I STUDY

TECHNICAL PROGRESS REPORT NO. 2

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INTRODUCTION

On July 1, 1977 the Oregon Department of Geology and Mineral Industries began work on two geothermal energy resource projects with funds provided by the U.S. Energy Research and Development Administration (now U.S. Department of Energy) under contract number EG-77-C-06-1040. The projects are: a geothermal resource assessment of Mt. Hood Volcano in the Cascade Range (Fig. 1) and a statewide inventory of low temperature geothermal resources.

The purpose of this report is to describe the continued progress in each of these studies made during the period, October 1, 1977 - March 31, 1978. An application for an extension and additional funding of these projects was submitted to the U.S. Energy Research and Development Administration (DOE) on September 14, 1977, funded on December 28, 1977 and later extended to December 31, 1978. Portions of this report were written by various researchers including Dr. Richard Couch, Mr. Craig M. White, Dr. David D. Blackwell, and Dr. Joseph F. Riccio.

MT. HOOD GEOTHERMAL RESOURCE ASSESSMENT PROJECT

In February 1977 the U.S. Energy Research and Development Administration (ERDA), now Department of Energy (DOE); U.S. Geological Survey (USGS); U.S. Forest Service (USFS); and Oregon Department of Geology and Mineral Industries (DOGAMI) jointly undertook a geothermal energy resource assessment of Mt. Hood Volcano in the Cascade Range, 50 airline miles east-southeast of the city of Portland. The first technical progress report for this assessment was presented in October 1977. The report describes technical progress since the above report administered by DOGAMI. Other phases of the field study have been managed by the USGS and DOE.

Some of the field studies administered by DOGAMI have been managed by its staff personnel and/or consultants, whereas other phases have been conducted by university researchers working under sub-contract to DOGAMI as noted below in the sections of the report describing individual research projects.

The goal of the Mt. Hood resource assessment project is the evaluation of a geothermal resource capable of electric and/or non-electric energy application. The current studies described herein are designed to aid in the selection of one or more deep exploratory drill holes to verify the existence of such a geothermal resource, assuming, of course, that the drilling would be environmentally acceptable.

Geology and Geochemistry

Geological studies of the Mt. Hood Volcano are being conducted by Craig M. White (Department of Geology, University of Oregon) and Donald A. Hull (DOGAMI). Rock geochemistry and magnetic polarity studies also are being done by Craig M. White.

Specific aspects of the geology and rock geochemistry of the Mt. Hood area have been studied in order to establish a physical and petrologic model for Mt. Hood volcanism. The initial phase of this study attempts to define the petrologic relationship among the young, siliceous rocks at Mt. Hood.

The Mt. Hood Volcano is comprised of four eruptive units: (1) voluminous, two-pyroxene andesite, which forms the bulk of the stratovolcano, (2) olivine andesite erupted from parasitic cones, (3) hypersthene-hornblende dacite erupted as flows or extruded as summit domes, and (4) dacitic block and ash flows (Wise, 1969, 1977). On the basis of radiocarbon dating, Crandall and Rubin (1977) subdivided the block and ash flows into three units: the Polallie flow (12,000 Y.B.P.), the Timberline flow (1700 Y.B.P.), and the Old Maid Flat flow (200-500 Y.B.P.). Minor eruptions of pumice also may have occurred in historic time in 1859 and 1865 (Harris, 1976).

XRF analyses for ten major and three trace elements (Rb, Sr, Zr) were made of 44 rock samples. Twenty specimens also were analyzed for additional three trace elements (Ba, Nb, Y). Emphasis was placed on analyses of cognate blocks from dated block and ash flows and andesite from flows in known stratigraphic sequence. The range of silica values of the analyzed samples from the major Mt. Hood eruptive units is given in Fig. 2.

Recent research on post-Pliocene volcanic rocks from the Mt. Jefferson area has demonstrated the value of trace element geochemistry in identifying individual magma batches in what otherwise appear to be a single related series of lavas (White and McBirney, 1978). At Mt. Hood, no consistent trends in trace element chemistry could be discerned except in small sequences of two or three flows. The "excluded" minor and trace elements in six andesite samples from the flow sequence above Mt. Hood Meadows do not increase serially

FIG 2

- COGNATE BLOCKS FROM BLOCK AND ASH FLOWS
- DACITE FLOWS AND PLUGS
- MAIN CONE HOOD ANDESITE
- BASALTIC ANDESITE SATELLITE ERUPTION

upward in the section, but rather are depleted in several of the uppermost flows (Fig. 3). Analyses for additional elements as well as continued surface and subsurface sampling will be necessary before a model can be formulated for the evolution of the main cone.

Thirteen specimens from cognate blocks in the block and ash flows of known age were analyzed for major and three trace elements. The major element chemistry is remarkably similar for samples from the three age groups, with all specimens having SiO_2 values between 62 and 64%. Trace element data for thirteen samples from block and ash flows and a single pumice sample are plotted in Fig. 4 along with additional data (Nb, Y, Ba) for five of the blocks.

A consistent pattern is seen in which the excluded trace and minor elements decrease in abundance in the blocks from younger flows. This trend is the reverse of what would be expected if the block and ash flows were a series of lavas related by fractional crystallization. The data strongly imply that each of the three flows represents a separate magma batch which is depleted in the "excluded" elements relative to the previous pulse. An alternate possibility exists that the block and ash flows represent successive eruptions from a single, compositionally zoned magma chamber. It is, however, difficult to envision a process which would result in trace element zonation without comparable systematic variations in major elements or phenocryst proportions.

The pumice unit does not continue this trend but rather is enriched in the "excluded" elements relative to its immediate predecessor. The chemical relationship as well as their temporal proximity suggests that the pumice and the Old Maid Flat flow may be products of a common magma reservoir.

Young siliceous volcanism is commonly cited as being of most interest in studies of potential geothermal resources. At Mt. Hood the three known

FIG. 3

COMPOSITIONAL VARIATION OF MINOR AND TRACE ELEMENTS IN 6 ANDESITE SAMPLES FROM THE SECTION ABOVE MT. HOOD MEADOWS. FLOWS ARE NUMBERED SEQUENTIALLY WITH #1 BEING THE LOWEST FLOW IN THE SECTION.

Fig. 4

TRACE AND MINOR ELEMENT COMPOSITIONAL RANGES FOR (1) 12,000 YEAR BLOCKS, (2) 1700 YEAR BLOCKS, (3) 200-250 YEAR BLOCKS AND (4) 100 YEAR (?) PUMICE. NUMBER OF ANALYZED SAMPLES IS NOTED ON EACH FIGURE.

eruptions of dacitic pyroclastic debris appear to represent geochemically distinct magma batches which repeatedly filled a long-lived conduit system. It is unlikely that siliceous volcanism at Mt. Hood was the product of successive tapping of a large, shallow magma chamber.

The occurrence of a very young pumice unit which may be related to the 200-250-year-old dacite eruptive is of interest. If the units are related by fractional crystallization in a closed magma chamber, a perfectly excluded trace element will double in concentration each time the magma volume is halved. The highest trace element concentration factor between the Old Maid Flat dacite blocks and the pumice is 19%, which would imply that only a small amount of the magma crystallized during the 100-150-year interval between the two eruptions. Much more data will be required before these assumptions can be confirmed; however, the method may prove useful in determining the probability of magma still existing within or below the Mt. Hood Volcano.

Magnetic Polarity

Magnetic polarities of the pre-Mt. Hood rocks were determined in the field with a fluxgate magnetometer. The polarities of at least three oriented specimens were determined at each locality. Figs. 5 and 6 show the locations of magnetically measured units on the geologic and magnetic anomaly maps, respectively.

The magnetic anomaly pattern is strongly influenced by topography and the strength and polarity of remanent magnetism. Prominent negative anomalies such as at Tom Dick and Harry Mountain and Gunsight Butte most likely reflect a high ridge of negatively polarized flows. The relatively flat anomaly pattern immediately west of Mt. Hood may be caused by the thick sequence of randomly polarized volcanic sediments of the Rhododendron Formation.

Geological and polarity studies will continue to aid in the interpretation of the aerial magnetic anomaly map. The negative anomalies on the south and west flanks of the mountain should be more fully investigated as they may indicate the presence of hot subsurface rock. The tear-shaped anomaly located above the Timberline Lodge area is of particular interest since there are no nearby outcrops of potentially reversed pre-Mt. Hood rocks.

Gravity

The Geophysics Group, under the direction of R. Couch and K. Keeling at Oregon State University, obtained gravity measurements of 239 stations in approximately 1600 km² area of Mt. Hood with a LaCoste and Romberg Model G Geodetic Gravity Meter #126. These stations combined with station data from the OSU Gravity Library total 250 stations and yield a spatial density of one station per 5.5 km².

Base stations for the measurements were established at Zigzag Ranger Station, Government Camp, White Bridge Park, Parkdale, and near Cooper Spur. The Zigzag Ranger Station gravity base station (980,489.14 mgl) was tied to the USAF gravity base station WA-142A (Woollard and Rose, 1963) located at Portland International Airport (980,648.3 mgl) by personnel of the USGS (personal comm. D.F. Barnes, 1969) and by personnel of the OSU Geophysics Group (unpublished data, 1975).

USGS benchmarks, spot elevations on USGS 7.5 minute and 15 minute topographic maps and barometric altimetry provided vertical control. The estimated uncertainties in the vertical control associated with these methods of elevation determination are +1, +5, and +10 feet, respectively. A recording barometric base station used to monitor barometric changes provided data to ascertain the validity and accuracy of altitudes determined by barometric altimetry.

USGS 7.5 minute and 15 minute topographic maps were used to determine horizontal position control. The estimated uncertainty is ± 0.02 minutes of latitude and longitude.

The observed gravity was corrected for meter drift and earth tides using the formulation of Longman (1959). The mean drift of the gravity meter observed during the reoccupation of base stations at the end of a gravity traverse or loop was ± 0.04 mgl and the standard deviation was 0.09 mgl. The uncertainty in the measurements caused by the drift in the meter was generally much less than caused by the uncertainty in the corresponding station elevation.

Theoretical gravity (TG) was computed using the International Gravity Formula, IGS-1930 (Heiskanen and Vening Meinesz, 1958). The free-air gravity is given by the equation

$$FA = OG - TG + (0.09411349 - 0.000137789 \sin^2 \theta)h - 0.67 \times 10^{-8} h^2$$

where θ is the latitude, and h is the elevation of the station above mean sea level in feet. A simple Bouguer gravity anomaly (SBS) was calculated with the equation

$$SBA = FA - 0.012774 h\rho$$

where ρ the reduction density was assumed to be 2.40 gm/cm^3 and h is the station elevation in feet above mean sea level. Terrain corrections for Hayford-Bowie zones A and B (Robins and Oliver, 1970), that is, from the gravity station to a radial distance of 68 meters, were made in the field at the time of measurement.

A topographic map of the Mt. Hood area, based on data contained in the USGS 1:250,000 quadrangle map The Dalles NL 10-9, is shown on Fig. 7. The high relief and few roads made access to the area difficult; consequently to achieve approximately uniform grid of stations, most measurements were made by back-packing the meter to the station sites.

Fig. 8 shows the location of the 250 gravity stations in the Mt. Hood area. Fig. 9 is a free-air gravity map of Mt. Hood based on the data from the stations located in Fig. 8. A maximum free-air anomaly of more than 150 mgls occurs over the peak of Mt. Hood. The gravity anomaly contours correspond very closely to the topographic contours of Fig. 7. No unusual anomalies, positive or negative, are noticeable on the flanks of Mt. Hood. Further analysis of these data, planned for the next phase of this program, will include a complete Bouguer gravity anomaly (CBA) map of the area. Further, the data will be reviewed for indications of a suspected east-west trending fault near the base of Mt. Hood.

Thermal Modelling

Thermal modelling of the Mt. Hood Volcano area has been undertaken by D. D. Blackwell of Southern Methodist University. Up to the present time, preliminary interpretation of the regional heat flow and geothermal gradient data in the Cascades has been initiated.

Water Sampling

In order to better understand the hydrologic regime and in an attempt to ascertain the degree of mixing between cold near-surface ground water and deep thermal water, a program of systematic water sampling was begun in May 1977 and continued throughout the year and into early 1978. Waters sampled include cold springs, cold surface drainages, Swim Warm Springs (located near the town of Government Camp on the south side of Mt. Hood) and condensate from the fumaroles at Crater Rock.

Sampling is a joint effort by Harold A. Wollenburg (Lawrence Berkeley Laboratory), James Robison (USGS) and Richard G. Bowen (consultant to DOGAMI).

TOPOGRAPHIC MAP
MOUNT HOOD AREA, OREGON

AREA OF THIS MAP

DATA FROM USGS 1:250,000 QUADRANGLE MAP
THE DALLES NL 10-9

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
CONTOUR INTERVAL 1000 FEET

OREGON STATE UNIVERSITY
DECEMBER, 1977

Figure 7

GRAVITY STATIONS
MOUNT HOOD AREA, OREGON

AREA OF THIS MAP

GRAVITY STATIONS

- ▲ J THIRUVATHUKAL 1969 OSU
- K KEELING 1977 OSU

UNIVERSAL TRANSVERSE MERCATOR PROJECTION

OREGON STATE UNIVERSITY
DECEMBER, 1977

Figure 8

FREE-AIR GRAVITY MAP
MOUNT HOOD AREA, OREGON

AREA OF THIS MAP

KILOMETERS

MILES

OREGON STATE UNIVERSITY
DECEMBER, 1977

GRAVITY DATA FROM
J THIRUVATHUKAL 1969 OSU
K KEELING 1977 OSU

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
CONTOUR INTERVAL 10 MGALS
ESTIMATED STATION UNCERTAINTY ± 2 MGAL

Figure 9

Analyses of the water samples are being provided by Lawrence Berkeley Laboratory, USGS, and the State of Oregon.

Some preliminary data from water samples from the Mt. Hood area have been received from LBL. These data demonstrate the dilution effects occurring at Swim Warm Springs. LBL will use mixing model calculations to determine main source temperatures.

Drilling

Pending approval of an extension of an existing contract between DOE and DOGAMI, temperature gradient drilling has not been initiated during the current report period.

Northwest Natural Gas Company, a private utility serving the Portland area, suspended their temperature gradient exploratory hole 2S/8E-15 CD, in Old Maid Flat west of Mt. Hood at 564 m (1,850 feet) in late 1977.

Land Status

Significant changes have occurred in land management classification within the Sandy area and additional changes are anticipated in the future. The boundary of the Bull Run watershed has materially changed since submission of the first progress report. It is believed that additional gerrymandering may occur. Further, major additions to the existing Mt. Hood Wilderness Area have been included in the American Endangered Wilderness Bill. The effect of these wilderness withdrawals is to narrow the area available at Mt. Hood for continuing geothermal energy research.

STATEWIDE LOW TEMPERATURE GEOTHERMAL RESOURCE INVENTORY

In addition to the Mt. Hood project, DOGAMI is engaged in a statewide inventory of low temperature geothermal resources; i.e., in the range of 20° - 90° Celsius. The initial phase of the inventory consisted of a compilation of published and unpublished chemical data on hot springs and hot water wells for inclusion in the USGS computer-based GEOTHERM program. Analyses of 25 hot springs not previously included in GEOTHERM have been compiled and the first phase has been completed. Only limited work on the inventory has been done during this report period, pending receipt of additional funding.

CONCLUSIONS

Several phases of the Mt. Hood geothermal resource assessment project are nearing completion. Most of the field work has been completed for the geologic study, gravity survey, and water sampling portions of the project. Thermal modelling, water analyses, rock analyses and age dating, and preparation of a complete Bouguer gravity map are in progress. Drilling in Old Maid Flat by Northwest Natural Gas on the west side of Mt. Hood will be resumed as soon as necessary permits have been obtained from the USFS and USGS, funds have been received, and drilling contracts completed.

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