GL00974

VICTOR ATIYEH
GOVERNOR

Department of Geology and Mineral Industries

ADMINISTRATIVE OFFICE

1069 STATE OFFICE BLDG., PORTLAND, OREGON 97201 PHONE (503) 229-5580

July 10, 1979

Mr. Jack C. Cummings, Director
Contracts Division
U.S. Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

Dear Mr. Cummings:

Please find enclosed ten (10) copies of our final report of the Statewide Low Temperature Geothermal Resource Evaluation with enclosures covering the period July 1, 1977, to June 15, 1979, for contract number (EG-77-C-06-1040) AC06-77-ET-28369.

Because of an unforeseen delay in the printing of GMS-11, the map is not currently available but will be sent to you shortly under separate cover.

Sincerely yours,

John D. Beaulieu

John D. Beaulieu
Deputy State Geologist

JDB:lk
Encl. 1. GMS-10
2. Open File Report 0-79-3
3. Special Paper 4

cc John W. Salisbury
Gerald Brophy
Clayton Nichols
David L. Williams

RESEARCH PROPOSAL

SUBMITTED TO DIVISION OF GEOTHERMAL ENERGY

U. S. DEPARTMENT OF ENERGY

Title

LOW TEMPERATURE GEOTHERMAL RESOURCE ASSESSMENT, PHASE III

By

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
1069 State Office Building
Portland, Oregon 97201

Amount requested: $300,000

	DOE	DOGAMI	TOTAL
Fiscal 1981	$300,000	$12,230	$312,230

Starting date: April 1, 1981 through April 1, 1982

ENDORSEMENTS

Principal Investigator

George R. Priest — 2/6/81

George R. Priest   Date

Approving Administrative Official

John D. Beaulieu — 2/6/81

Donald A. Hull, State Geologist   Date

C O N T E N T S

INTRODUCTION

During Phase I of the Western States Cooperative Direct-Use Geothermal Program (Contract No. EG-77-C-06-1040) available data on low temperature ($20^{o}C$ - $90^{o}C$) geothermal resources were collected in Oregon. Based on review of these data, nine low-temperature resource areas were identified (Fig. 1). During the Mt. Hood Geothermal Resource Assessment project (1978), Contract No. AC06-77-ET-28369, three other low-temperature resource areas were identified: Parkdale, northeasterly of Mt. Hood, Powell Buttes, northeast of Bend, and the Corbett-Camp Collins area, 9.6 km (6.0 mi) east of Portland (Fig. 1).

Phase II of the direct-heat geothermal program primarily entailed the selection of specific sites, based on Phase I data, within the nine resource areas for detailed evaluation. Geological-geophysical investigations of the specific sites were conducted in order to select drill test locations. Sites were drilled on a priority basis for reservoir confirmation and assessment. Results, including maps and reports, were published by DOGAMI on an open-file basis and made available to the geothermal community, governmental agencies, and the public. Development of direct-use geothermal resources will have a significant near-term impact by fulfilling, in part, the energy requirements of Oregon and the United States.

This proposal describes the studies necessary to continue and complete most aspects of the Phase II program, and to consolidate and synthesize available data with the view of developing a coherent interim statement of the geothermal potential of the State of Oregon. Summary costs by task are provided in the Budget Section of this proposal.

Not contemplated in this proposal is intermediate to deep geothermal drilling for final confirmation and assessment of promising geothermal

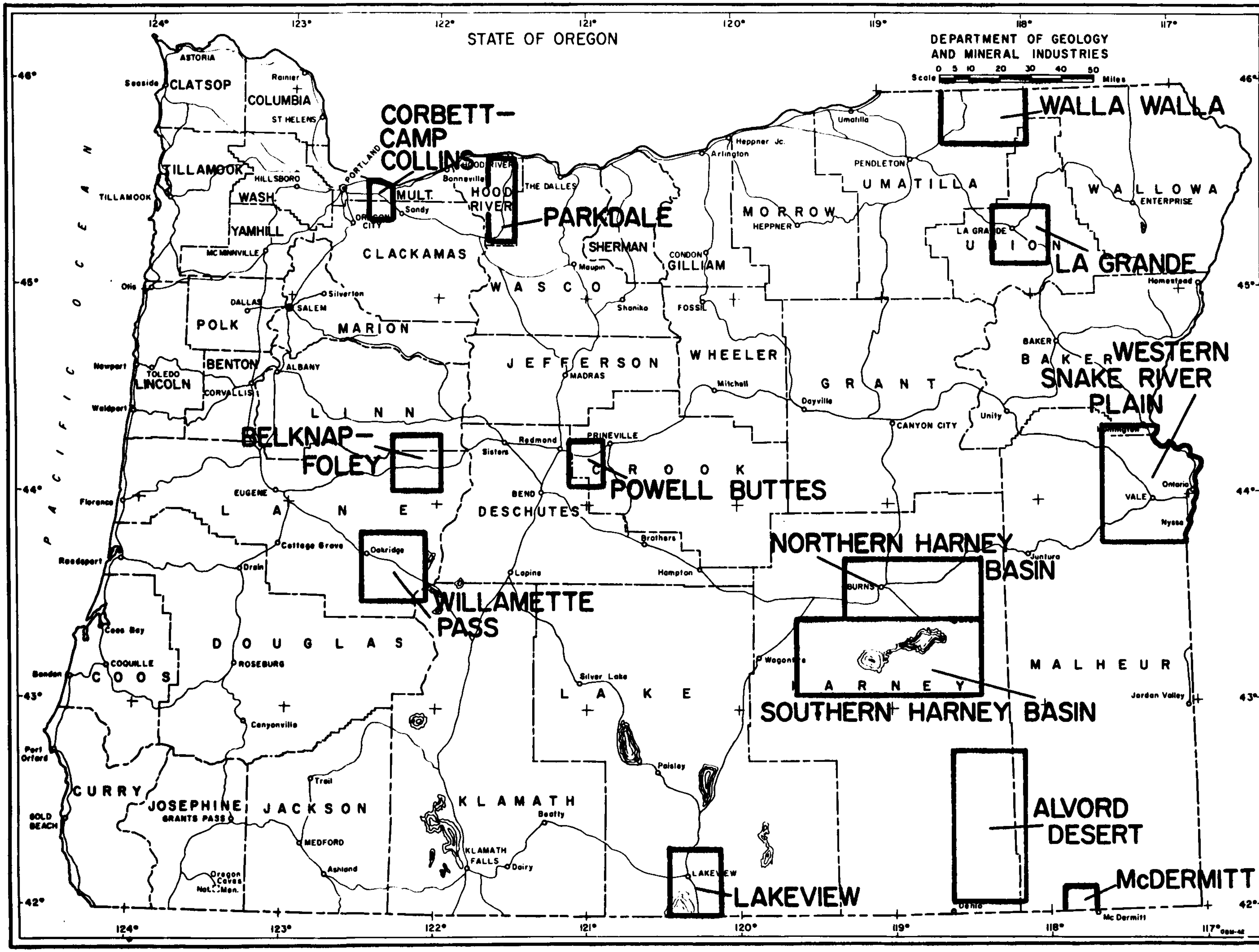

Figure 1: Map showing location of study area.

targets such as the Lakeview area. As these areas are identified, they will continue to be brought to the attention of DOE.

The thrust of the current proposal is to emphasize low cost data and sample collection statewide and to formulate an up-to-date revised geothermal assessment for the State of Oregon which includes a measure of the resource constrained by geologic parameters and a set of conceptual geothermal models to priority systems in the state. Phase III, this study, draws upon the regional data developed in previous studies, integrates the earlier Cooperative and Western Cascades efforts into one coherent study, and focuses attention on discrete resource areas in Oregon.

ORGANIZATION AND MANAGEMENT PLAN

The Department of Geology and Mineral Industries (DOGAMI) is responsible under Oregon State Law for the conduct of geologic research and the regulation for the exploration and development of minerals and mineral fuels including geothermal energy. DOGAMI and its predecessor organization have been in existence since 1913. The agency has a staff of 15 geologists and engineers; a chemical, assay and spectrographic laboratory; library; cartographic facilities; and an editorial and accounting staff. These facilities are available to the project described in this proposal at no additional cost.

DOGAMI has been engaged in continuing geothermal research, involving a variety of geological, geochemical and geophysical studies, for the past thirteen years. The results of these efforts are included in the publication series of the Department.

The principal investigator is Dr. George Priest, Geothermal Specialist, DOGAMI. His resume is attached.

Dr. Priest is currently the Program Manager for DOGAMI of the Low-Temperature Geothermal Resource Assessment, Phase II, 1979-80, Contract No. DE-FC-07-79ET27220 and the Geothermal Resource Assessment of the Western and Central Cascades, including Mt. Hood, Contract No. DF-FC-07-79ID12044.

DOGAMI, as project manager for work in Oregon funded by the U.S. Department of Energy (DOE), will: (1) coordinate various State and Federal agencies and other organizations which may participate in this project; (2) act as liaison and coordinator between the project and other ongoing Federal and State supported geothermal projects; (3) coordinate site-specific geological-geophysical studies; and (4) prepare and compile final maps and reports for the project. Geophysical studies, if required, will be administered by DOGAMI. Consulting geophysicists and geologists will be utilized, wherever necessary to complement the assessment portion of this proposal.

DOGAMI will administer all phases of the Low-Temperature Resource Assessment described for which funding is herein to be made available. DOGAMI will conduct the necessary geologic studies; air-photo and imagery interpretation; temperature-gradient studies; and geochemical sampling and evaluation. DOGAMI would also manage the accounting functions inherent to this proposal.

An organization chart of DOGAMI personnel that will be utilized in the Phase III (1980-81) study is shown in Figure 2.

ORGANIZATION CHART

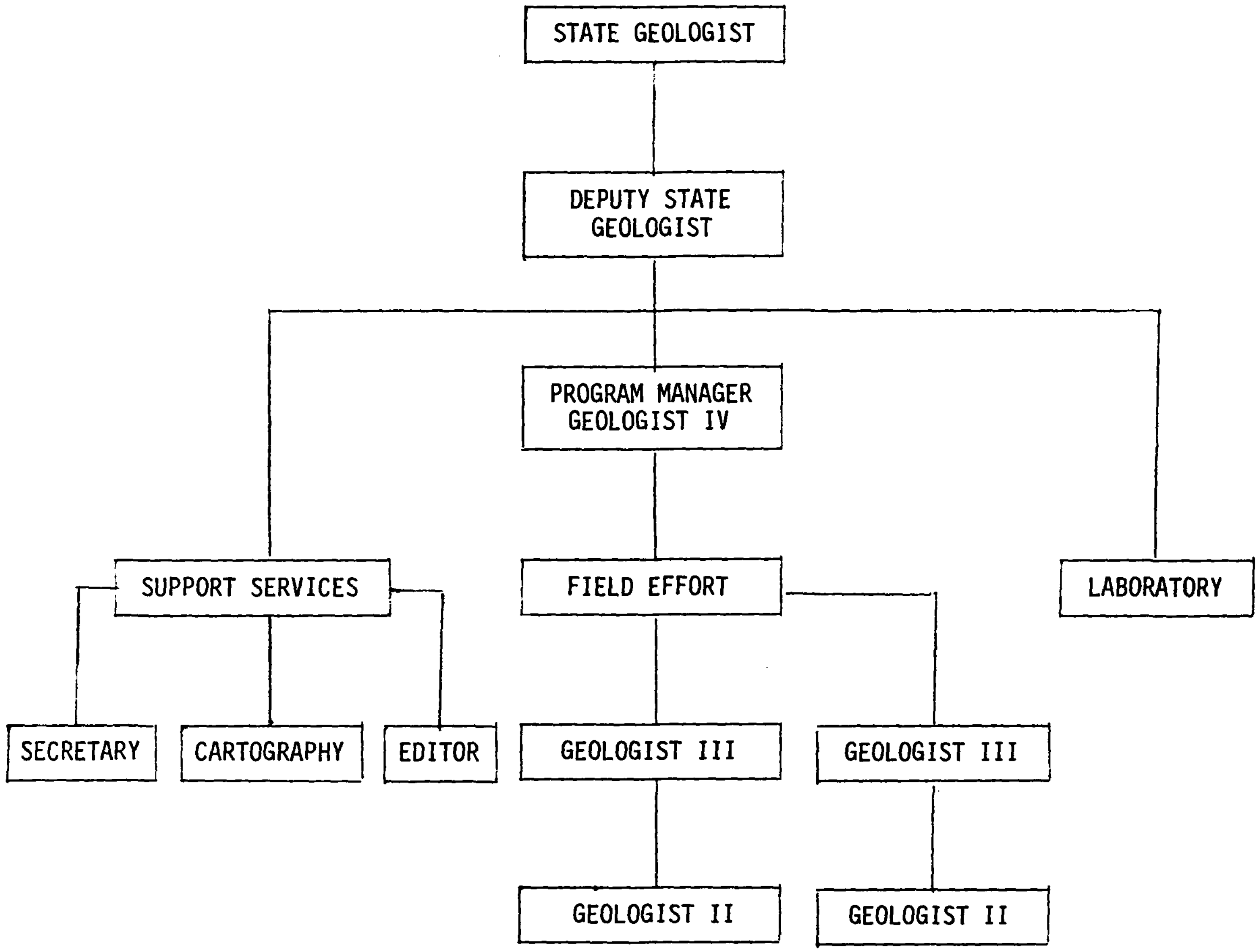

Figure 2

ASSESSMENT PLAN

Task 11 - Geologic Map Refinement

Tasks 1-10 have been undertaken under previous phases of this study program.

Geologic maps, at an appropriate scale, will be refined for the Northern Harney Basin, Parkdale, Western Snake River Plain, and, if time permits, the Lakeview area (Fig. 1). The maps will depict all known major structures or trends as well as surface geothermal manifestations. Cross-sections based on available geologic data will be drawn through the resource areas.

Besides black and white, color and color IR photos, air-photo studies will involve the interpretation of SLAR, LANDSAT (ERTS), and NASA U-2 as available. Ground-truth verification will resolve ambiguous interpretations and will complement the conceptual synthesis work defined in Task 15. Geophysical profiles perpendicular to structure may be used to better define faulting beneath alluvium in basins, if detailed geological work and existing geophysical data are not definitive.

Task 12 - Statewide Reconnaissance

Effort to acquire additional information on the location, temperature, water samples, flow data, and chemistry of thermal springs and wells of the State of Oregon will be enhanced in this study and will include emphasis on the south-central Cascades, Basin and Range province, structural basins of the Columbia Plateau and the Portland-Clackamas River area. These data will be included in existing DOGAMI and GEOTHERM data base files and updates of the geothermal map base of Oregon.

Task 13 - Assessment of the Corbett-Camp Collins Area

Initial assessment of the Corbett-Camp Collins area near Portland will be pursued by detailed temperature gradient measurement and water analysis of all existing springs and wells and drilling of shallow (152 m) temperature gradient wells. In addition, reconnaissance geologic mapping and lineament analysis will be completed. All data will be included in existing DOGAMI and GEOTHERM data base files and updates of the geothermal map base of Oregon.

Task 14 - Summary Assessment of Geothermal Resources

all task 11 area

Geothermal models will be developed from the data, and specific development steps will be recommended for each study area. The product of this task will be detailed assessment reports incorporating all relevant data for priority areas that have high potential. A general summary report covering all areas studied will also be completed. These reports will guide statewide resource assessment and will provide a basis for evaluating or planning exploration ventures by either government or the private sector.

Task 15 - Publication

The deliverables of this effort include the following:

Task 11 - Various in-house geologic map revisions

Task 12 - Spring and well data in GEOTHERM

Task 13 - Assessment of the Corbett-Camp Collins area

Task 14 - Summary Assessment reports

Publications contemplated in this investigation include:

Report of geothermal gradient data

Special Papers on high priority resource areas

Special Paper summarizing the geothermal resource potential of all of the study areas

Geologic maps of priority areas

7.

RELATED STUDIES

A statewide inventory of low-temperature geothermal resources (Phase I) (i.e., geothermal waters with a reservoir temperature of 90°C or less) was begun on July 1, 1977. The inventory, as originally planned, consisted of two parts - the first was a compilation of chemical data on Oregon's thermal springs and wells, and the second part was an inventory of low-temperature reservoirs utilizing a combination of geochemistry, heat flow data, temperature-gradient data, and geological-geophysical information.

Geochemical data obtained from the Phase I study were sent to USGS for their inclusion in the GEOTHERM data base. The collection of low-temperature data during Phase II (1979-80) was likewise submitted to USGS.

DOGAMI, under Contract No. DE-FC07-79ID12044, drilled temperature-gradient holes in the Central Cascades area. This work was completed in late 1980. Data that may relate to an understanding of the geothermal regime in the Willamette Pass and Belknap-Foley resource areas was incorporated in the final report(s) of these two areas. Similarly, data generated under Contract No. AC06-77-ET-28369 for the geothermal assessment of Mt. Hood was utilized in the evaluation of the Parkdale area.

Because of its long-term involvement in the study of Oregon's geothermal resources, DOGAMI holds a considerable quantity of unpublished data which will be available for this project and will be included in the report.

RESUMÉ AND BIBLIOGRAPHY

RESUMÉ

GEORGE R. PRIEST

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Portland, Oregon 97201
(503) 229-5580

Personal Information

Birth date: 7-14-49
Height: 5' 9"; weight: 150 lbs.
Spouse: Barbara J. Priest

Education

B.S., Geology, Oregon State University, Corvallis, Oregon, 6-6-71
M.S., Geology, University of Nevada, Reno, Nevada, 8-15-74
Ph.D., Geology, Oregon State University, Corvallis, Oregon, 8-15-79

Industrial Experience

Geologist 4, Geothermal Specialist, Oregon Department of Geology and Mineral Industries, 11-1-80 to present (Dr. Donald A. Hull, supervisor).

Geologist 3, Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, Oregon 97201, 9-3-79 to 10-31-80 (Dr. Joseph Riccio, supervisor).

Geothermal Exploration Geologist, Chevron Resources Company, P.O. Box 3722, San Francisco, California 94119, 6-20-79 to 9-15-79 (Jim Salveson, supervisor).

Consulting Geologist, to Hanna Mining Company, Coastal Mining Division, 388 W. 2550 S., Salt Lake City, Utah 84115, 3-20-78 to 3-23-78; 3-27-78 (Wade Hodges, supervisor).

Geochemist, Lawrence Livermore Laboratory, P.O. Box 808, Livermore, California 94550, 7-5-77 to 9-7-77 (Dr. Kevin K. Knauss and Dr. Terry L. Steinborn, supervisors).

Exploration Geologist, Cyprus Mines Corporation, S. 400 Jefferson Street, Suite 161; Spokane, Washington 99204, 7-25-74 to 9-15-75 (Dr. E.A. Schmidt, supervisor).

Consulting Geologist; to Mr. Bruce Miller, consulting exploration geologist, Geology Department, University of Nevada, Reno, Nevada 89502, 7-1-74 to 7-6-74.

Consulting Geologist, Project Manager, for Dr. D.B. Slemmons, Geology Department, University of Nevada, Reno, Nevada 89502, 11-73 to 3-74.

Engineering Geologist, Woodward-Clyde and Associates, Berkeley, California; 5 days 1-74 (Alfred Ringa, supervisor).

Exploration Geologist, Phelps Dodge Corporation, Reno, Nevada 89502, 6-15-72 to 9-15-72 (Robert Ludden, supervisor).

Academic Experience

Assistant Professor, Portland State University, Department of Earth Sciences, Portland, Oregon 97207, 9-15-78 to 6-15-79 (Dr. Marvin H. Beeson, Department Chairman).

Teaching Assistant, five years, including the following subjects:

- Physical geology (2.0 academic years)
- Historical geology (0.5 academic years)
- Structural geology (0.5 academic years)
- Photogrammetry (0.5 academic years)
- Mineralogy (3.0 academic years)

Description of Industrial Work

Geologist 4 - Oregon Department of Geology and Mineral Industries: Supervisor for geothermal division; responsible for formulating and carrying out geothermal research and resource evaluation studies.

Geologist 3 - Oregon Department of Geology and Mineral Industries: Managed the Western Cascades geothermal drilling program for the State of Oregon. Supervised two employees and a drill crew in a Department of Energy geothermal research program. Did detailed mapping and sampling throughout the Western Cascades and originated and wrote grant proposals for further research in the Western Cascades.

Geothermal exploration - Chevron Resources Company: Completed a detailed geologic map of approximately 60 square miles of the Beowawe KGRA. In mapping this complex area, intersecting Basin and Range faults in Paleozoic and Tertiary rocks were dealt with. All structural and stratigraphic data were utilized to develop a model for the geothermal system in order to site deep drill holes. A geologic field assistant was supervised and trained during the investigation.

Consulting Geologist - Hanna Mining Company: Assisted the Hanna Mining Company in their efforts to explore two major epithermal, bonanza gold districts in central Nevada. Instructed a number of their western region geologists in the interpretation of complex volcanic textures and field relationships in these two heavily altered areas. After completion of the field project, a brief report on the potential use of trace and major-element modelling in exploration for hydrothermal ore deposits was submitted.

Geochemist - Lawrence Livermore Laboratory: Performed basic research on the origin of uranium ore deposits by a complex dissolution, alpha-spectrometric method which allowed determination of uranium and thorium-series-isotope activities. The aim of the project was to determine whether soluble uranium ions were moving out of uraniferous granitic rocks of NE Washington by testing for secular equilibrium between parent ^{238}U and daughter ^{230}Th. This work was performed under the guidance of Dr. Kevin K. Knauss. A publication on these data should be forthcoming in the near future.

While assisting Dr. Terry L. Steinborn, was introduced to the latest experimental stream-sampling techniques for uranium exploration. Became familiar with both water and sediment techniques of sampling and analysis.

Exploration Geologist - Cyprus Mines Corporation: Responsible for managing several mineral exploration drilling and mapping projects in varied geologic terranes in Nevada, California, Washington, and Montana. While working with Cyprus Mines Corporation, hundreds of feet of diamond drill core and rotary drill chips were logged, and claim and magnetometric surveys conducted. Dealt with various Federal regulatory agencies and supervised reclamation of numerous drill sites.

Consulting Geologist to Mr. Bruce Miller: Assistance was requested in running a resistivity survey over a small hydrothermal zinc prospect owned by Mr. Miller. Became familiar with this unusual type of ore deposit and the resistivity technique in the course of this work.

Consulting Geologist to Dr. D.B. Slemmons: Worked for five months on a project to evaluate regional targets for siting of nuclear reactors in northwestern Nevada. This study was contracted to Dr. Slemmons by Sierra Pacific Power.

Forty thousand square miles of NW Nevada were evaluated for presence of active and potentially active faults, utilizing high aerial and ERTS photography, as well as helicopter reconnaissance. Produced about 60% of the raw data for the hazard maps and supervised seven other part-time air-photo analysts who generated the balance of the information. Responsible for all phases of the study, including quality control, and assisted Dr. Slemmons in compilation of the final report.

Engineering Geologist - Woodward-Clyde and Associates: During employment with Dr. Slemmons (above) a leave of absence was granted to assist Woodward-Clyde and Associates in meeting an urgent deadline. Compiled a large body of published geological maps located along a major Canadian-United States natural gas pipeline route. Responsible for translating the geologic information from these maps into nontechnical and engineering terminology for planning purposes.

Exploration Geologist - Phelps Dodge Corporation: During a summer's work with Cyprus Mines Corporation, was initially responsible for helping to supervise drilling and claim-surveying operations on a large mesothermal "porphyry" copper prospect in central Nevada. In the course of logging hundreds of feet of diamond drill core across the contact of the quartz monzonite source, became intimately familiar with contrasting regional metamorphic and metasomatic alteration assemblages associated with these important copper ore bodies.

In the latter part of the summer, was involved in regional reconnaissance of several important bonanza gold districts in central Nevada. Utilizing both four-wheel drive vehicles and helicopters; assisted in compilation of alteration-mineralization maps of the Rawhide, Round Mountain and Manhattan gold districts. Also conducted similar evaluations of adjacent scheelite and molybdenum deposits in the Rawhide district.

Description of Academic Work

Experienced as a teaching assistant for many freshman-level physical and historical geology laboratories as well as junior-level structural geology and photogrammetry laboratory classes. Principal laboratory teaching, however, has been in the fields of crystallography, mineralogy and lithology. These courses were principal responsibilities as a doctoral candidate for three years at Oregon State University.

During the last term at Oregon State University a survey course in basic geology was taught to 150 non-geology majors. As an assistant professor at Portland State University during the 1978-1979 academic year had responsibility for teaching courses in mineralogy-crystallography, general geology, economic geology, igneous and metamorphic petrology, lithology, as well as graduate-level volcanology and igneous petrology.

Instructional Goals

An integrated approach to instruction is believed in. Every course should provide both practical application and theoretical justification of the lecture subjects.

In pursuit of this method, an effort has been made consistently to provide quantitative evaluation of all lecture topics where such data are available and within comprehension. Practical applications of theoretical concepts from a background in mineral exploration and volcanologic research are also used.

In addition, an attempt is made to teach basic geologic skills in every course, if at all possible. The ability to recognize rocks and minerals in hand specimens and interpretation of geologic features in the field are considered to be of paramount importance to every earth science student.

Goals in university teaching will be to teach both undergraduate and graduate-level courses in igneous petrology, especially volcanic petrology. Qualified to teach economic geology at both the undergraduate and graduate level and will be willing also to teach undergraduate mineralogy, crystallography, and igneous and metamorphic petrology-petrography.

Research Interests

Wish to use fundamental geochemical principles to solve problems in planetary science. Interest is mainly in the application of trace element geochemistry to problems in high-temperature geochemistry and volcanic stratigraphy.

An integrated, field-laboratory approach should be used in the solution of earth science problems. In pursuit of this ideal an endeavor has been made to cast all geochemical work in a framework of sound field geologic knowledge.

Industrial Interests

Interest lies mainly in geothermal and uranium exploration research; also very interested in practical exploration for geothermal energy, particularly in young volcanic terranes. Other fields of considered employmnnt are environmental geology and mineral exploration.

Geophysics

Resistivity and magnetometric surveys of base metal exploration targets have been run and evaluated. Also interpreted magnetic and gravity anomaly maps in terms of structural geology.

Mineral and Rock Identification

Able to identify a large variety of minerals utilizing ore microscopy, petrography, X-ray diffraction, and hand sample analysis. Three years of mineralogical laboratory teaching have greatly improved ability to identify minerals and rocks in hand specimens.

Mapping Experience

Able to map in the field and on air photos in all types of geologic terrane. Both detailed, large scale (1:1,200) and broad, small scale (1:62,500) geologic maps in volcanic, intrusive, metamorphic, and sedimentary terranes have been completed.

Active fault maps utilizing the fault evaluation system of Woodward-Clyde and Associates have also been produced and evaluated. During graduate-level course work in engineering geology, land-use-planning maps were produced which evaluated a large field area for slope stability; foundation and waste disposal characteristics of soil; absolute slope; sources of aggregate; active faults; water availability; and flooding potential.

Geochemical Analysis

Three slightly different X-ray fluorescence techniques for major and trace element analysis of whole rocks have been used. A variety of trace and major elements by both radiochemical and instrumental neutron activation have also been determined. During work at the Lawrence Livermore laboratory wet chemical separation techniques have been used to separate U and Th isotopes to determine absolute isotopic concentration and activity via alpha-spectroscopy.

George R. Priest

THESIS RESEARCH

Thesis title: Geology and geochemistry of the Little Walker volcanic center, east-central California.

Description of the Problem and the Attack:

The Little Walker volcanic center is a major latitic ash-flow center located in east-central Sierra Nevada, California, about 17 km WNW of Bridgeport, California. It was the source of the voluminous welded and non-welded quartz-latite tuffs of the Eureka Valley Tuff about 9.5 m.y. ago. These ash flows cover about 4,000 square kilometers of the Sierras and probably had a total volume of at least 60 cubic kilometers before erosion.

It was the aim of the thesis study to accurately locate the margins of a large caldera inferred to be present at the center, and evaluate the economic potential of mineralized areas. To accomplish these two objectives, the writer has mapped about 304 square kilometers of the Little Walker center in varying degrees of detail and geochemically analyzed numerous lavas which were erupted before, during, and after the major ash-flow eruptions. Chemical analyses were obtained by X-ray fluorescence and neutron activation methods.

Using phenocryst mineralogy and major element data for whole rock specimens, numerous least-squares mixing models have been tested, using remote-batch computer methods. Viable fractionation models obtained from the mixing calculations have then been tested with the trace element data using surface equilibrium Rayleigh fractionation models.

To obtain information about the source rock which may have been partially melted to produce the parental magmas of the center, numerous fractional fusion and batch melting calculations have been obtained for various potential source mineralogies, using geochemically reasonable eutectic and cotectic melting proportions. Such calculations are chiefly constrained by the trace element data and can be used to infer the probable trace element composition and mineralogy of the source rock, as well as the degree of partial melting which may have produced the parental magmas.

Geochemical traverse sampling and mapping of widespread epithermal alteration of the western half of the center provided the means of evaluating its gold-silver potential. Assistance in evaluation of the gold-silver mineralization was provided by support from the Freeport Mining Company, Reno, Nevada. A subsidiary study of uranium resources focused attention on the viability of the uraniferous volcanic rocks as primary and secondary sources of uranium. Trace element data from the volcanic units and from stream samples provided the basis for this part of the study.

Thesis Advisors: * Head Advisor ** Informal Advisor

*Dr. Edward M. Taylor, Department of Geology, Oregon State Univ., Corvallis, OR
Dr. William H. Taubeneck, " " "
Dr. E. Julius Dasch, " " "
Dr. Keith F. Oles, " " "
Dr. Roman A. Schmitt, Department of Nuclear Chemistry, Oregon State University, Corvallis, OR 97331
**Dr. Donald C. Noble, Department of Geology and Geologic Engineering, Michigan Technological University, Houghton, MI 49931

Publications

Priest, G.R., 1978, Phenocryst-groundmass distribution coefficients for some intermediate lavas of the Little Walker volcanic center, Mono County, California. In manuscript, 11 p.

__________, 1978, Trace and major element evidence for the origin of quartz latite and aluminous low-Mg latite: Oregon Acad. Sci. Proc. v. 14, p. 154-155.

__________, Latites, quartz latites: in Fairbridge, R. and Green, J., eds., Volcanoes and volcanology: Dowden, Hutchinson and Ross, Inc., publishers, in press, 5 p.

__________, Noble, D.C., Bowman, H.R., Geochemistry of a potassic volcanic center, Little Walker center, Mono County, California: in manuscript, 10 p.

__________, Noble, D.C., and Dickinson, W.R., Geologic evolution of the Little Walker volcanic center, Mono County, California: in manuscript, 20 p. + map at 1:24,000.

__________, Noble, D.C., Bowman, H.R., Hebert, A.J., and Wollenberg, H.A., 1975, Eruptive and geochemical evolution of the Little Walker volcanic center: California Division of Mines and Geology, California Geology, v. 28, no. 5, p. 106.

__________, Bowman, H.R., Hebert, A.J., Silberman, M.L., Street Jr., K., and Noble, D.C., 1974, Eruptive history and geochemistry of the Little Walker volcanic center, east-central California. A progress report: Geol. Soc. America Abs. with Programs, v. 6, p. 237.

__________, Riccio, J., Woller, N., Gest, D., and Pitts, S., 1980, Heat flow along the High Cascade-Western Cascade transition zone, Oregon: Oregon Acad. Sci. Proc., v. 16, in press.

Personal References

Dr.E. M. Taylor, Geology Department, Oregon State University, Corvallis, Oregon 97331.

Dr. W. H. Taubeneck, Geology Department, Oregon State University, Corvallis, Oregon 97331.

Dr. K. F. Oles, Geology Department, Oregon State University, Corvallis, Oregon 97331.

Dr. D. B. Slemmons, Geology Department, Mackay School of Mines, University of Nevada, Reno, Nevada 89502.

Dr. D. C. Noble, Department of Geology and Geological Engineering, Michigan Technological University, Houghton, Michigan 49931.

DOGAMI GEOTHERMAL ENERGY PUBLICATIONS

STATE OF OREGON

DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

GEOTHERMAL ENERGY PUBLICATIONS

1966

Bodvarsson, G., 1966, Energy and power of geothermal resources: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 28, no. 7, p. 117-124.

Groh, E.A., 1966, Geothermal energy potential in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 28, no. 7, p. 125-135.

1967

Peterson, N.V., and Groh, E.A., 1967, Geothermal potential of the Klamath Falls area, Oregon, a preliminary study: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 29, no. 11, p. 209-231.

1969

Godwin, L.H., and Peterson, N.V., 1969, Geothermal energy, in Mineral resources of Oregon: Oregon Department of Geology and Mineral Industries Bulletin 64, p. 299-304.

1970

Bowen, R.G., and Peterson, N.V., 1970, Thermal springs and wells in Oregon: Oregon Department of Geology and Mineral Industries Miscellaneous Paper 14 (listed on back of location map, scale 1:1,000,000).

1971

Bowen, R.G., 1971, Geothermal activity in 1970: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 33, no. 1, p. 16-18.

1972

Bowen, R.G., 1972, Geothermal activity in 1971: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 34, no. 1, p. 12-15.

Bowen, R.G., 1972, Geothermal gradient studies in Oreogon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 34, no. 4, p. 68-71.

1973

Bowen, R.G., 1973, Geothermal activity in 1972: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 35, no. 1, p. 4-5.

Bowen, R.G., and Blackwell, D.D., 1973, Progress report on geothermal measurements in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 35, no. 1, p. 6-7.

1974

Bodvarsson, G., 1974, Telluric current exploration for geothermal anomalies in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 36, no. 4, p. 93-107.

1974 (continued)

Bowen, R.G., 1974, Geothermal activity in 1973: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 36, no. 1, p. 9-11.

Walker, G.W., 1974, Some implications of late Cenozoic volcanism to geothermal potential in the High Lava Plains of south-central Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 36, no. 7, p. 109-119.

1975

Bowen, R.G., 1975, Geothermal activity in 1974: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no.1, p. 9-10.

Bowen, R.G., 1975, Geothermal gradient data: Oregon Department of Geology and Mineral Industries Open-File Report 0-75-3, 114 p.

Bowen, R.G., 1975, Geothermal power, in Proceedings of the Citizens' Forum on Potential Future Energy Sources, Portland, Oreg., January 17, 1974: Oregon Department of Geology and Mineral Industries Miscellaneous Paper 18, p. 43-50.

Bowen, R.G., and Blackwell, D.D., 1975, The Cow Hollow geothermal anomaly: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 7, p. 109-121.

Bowen, R.G., Blackwell, D.D., and Hull, D.A., 1975, Geothermal studies and exploration in Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-75-7, 66 p.

Couch, R.W., French, W., Gemperle, M., and Johnson, A., 1975, Geophysical measurements in the Vale, Oregon, geothermal resource area: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 8, p. 125-129.

Hull, D.A., 1975, Geothermal gradient data, Vale area, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-75-4, 18 p.

Hull, D.A., 1975, Geothermal studies in the Vale area, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 6, p. 104-106.

Larson, K., and Couch, R.W., 1975, Preliminary gravity maps of the Vale area, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 8, p. 138-142.

1976

Bowen, R.G., Blackwell, D.D., Hull, D.A., and Peterson, N.V., 1976, Progress report on heat-flow study of the Brothers fault zone, central Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 38, no. 3, p. 39-45.

Hull, D.A., 1976, Electrical resistivity survey and evaluation of the Glass Buttes geothermal anomaly: Oregon Department of Geology and Mineral Industries Open-File Report 0-76-1, 11 p.

Hull, D.A., Bowen, R.G., Blackwell, D.D., and Peterson, N.V., 1976, Geothermal gradient data, Brothers fault zone, central Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-76-2, 24 p.

Hull, D.A., and Newton, V.C., 1976, Geothermal activity in 1975: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 38, no. 1, p. 10-17.

1977

Bowen, R.G., Blackwell, D.D., and Hull, D.A., 1977, Geothermal exploration studies in Oregon: Oregon Department of Geology and Mineral Industries Miscellaneous Paper 19, 50 p.

Hull, D.A., Bowen, R.G., Blackwell, D.D., and Peterson, N.V., 1977, Preliminary heat-flow map and evaluation of Oregon's geothermal energy potential: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 39, no. 7, p. 109-123.

Hull, D.A., Blackwell, D.D., Bowen, R.G., and Peterson, N.V., 1977, Heat-flow study of the Brothers fault zone, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-77-3, 43 p.

Hull, D.A., Blackwell, D.D., Bowen, R.G., Peterson, N.V., and Black, G.L., 1977, Geothermal gradient data: Oregon Department of Geology and Mineral Industries Open-File Report 0-77-2, 134 p.

Hull, D.A., and Newton, V.C., 1977, Geothermal activity in 1976: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 39, no. 1, p. 7-15.

Wimer, R.D., LaMori, P.N., and Grant, A.D., 1977, Potential environment issues related to geothermal power generation in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 39, no. 5, p. 73-91.

1978

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.

Bowen, R.G., Peterson, N.V., and Riccio, J.F., 1978, Low- to intermediate-temperature thermal springs and wells in Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-10 (listed on back of location map, scale 1:1,000,000).

Couch, R.W., Gemperle, M. and Connard, G., 1978, Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-9, scale 1:125,000.

Hull, D.A., Blackwell, D.D., and Black, G.L., 1978, Geothermal gradient data: Oregon Department of Geology and Mineral Industries Open-File Report 0-78-4, 187 p.

Newton, V.C., and Hull, D.A., 1978, Geothermal Energy in 1977: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 40, no. 1, p. 8-16.

Oregon Department of Geology and Mineral Industries, 1978, Geophysical logs, Old Maid Flat #1, Clackamas County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-78-6, 2 p., 7 logs.

Pitts, G.S., and Couch, R.W., 1978, Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-8, scale 1:125,000.

1979

Riccio, J.F., ed., 1979, Geothermal resource assessment of Mount Hood: Oregon Department of Geology and Mineral Industries Open-File Report 0-79-8, 273 p., 5 maps.

Riccio, J.F., 1979, Preliminary geothermal resource map of Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-11, scale 1:500,000.

Riccio, J.F., and Newton, V.C., 1979, Geothermal exploration in Oregon in 1978: Oregon Department of Geology and Mineral Industries, Oregon Geology, v. 41, no. 3, p. 39-46.

U.S. Geological Survey and Oregon Department of Geology and Mineral Industries, 1979, Chemical analyses of thermal springs and wells in Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-79-3, 170 p.

Wollenberg, H.A., Bowen, R.G., Bowman, H.R., and Strisower B., 1979, Geochemical studies of rocks, water, and gases at Mt. Hood, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-79-2, 57 p.

1980

Brown, D.E., Black, G.L., and McLean, G.D., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Craig Mountain-Cove area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-4.

Brown, D.E., Black, G.L., and McLean, G.D., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Powell Buttes area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-8.

Brown, D.E., McLean, G.D., and Black, G.L., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the northern Harney Basin, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-6.

Brown, D.E., McLean, G.D., and Black, G.L., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the southern Harney Basin, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-7.

Brown, D.E., McLean, G.D., and Black, G.L., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Western Snake River Plain, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-5.

Brown, D.E., McLean, G.D., Priest, G.R., Woller, N.M., and Black, G.L., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Belknap-Foley area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-2.

Brown, D.E., McLean, G.D., Woller, N.M., and Black, G.L., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Willamette Pass area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-3.

1980 (continued)

Geoscience Research Consultants, 1980, Geologic linears of the northern part of the Cascade Range, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 12, 25 p.

MacLeod, T., and Hill, J. (Logging Geologists, R.F. Smith Corporation), 1980, Engineering and air and mud drilling data of DOGAMI geothermal exploratory well Old Maid Flat 7A: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-11, 16 p.

Oregon Department of Geology and Mineral Industries (Hull, D.A., principal investigator), 1980, Progress report on activities of the low-temperature resource assessment program 1979-1980: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-14, 79 p.

Peterson, N.V., and Brown, D.E., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Alvord Desert area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-10.

Peterson, N.V., Brown, D.E., and McLean, G.D., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Lakeview area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-9.

White, C. 1980, Geology and geochemistry of Mt. Hood volcano: Oregon Department of Geology and Mineral Industries Special Paper 8, 26 p.

White, C., 1980, Geology of the Breitenbush Hot Springs quadrangle, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 9, 26 p.

1981

Oregon Department of Geology and Mineral Industries, 1981, Geophysical logs, Old Maid Flat Well 7A, pt. 1: Oregon Department of Geology and Mineral Industries Open-File Report 0-81-2A.

Oregon Department of Geology and Mineral Industries, 1981, Geophysical logs, Old Maid Flat Well 7A, pt. 2: Oregon Department of Geology and Mineral Industries Open-File Report 0-81-2B.

B U D G E T

BUDGET SUMMARY

Personnel		
Geologist III ($3207 x 10 x 1.0 FTE x 1.08)	$34,634	
Geologist III ($3207 x 10 x 1.0 FTE x 1.08)	34,634	
Geologist II ($2775 x 10 x 1.0 FTE x 1.08)	29,968	
Geologist II ($2775 x 10 x 1.0 FTE x 1.08)	29,968	
Cartographer ($2281 x 10 x 0.5 FTE x 1.08)	12,317	
Chemist ($2910 x 1.0 x 1.0 FTE x 1.08)	3,143	
Editor ($2775 x 10 x 0.5 FTE x 1.08)	14,984	
Subtotal		$159,648
Services and Supplies		
Travel		
400 days @ 39.45/day per diem	5,780	
40,000 mi @ 12¢/mi	4,800	
400 days @ 9.50/day for vehicle	3,800	
Idaho Falls or Salt Lake and return (4 trips)	2,200	
K-Ar dates, thin sections, chemical analyses	5,000	
Direct supplies (maps, negatives, photos, reagents, etc.)	5,842	
Printing	20,000	
Subtotal		$ 57,422
Subcontracts		
Geophysical profiles	10,000	
Drilling	30,000	
Subtotal		$ 40,000
Subtotal		$257,070
Indirect costs @ 16.7%		42,930
TOTAL		$300,000

BUDGET MATRIX - DOE FUNDING

	Task 11 Map Refinement	Task 12 Statewide Recon.	Task 13 Corbett Drilling	Task 14 Summary Assessment	Task 15 Printing & Report Prep.	Total
Personnel						
Geologist III	$17,317	-	-	$17,317	-	$ 34,634
Geologist III	-	-	$17,317	17,317	-	34,634
Geologist II	-	$29,968	-	-	-	29,968
Geologist II	15,000	14,968	-	-	-	29,968
Cartographer	-	-	-	-	$12,317	12,317
Chemist	-	3,143	-	-	-	3,143
Editor	-	-	-	-	14,984	14,984
Services and Supplies						
Travel	11,790	11,790	2,000	1,000	-	26,580
Age dates, etc.	5,000	-	-	-	-	5,000
Supplies	1,000	2,842	1,000	-	1,000	5,842
Printing	-	-	-	-	20,000	20,000
Subcontracts						
Gravity profiles	10,000 Burns?	-	-	-	-	10,000
Drilling	-	-	30,000	-	-	30,000
Subtotal	$60,107	$62,711	$50,317	$35,634	$48,301	$257,070
Indirect Costs	10,038	10,472	8,403	5,951	8,066	42,930
TOTAL	$70,145	$73,183	$58,720	$41,585	$56,367	$300,000

GEOLOGY AND MINERAL INDUSTRIES

OVERHEAD

PERSONNEL

Z6320	Director	60,360	
Z3064	Deputy Director	53,424	
Z0010	Administrative Assis.	28,272	
Z0051	Business Manager	39,816	
C0101	Accounting Clerk	19,368	
C3006	STD SCNTFC-TECH TR. (80%)	7,747	
			210,924
OPE	20.3%		42,817
	Total Personnel		251,391

SERVICE AND SUPPLIES (PROGRAM 1 3B)

(1)	Instate and Reg. Travel	16,809	
(2)	Out-of-State Travel	3,363	
(3)	Office Expenses		
	a) Phone (6 of 17 phones) (excluding proj.)	4,200	
	b) Shuttle Mail	5,[illegible]16	
	c) Central Stores	1,944	
	d) Copier	3,936	
(4)	Fiscal Control	12,664	
(8)	Attorney General	1,388	
(9)	Insurance	1,961	
(11)	Housing and Grounds (670 x 62 x 24)	9,970	
	Total Services and Supplies		61,272
	Total Overhead		312,603
	Total Budget, Minus Overhead		1,867,625
	Overhead Rate		16.7%

GEOLOGY AND MINERAL INDUSTRIES

OPE

Indirect Overhead OPE			15%
sick leave			
vacation			
other			
Direct Overhead OPE			27%
FICA		6.1	
FERS		16.2	
Other		4.7	
Health Ins.			
Life Ins.			
Dental Ins.			
SAIF			
ERB			
Misc			
	TOTAL		42%

S.M.U.

Introduction

This budget includes time for technicians during data-generation at S.M.U., as well as time for Dave Blackwell and his assistants to train our personnel in the use of new equipment this summer. In addition, time is included for Dave Blackwell to write heat-flow reports for specific sites and regions.

Budget

Personnel:

WORK AT S.M.U.		
Dave Blackwell (0.1 F.T.E. for 9 mo)	4,410	
John Steel (0.45 F.T.E. for 10 mo)	8,757	
Bob Spafford (0.375 F.T.E. for 12 mo)	7,425	
Secretary (0.375 F.T.E. for 12 mo)	3,458	
Laboratory Technician (0.5 F.T.E. for 9 mo)	4,500	
SUBTOTAL	28,550	
Benefits (10%)	2,855	
FIELD WORK IN OREGON		
Dave Blackwell (1.0 F.T.E. for 1 mo)	4,666	
John Steel (1.0 F.T.E. for 1 mo)	3,892	
Field Assistant (1.0 F.T.E. for 2 mo)	1,900	
SUBTOTAL	10,458	
Benefits (10%)	1,046	
TOTAL SALARIES & BENEFITS		42,909
Travel & Per Diem		11,350
Supplies (50% on-campus, 50% off-campus)		4,000
Computer time		6,000
Overhead - on-campus work (40%)		15,762
Overhead - off-campus work (23.4%)		5,816
TOTAL		$85,837

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FINAL TECHNICAL REPORT

OREGON LOW TEMPERATURE RESOURCE ASSESSMENT PROGRAM

by

George R. Priest, Gerald L. Black, and Neil M. Woller, Oregon Department of Geology and Mineral Industries

TABLE OF CONTENTS

ABSTRACT

Numerous low-temperature hydrothermal systems are available for exploitation throughout the Cascades and eastern Oregon. All of these areas have heat flow significantly higher than crustal averages and many thermal aquifers. In northeastern Oregon low temperature geothermal resources are controlled by regional stratigraphic aquifers of the Columbia River Basalt Group at shallow depths and possibly by faults at greater depths. In southeastern Oregon most hydrothermal systems are of higher temperature than those of northeastern Oregon and are controlled by high-angle fault zones and layered volcanic aquifers. The Cascades have very high heat flow but few large population centers. Direct use potential in the Cascades is therefore limited, except possibly in the cities of Oakridge and Ashland, where load may be great enough to stimulate development. Absence of large population centers also inhibits initial low temperature geothermal development in eastern Oregon. It may be that uses for the abundant low temperature geothermal resources of the state will have to be found which do not require large nearby population centers. One promising use is generation of electricity from freon-based biphase electrical generators. These generators will be installed on wells at Vale and Lakeview in the summer of 1982 to evaluate their potential use on geothermal waters with temperatures as low as 80° C (176° F).

It is clear also that the low temperature geothermal resources identified here and others like them elsewhere in the state must be viewed in a broader context which considers the very favorable geologic setting for geothermal potential in general. Thus, low temperature resources identified today really constitute part of a data base which may lead to the discovery of a larger temperature resource base tomorrow, technology and economics permitting.

INTRODUCTION

This report is the summary and conclusions of an investigation of low-temperature (20 to 90° C) geothermal resources begun May 23, 1979 by the Oregon Department of Geology and Mineral Industries (DOGAMI) with support from the United States Department of Energy (USDOE) under Cooperative Agreement No. DE-FC07-79ET27220. The report summarizes low-temperature resource assessment data generated for the following project areas (Figure 1):

1. Corbett-Moffett
2. Parkdale
3. Milton-Freewater
4. La Grande (Craig Mountain-Cove area)
5. Belknap-Foley Hot Springs
6. Willamette Pass
7. Powell Buttes
8. Northern Harney Basin
9. Southern Harney Basin
10. Western Snake River Plain
11. Lakeview
12. Alvord Desert
13. McDermitt

Raw data and preliminary conclusions for these areas are included in the following published DOGAMI reports and maps and will not be included here:

1. Heat flow of Oregon: Special Paper 4, 1978, includes 1 map.
2. Geothermal gradient data for Oregon: Open-File Report 0-78-4, 1978.
3. Chemical analyses of thermal springs and wells in Oregon: Open-File Report 0-79-3, 1979.
4. Geology of the La Grande area, Oregon: Special Paper 6, 1980, includes 1 map.
5. Preliminary geology and geothermal resource potential of the Belknap-Foley area: Open-File Report 0-80-2, 1980, includes 1 map.

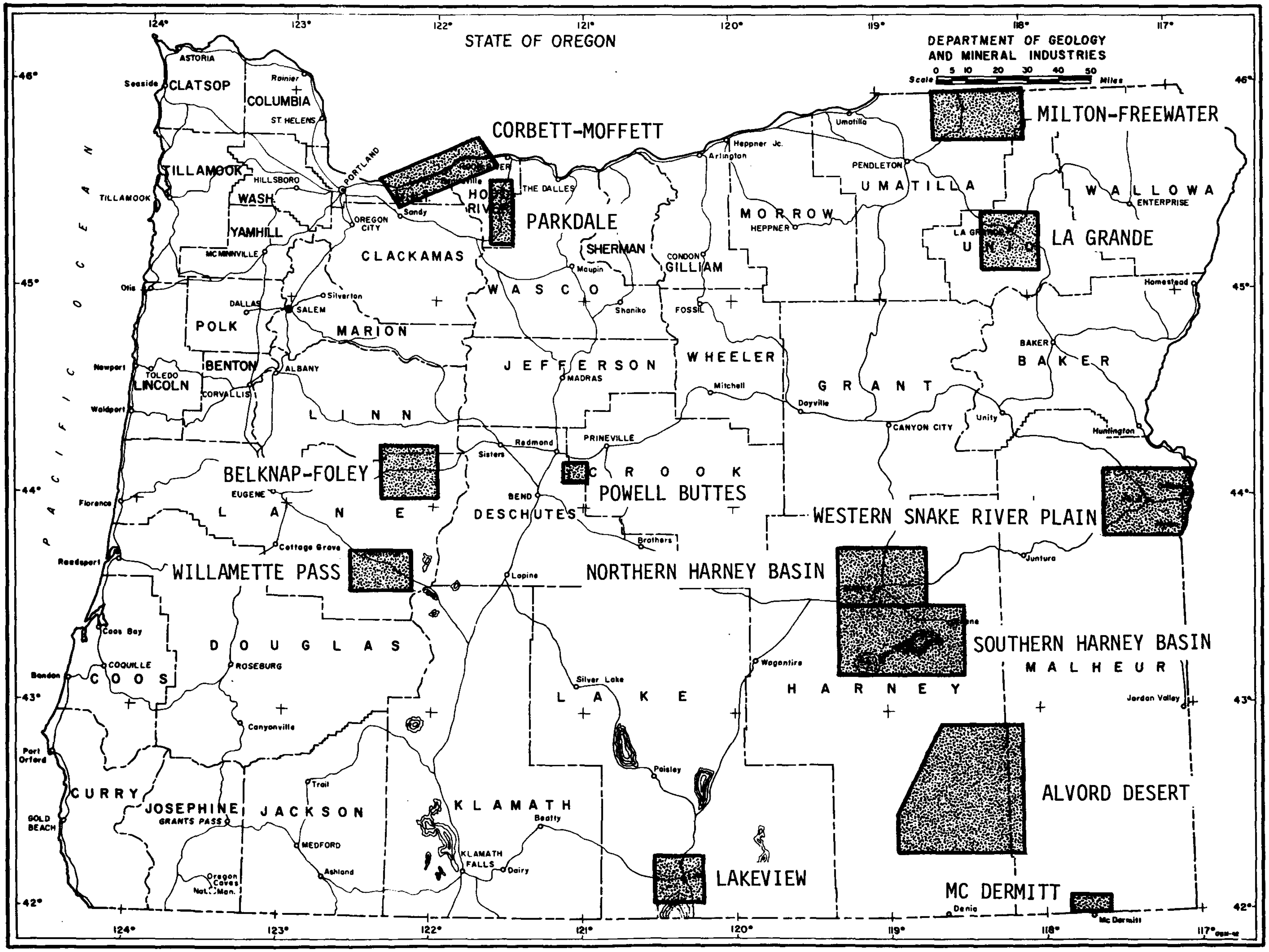

Figure 1. Location of project areas.

6. Preliminary geology and geothermal resource potential of the Willamette Pass area: Open-File Report 0-80-3, 1980, includes 1 map.
7. Preliminary geology and geothermal resource potential of the Craig Mountain Cove area: Open-File Report 0-80-4, includes 1 map.
8. Preliminary geology and geothermal resource potential of the western Snake River Plain: Open-File Report 0-80-5, 1980, includes 4 maps.
9. Preliminary geology and geothermal resource potential of the northern Harney Basin: Open-File Report 0-80-6, 1980, includes 4 maps.
10. Preliminary geology and geothermal resource potential of the southern Harney Basin: Open-File Report 0-80-7, 1980, includes 8 maps.
11. Preliminary geology and geothermal resource potential of the Powell Buttes area: Open-File Report 0-80-8, 1980, includes 1 map.
12. Preliminary geology and geothermal resource potential of the Lakeview area: Open-File Report 0-80-9, includes 2 maps.
13. Preliminary geology and geothermal resource potential of the Alvord Desert area: Open-File Report 0-80-10, 1980, includes 2 maps.
14. Progress report on activities of the low-temperature resource-assessment program 1979-80: Open File Report 0-80-14.
15. Geothermal gradient data for Oregon for 1978: Open-File Report 0-81-3A.
16. Geothermal gradient data for Oregon for 1979: Open-File Report 0-81-3B.
17. Geothermal gradient data for Oregon for 1980: Open-File Report 0-81-3C.
18. Map showing geology and geothermal resources of the southern half of the Burns 15' Quadrangle: GMS 20, in press.
19. Map showing geology and geothermal resources of the Vale East 7 1/2' Quadrangle, Oregon: GMS 21, in press.

20. Geothermal gradient data for Oregon for 1981: Open-File Report O-82-4.

The Department is continuing its resource assessment efforts in other areas throughout Oregon with concentration on the Cascades. Resource assessment data will soon be available in open file for the low-temperature resources of Ashland, Oregon when a 1982 drilling program is completed under contract DE-FC07-79ID12044. Preliminary conclusions concerning the Klamath Falls and Bend areas will also be available in an upcoming special paper on the geology and geothermal resources of the Oregon Cascades (DOGAMI Special Paper 15). A preliminary summary of this paper will be included in the conference proceedings volume for the 1982 USDOE-sponsored conference at Salt Lake City, Utah. A similar paper, aimed primarily at a summary of the data gathered at Powell Buttes, was presented in the 1981 USDOE conference at Glenwood Springs, Colorado (see DOE/ID/120-79-39, ESL-59, published by the Earth Science Laboratory, University of Utah Research Institute, Salt Lake City, Utah).

CORBETT-MOFFETT

The Corbett-Moffett area extends from Cascade Locks in the Columbia Gorge to the lower Sandy River-Troutdale area (Figure 1). Hot springs at Carson (49°C) and North Bonneville (36°C) on the Washington side, a warm well at the new site of North Bonneville (37°C) and three slightly warm springs in the Troutdale area are the main surface manifestations of the geothermal resources. These springs are in a northeast-southwest line in a distinct lineament on high altitude SLAR and ERTS imagery. The cause of this lineation and spring alignment has, as yet, not been determined.

Cascade Locks (population 835) is the largest city within the Columbia Gorge. Several smaller communities lie between Cascade Locks and Troutdale. Lumber mills at Bridal Veil and Cascade Locks and tourism are the economic bases for the population. There is also a sizable number of local residents who work at Bonneville Dam.

At the western end of the Corbett-Moffett area the population is considerably larger. Troutdale (population 5,940) and Gresham (population 33,250) are the centers of lush farming and light industrial areas. Near Troutdale, a warm artesian well at Camp Collins (23°C), a slightly anomalous spring at Corbett Quarry (18°C), and a warm spring across the Columbia River at Camas suggest that a possible resource may lie at depth.

DOGAMI undertook study of the Corbett-Moffett area under the current USDOE low-temperature grant. The aims of the study were: 1) to investigate the possibility of geothermal resources occurring on the south side of the Columbia Gorge; 2) to investigate the low-temperature manifestations at Camp Collins and Corbett Quarry; and 3) to see if the main source of geothermal waters was: a) a deep-seated northeasterly geologic structure; b) several northwesterly or northerly cross-cutting geologic structures (such as the Lacamas Fault in the Camas area) which could cause localization of geothermal waters; or c) the deep incission of the Columbia River interacting with the regional heat flow to yield higher than ambient temperature.

DOGAMI began a vigorous spring sampling and water well "scrounge" program to identify promising sites for drilling of geothermal heat flow test holes. Although many springs were tested, only in the immediate area of Camp Collins were new thermal waters discovered. None of the thermal found in the Camp Collins area exceeded the Camp Collins well in temperature or ion/mineral content.

Six holes were drilled by DOGAMI in the Corbett-Moffett area in 1981. Locations and results are as follows:

1) Dry Creek Falls - This hole was located at the foot of the cliffs south of Cascade Locks. Although the site was over 1 mile from Cascade Locks, the site was the nearest available with the possibility of yielding good results. The gradient was 35.4° C. The gradient at this site was below the expected regional gradient. This may be due to a downflow groundwater system at the site.

2) Tanner Creek - This site is across the Columbia River from thermal anomalies at Moffett Hot Springs and North Bonneville. Hammond (1980) mapped a northwesterly fault crossing the Columbia Gorge in this area. The gradient was 77° C/km. The results at this site were slightly higher than the expected regional gradient.

   The Tanner Creek site is located close to the Bonneville Dam complex, with its fish hatchery, maintenance shops, administration buildings, and tourist facilities. However, unless still warmer waters are encountered (by either deeper drilling or striking a still higher heat flow anomaly in the same vicinity), it is not likely that low temperature utilization will be feasible in this area.

3) Corbett Quarry - located at the site of a slightly warm spring. The gradient was 29.3° C/km down to 110 m, where it became isothermal. The gradient is isothermal at approximately the same temperature as the nearby spring and is probably the product of upflow from the same source which feeds the spring.

4) Howard Canyon - This site was chosen to hit the Columbia River Basalt in an area where it may have fracture permeability. It is on the hinge of a monoclinal fold of the permeable basalts, on the projected strike of the Lacamas Fault. The gradient was 40.5° C/km. The results were consistent with heat flow modeling of the northern Oregon Cascades of Blackwell and others (1978). The gradient indicates that the site is outside of the High Cascades heat flow anomaly.

5) Sandy River - This site is also in the trend of the Lacamas Fault which has been mapped in southern Washington. It is also across the Sandy River from Camp Collins. The gradient was 42° C/km which is again consistent with regional background values outside the High Cascade heat flow anomaly.

6) Camp Collins - This hole was expected to determine the nature of the resource at nearby Camp Collins. Unfortunately, the hole had to be terminated before reaching its scheduled depth because of drilling problems and budget limitations. However, the gradient was 124° C/km to a depth of 74 m. Deeper drilling needs to be done to evaluate this extremely anomalous result.

The Camp Collins site remains attractive for investigation although no evidence of a large-scale shallow hydrothermal system was revealed which might be utilized by the nearby population center of Gresham. While it does not seem likely that other than very low-temperature resources occur in this area, based on the low gradients in adjacent wells, the very high local temperature gradient suggests that deeper drilling might have a chance of encountering higher temperature water than currently utilized at Camp Collins.

Thermal aquifers may occur in Columbia River Basalt Group (CRBG) rocks at unknown depths (perhaps 1000 m?) beneath the Gresham area, although drilling for such aquifers in the Mt. Hood area has not been successful. If water is present in CRBG at 1 km in the Gresham area, it will be at about 50° C, assuming the heating of the Camp Collins water occurs at depth within the area. Perhaps more likely is the possibility that thermal waters migrated laterally within an aquifer of the CRBG from the Cascade thermal anomaly to the east, and rose to shallow levels in the lower Sandy River area via local fracture zones associated with folding of the CRBG. This is supported by the general vertical impermeability of the volcanic pile in the Mt. Hood area, the hydrostatic head of wells penetrating the CRBG in the Camp Collins area, and the absence of young local Quaternary volcanic centers. Engineering studies should be pursued to evaluate whether further exploration for a low-temperature resource is justified. The study should take into account the probable low-temperature of the resource, high risk of finding inadequate fluid, and high costs of drilling deep wells, as well as the high potential load available.

Based on the results of the studies undertaken for this report, the best model explaining the occurrence of thermal phenomena in the Corbett-Moffett area would be the localization of low-temperature geothermal waters by the intersection of the Columbia Gorge with cross-cutting northwesterly and northerly geologic structures. Future recognition of additional geologic structures in the Columbia Gorge would merit further geothermal investigation.

PARKDALE

The Parkdale area is located at the south end of Hood River Valley (Figure 1). The area is noted for its lush farmland and orchards. Local population centers include Parkdale, Dee and Odell.

Interest in low-temperature geothermal energy in the Parkdale area is based on the existence of a warm well, a young lava flow whose estimated age is 500 years, and youthful faults to promote convective circulation that may allow thermal water from the Mt. Hood heat flow anomaly to rise to shallow depths.

Heat flow data from the area is sparse. There is an abundance of spring water and runoff available to meet most of the needs of the population and agribusiness. Those not so fortunate have found ground water at shallow depths in the valley fill of river sediments. Consequently there are few water wells drilled in the valley, and those present do not penetrate the sediments to any substantial depth.

The abundant rainfall and the permeability of the river deposits create a masking effect in which shallow cold ground water tends to conceal regional gradients in wells that do not penetrate through the shallow aquifers.

The warm well that provides the Dee Fish Hatchery with 24° C has been temperature logged by DOGAMI. The temperature log shows two shallow aquifers; one at 60 to 110 m yields water of 24.2° C, and one at 110 to 175 m yields 22° C water. Geothermetric calculations using data from geochemical analysis suggest reservoir temperatures of approximately 125° C.

DOGAMI undertook an assessment of the low-temperature geothermal resources of the Parkdale area for this report. The investigation was a three-pronged study involving geochemical water sampling, regional "scrounging" for available open wells for temperature gradient logging, and geologic mapping.

Nineteen springs were sampled in 1981. Some of the springs were located on maps and used for local water supplies. Others were located during the course of the geologic mapping project and were possibly related to structural geologic features. However, none of the sampled springs showed any geothermal component, and measured temperatures were invariable low. The lone exception was the resampled well at Dee's fish hatchery, already mentioned.

The effort to locate additional wells available for temperature logging was only moderately successful. DOGAMI's files now include a total of 15 wells in the area with temperature logs. Many of these are isothermal or have negative gradients, indicating that these wells did not penetrate through the cold water "blanket" generated by recharge from Mount Hood. Two of the 15 wells were drilled by DOGAMI in previous years for heat flow determination and encountered the same problem. The few good quality gradients that exist for the area are in the range of 25° C - 55° C/km, with a high heat flow maximum of 87 mW/m^2. However, the gradient of this well (yielding a heat flow of 87 mW/m^2), was not clear and the calculated heat flow is regarded as a maximum value.

Geologic mapping was intended to identify faulting and determine the age of the episodes. The Parkdale scarp, the fault that terminates the east side of the valley, was studied by Department staff. The major movement on the fault occurred between 2.66 ± 2.0 m.y. and 2.08 ± 0.24 m.y.B.P., with a displacement of greater than 2,000 feet. Last movement of the fault postdates 2.08 ± 0.24 m.y., making this fault one of the youngest known faults in the Oregon Cascade Range.

Although available regional gradient and spring sampling data do not indicate geothermal resources in the Parkdale area more promising than for the region in general, the identification of young faulting and the proximity to Mt. Hood suggests that further work should be done in the area. Available gradient data is not sufficient to analyze the potential adequately. Lack of a large urban population in the area probably precludes development of a district heating system, should adequate geothermal resources be found. Other, smaller-scale uses, such as the aquaculture system, already being utilized at the Dee Fish Hatchery, and food processing, might be possible on a much larger scale than currently in utilization.

MILTON-FREEWATER

The Milton-Freewater area, as defined for purposes of this report, is composed of that part of the Walla Walla Basin which lies in Oregon (Figure 1). The Walla Walla Basin is a triangular shaped area which lies astride the Oregon-Washington border approximately 30 miles (48 km) northeast of Pendleton, Oregon. The only significant population centers in Oregon are Milton-Freewater (pop. 5,110) and the small unincorporated town of Umapine. Agriculture is the main source of income for the region.

The Walla Walla Basin is a structural depression located in the Columbia Plateau physiographic province of eastern Oregon and Washington, which is composed mostly of flood basalts of the Miocene Columbia River Group. That part of the plateau located in Oregon is known as the Deschutes-Umatilla Plateau. The basin is bordered on all sides by anticlines. To the east is the northeast trending Blue Mountains Anticline, to the south the west-northwest trending Horse Heaven Anticline, to the west the north-south trending Divide Anticline, and to the north in Washington is a low east-west trending arch.

As has been previously mentioned, the Columbia Plateau is underlain by a thick sequence of Miocene tholeiitic flood basalts, the Columbia River Group. In the Walla Walla Basin, the basalts are exposed only in the bottoms of streams flowing into the basin, and on the flanks of the anticlines bordering the basin. Within the basin the basalts are covered by a series of unconsolidated Pleistocene and Holocene deposits which are as much as 650 feet (198 m) in thickness. The deposits include gravels, clays, loess, silts, siltstones, glacio-fluviatile deposits, and alluvium.

There are no surface thermal phenomena in the Walla Walla Basin. Early interest in the area was generated by rumors of warm irrigation wells, some of which were artesian at temperatures in excess of 38° C, though most fall into the range 15-27° C. The warmest wells all turned out to be located in the center of the basin near the town of Touchet, in Washington.

The Department of Geology and Mineral Industries (DOGAMI) effort in the region has been quite limited. To this date temperature gradients have been measured in only seven open water wells in Oregon, though a larger data set exists for the Washington side of the Walla Walla Basin. No well sampling program has been instigated, but limited geochemical data is available from groundwater studies which have included the Walla Walla Basin. Silica geothermometers indicate minimum reservoir temperatures in the range 100°-120° C for some of the warmer wells in the area.

Based on the limited temperature gradient data available, it appears that the heat flow averages about 55 mWm^{-2} in the Walla Walla Basin. Typical gradients are 35° Ckm^{-1} in the basalts and 50° Ckm^{-1} in the lower thermal conductivity sediments overlying the basalts.

According to ground water studies, there are major sets of aquifers in the area. The first is associated with older Pleistocene gravels. The water from wells drilled into these aquifers is typically cold and unconfined. The second is associated with flow contacts in the Columbia River Basalt. Waters from these aquifers are typically warm and artesian, and the wells commonly produce several thousand gallons per minute of water.

It is clear that there is a low-temperature resource in the Walla Walla Basin with abundant fluid and temperatures adequate for space heating and other lower temperature direct-use applications (most probably agricultural applications). The high temperatures, in most cases, result from a combination of the somewhat high regional heat flow (55 mWm^{-2}) and the insulating cap of low thermal conductivity unconsolidated sediments. Where temperatures in excess of 38° C occur, as in the Touchet area of Washington, it is probable that the fluids are derived from convection systems associated with mapped normal faults.

It appears, given the nature of the Columbia River Basalts in the Oregon portion of the Columbia Plateau, that adequate quantities of warm fluids can be obtained at any specific site. The temperature obtained in a specific well will depend primarily upon the depth drilled. Therefore, future efforts should be directed primarily toward site specific engineering studies, to determine if the resource is adequate to supply the expected load. In certain areas detailed geologic mapping and geophysical studies may be useful for locating faults. Convective systems associated with the faults could provide higher temperatures than would normally be expected at a given depth.

LA GRANDE

The La Grande area is located within the Blue Mountains physiographic province of northeastern Oregon (Figure 1). It is bordered by the Blue Mountains on the north and west, and by the Wallowa Mountains on the east. The three main population centers of La Grande (pop. 11,140), Union (pop. 2,160) and Cove (pop. 500), all lie within the Grande Ronde Valley.

The Grande Ronde Valley is a structural depression which is bordered on all sides by normal faults with displacements of several thousand feet. The floor of the valley is composed of unconsolidated Plio-Pleistocene lacustrine and fluvial sediments, landslide deposits, and alluvial fans. The bedrock making up the valley margins is composed exclusively of rocks of the Miocene Columbia River Basalt Group.

Hot springs are common throughout the study area, particularly along the southern and eastern margin of the Grande Ronde Valley. The hottest spring is the Hot Lake Resort Spring, 11.7 km southeast of La Grande, with a surface temperature of 85°C. Most of the other springs possess surface temperatures in the range 20-30°C. All of the springs are fluid-dominated deep circulation systems which are associated with the normal faults at the margins of the Grande Ronde Valley.

The Department of Geology and Mineral Industries (DOGAMI) commenced its geothermal effort in the Grande Ronde Valley in the summer of 1977 with the measurement of temperature gradients in existing water wells. In the spring of 1980 a spring sampling program was completed, and in the winter of 1979/1980 three heat flow holes were drilled in the city of La Grande. Originally 4 holes with a 152 meter (500 ft) nominal depth were scheduled, but extreme drilling problems resulted in the completion of only three holes, the deepest of which was completed to 120 m.

During the DOGAMI sampling program, twenty-five thermal springs and wells were sampled and analyzed. These, when combined with previously published data, resulted in a total of seventy-five analyses available for evaluation. It is felt that the chalcedony and 4/3B Na:K:Ca geothermometers probably give the best estimates of minimum reservoir temperature. For most of the springs and wells, these estimates fell in the range 100-125°C. The highest calculated temperatures were for those springs associated with the basin-bounding normal faults. The highest estimated minimum reservoir temperature for the Hot Lake Resort Well was 100°C.

Heat flow data for the Grande Ronde Basin is sparse, and the quality of most of the data that has been obtained is not good. Because most of the holes were measured in the unconsolidated sediments of the La Grande Basin, where the effects of refraction, sedimentation, and groundwater circulation tend to depress temperatures, the measured temperature gradients were often anomalously low or even isothermal. Of the three holes drilled by DOGAMI in the city of La Grande, one was totally useless for heat flow determinations (due to a negative temperature gradient) and there were significant problems in interpretation associated with the other two. These two holes resulted in heat flow values of 42 mWm^{-2} and 84 mWm^{-2}. Based on the total data set, the best estimate for heat flow in the Grande Ronde Valley is 60-80 mWm^{-2}, and the best gradient is $50 \pm 20°Ckm^{-1}$.

One of the DOGAMI holes, drilled adjacent to the city hospital, encountered 15-21°C water flowing at 114 lpm; a temperature and flow rate adequate for space heating applications using a heat pump.

It appears that the areas with the highest potential for the direct use of low temperature geothermal fluids are those adjacent to thermal convection systems associated with valley bounding normal faults. Of the many warm springs in the Grande Ronde Valley, those associated with the Craig Mountain fault and its extensions along the southern margin of the valley appear to be the most promising. Normal faults are also present in La Grande, and the warm water encountered in one of the DOGAMI drill holes is evidence that thermal convection anomalies may be associated with these faults. At the present time the City of La Grande is drilling a 1700-ft hole near one of the DOGAMI drill sites. Although it is being drilled primarily as a city water supply, DOGAMI will be allowed to temperature log the hole. If the temperatures are adequate, serious consideration will be given to forming a geothermal heating district to supply the many public loads in the area (three schools, city and county offices, and the Eastern State College Campus).

There is also considerable low temperature geothermal potential toward the center of the Grande Ronde Valley, where deep irrigation wells (900-1700 ft) commonly encounter large (often artesian) flow rates of several hundred to several thousand gallons per minute of water in the temperature range 19-32°C. The aquifers in these wells are the flow contacts between basalts of the Columbia River Group, and the heat is provided by the regional geothermal gradient. Although the temperatures in the wells are not particularly high, the large volumes of water available should make them an attractive economic target.

BELKNAP-FOLEY

The Belknap-Foley area is located at the eastern margin of the central Western Cascade Range of Oregon, approximately 80 km (50 mi) east of Eugene (Figure 1). McKenzie Bridge, Rainbow, and Blue River are the only towns in the study area. They are very small unincorporated communities. Because few people live in the area, there is little likelihood that a large-scale heating district could be economically installed. For this reason, no drilling was done for this study, although five temperature-gradient wells were drilled to about 150 m by the Department for regional heat flow measurement in the Cascades project (Cooperative Agreement DE-FC07-79ID12044). All hot springs were sampled and a geologic map was prepared in conjunction with both the Cascades and low-temperature projects. In addition, temperature gradients in five existing wells were measured, and a geologic map at a scale of 1:62,500 was prepared.

The geology of the area is dominated by its location at the boundary between the Western Cascades and the High Cascades. Rocks at the east margin of the area are chiefly Pliocene and younger basaltic lavas of the High Cascades, but most of the area is composed of Oligocene to Miocene lavas and tuffs characteristic of the Western Cascade physiographic province.

Although there is minor folding in rocks older than about 9 m.y.B.P., the major structures in the area are a series of north-south trending normal faults. These faults are concentrated at the High Cascade-Western-Cascade physiographic boundary at Horse Creek and the upper McKenzie River and in the South Fork of the McKenzie River at Cougar Reservoir. Rocks older than about 4 m.y. are consistently offset downward toward the east in both areas. Offset at Cougar Reservoir is at least 300 m and cumulative offset across Horse Creek is about 620 m.

The Horse Creek fault zone does not cut intracanyon lavas of the High

Cascades dated at 2.05 to 3.4 m.y.B.P. The Cougar Reservoir fault zone cuts rocks dated at 13.2 m.y. but does not cut Pleistocene gravels.

Hot springs and areas of anomalously high heat flow are associated with the north-south trending faults. The hottest springs are Belknap (86.7 to 71.0°C), Bigelow (61.0°C), and Foley (80.6°C) which are along the Horse Creek fault zone. Terwilliger Hot Springs (also called Cougar Reservoir and Rider Hot Springs) is adjacent to the Cougar Reservoir fault zone and has a temperature of between 42 and 44°C. Drilling near Terwilliger Hot Springs has shown that hydrothermal water also occurs at 150 m depth about 1/2 km east of the springs in an Oligocene(?) lava.

The most reliable geothermometric calculations for the Horse Creek fault zone group indicate reservoir temperatures in the 100 to 143°C range. Similar calculations for Terwilliger Hot Springs indicate reservoir temperatures of 95 to 103°C.

Of the five wells drilled in the Belknap-Foley area, three were located along the Horse Creek fault zone and two were adjacent to the Cougar Reservoir fault zone. Where heat flow was not obviously disturbed by nearby thermal springs, regional heat flow conforms to the pattern demonstrated by Blackwell and others (1978). Heat flow increases abruptly from values of about 70 to 83 mW/m^2 (terrain-corrected gradients of 53°C/km to 52°C/km) in the Cougar Reservoir area to about 111 to 114 mW/m^2 (terrain-corrected gradients of 71 to 74°C/km) in the Horse Creek area. The area thus lies on the transition zone between low heat flow (55 mW/m^2 or below) characteristic of the Western Cascades-Willamette Valley provinces and very high heat flow (over 100 mW/m^2) characteristic of the High Cascades province. These regional gradients and heat flow values indicate that hot springs in the area probably ascend from depths of about 1.2 to 2.0 km in the Horse Creek area and about 1.6 to 1.8 km in the Cougar Reservoir area.

The best target for furhter exploration is the Horse Creek fault zone. Drilling should be aimed at intercepting either the shallow aquifers near the hot springs or possible aquifers within the fault zone at depths appropriate for the temperatures desired. At depths of about 3 km, temperatures of about 200°C can be expected. Should fluid also be present, perhaps in fractured rocks near the fault zone, then electrical generation by direct-flash technology might be possible. Electrical generation from the hot spring waters is probably possible utilizing Rankine-cycle technology. For example, 40 kilowatts of electricity will be generated at Lakeview in the summer of 1982, using freon as a working fluid, from 80°C (176°F) water. This use, and small-scale local space heating uses near the hot springs are probably the most cost-effective means of exploiting the low-temperature resources of the area. Lack of a large population or industrial base precludes large-scale district heating systems unless it is possible to pipe thermal waters to the population centers of Springfield and Eugene. An engineering study is recommended to evaluate all of these possibilities.

WILLAMETTE PASS

The Willamette Pass area is located in the central Western Cascade Range of Oregon approximately 80 km (50 mi) southeast of Eugene, Oregon, up the Willamette River drainage (Figure 1). The only town in the area is the city of Oakridge (population of 4,300).

Because it is a significant population center a substantial effort was directed at defining geothermal resources near Oakridge. Toward that goal, a 122 m city water well was deepened to 344 m, and a 150 m temperature gradient well was drilled at a fault intersection 4 km southeast of Oakridge. A geologic map at a scale of 1:62,500 and complete sampling and temperature measurement in all available springs and wells was also completed. Eighteen water samples were analyzed and seventeen temperature gradients were measured and recalculated to heat flow. Seven of the gradients were measured in holes drilled for the Cascades project.

Rocks in the area are chiefly Oligocene(?) to late Miocene lavas and tuffs with minor Pleistocene or late Pliocene intracanyon basalt flows. The Pleistocene to late Pliocene basalts come from vents in the High Cascades to the east. The lack of youthful faulting makes the location of significant fractured rocks, which could hold thermal water, very difficult. Early Miocene tholeiitic (very iron-rich) lavas which have been mapped immediately outside of the map area near Lookout Point, may, however, be permeable. These rocks, together with buried intrusive rocks may provide the best aquifers for geothermal fluids in the area. Unfortunately, owing to the complexity of the geology of the area and the short time available for mapping, the depth to these potential reservoir rocks cannot be predicted with certainty throughout much of the area. It is highly probable, however, that neither of these rock types occur beneath Oakridge. Oakridge is located in a valley cut into rocks which appear to lie stratigraphically below the tholeiitic sequence. There is also no evidence of a major volcanic or plutonic center in or adjacent to the city. Lack of significant permeability at Oakridge is underscored by the insignificant fluid found in the 344 m city well. It is however, possible that permeability may exist in areas east of Oakridge since, as discussed below, hydrothermal fluids are obviously able to circulate enough to form warm springs in three areas within 6 to 15 km east of town. These warm springs are all in or adjacent to major faults and lineations. It is thus entirely possible that similar hydrothermal systems occur in or adjacent to unexplored faults between Oakridge and the hot spring belt. One temperature gradient well in such a fault zone at Hills Creek dam, however, did not reveal any anomalous gradients or heat flow indicative of circulating hydrothermal fluids.

Three warm spring areas occur east of Oakridge. Water is 62 to 73°C at McCredie Hot Springs, 40 to 41°C at Wall Creek Hot Springs and 30 to 44°C at Kitson Hot Springs. Most reliable geothermometric calculations for the three springs indicate possible reservoir temperatures of 112-126°C, 118-125°C, and 97-110°C, respectively.

Temperature gradient and heat flow measurements in the area show that the hot springs are in the transition zone between high (over 100mW/m^2) heat flow characteristic of the High Cascades and low (55mW/m^2 and less) heat flow characteristic of the Western Cascades and Willamette Valley. Heat flow in the hot springs belt is roughly 69 to 101 mW/m^2, with a terrain-corrected gradient of about 60°C/km. Heat flow east of the hot springs belt high as 115 mW/m^2 with terrain-corrected gradients as high as 67°C/km. West of the hot springs belt at Oakridge the heat flow is about 66 to 74mW/m^2 and the terrain-corrected gradient is between 36 to 40°C/km. Oakridge is thus on the westernmost edge of the heat flow anomaly generated by the High

Cascades. The gradients at Oakridge are, however, about half as high as gradients within the main High Cascades anomaly. The transition is very sharp, occurring over a distance of about 20 km. This is an additional reason to focus exploration as far east of Oakridge as is economically feasible.

In order to attain the reservoir temperatures calculated for the warm springs, waters would have to reach depths of about 1.0 to 1.5 km in the hot springs belt. In order to encounter similar temperatures (97-125°C) under Oakridge, meteoric water would have to circulate to depths of about 2.3 to 3.0 km. If potential circulation occurs only to 1.0 to 1.5 m at Oakridge, then water with temperatures of between about 48 and 57°C should be expected at depth. If rapid circulation of water occurs laterally from the High Cascades heat flow anomaly, then higher temperature water might be found near the city. No evidence of rapid lateral circulation has, as yet, been found.

Further exploration for low-temperature at Oakridge is warranted if potential uses can justify the capital outlay. There is a high probability that potential resources will be located at least a few km east of the city. Feasibility studies should be conducted which evaluate the viability of piping thermal water to Oakridge for various end uses. Known thermal spring areas have temperatures adequate for many uses, although the high content of dissolved salts in the water at Kitson Hot Springs may preclude many uses. Similarly high salt content was noted in the small amount of water found in the 344 m well drilled at Oakridge.

POWELL BUTTES

Powell Buttes is a large elliptically shaped topographic high located in the High Lava Plains physiographic province of east central Oregon, approximately 18 km southeast of Redmond and 29 km northeast of Bend, Oregon (Figure 1).

Powell Buttes is a volcanic vent complex composed of rhyolitic, rhyodacitic, and dacitic plugs, domes, flows, and tuffs of the Oligocene John Day Formation. Although colluvium mantles the flanks of the buttes, drill holes indicate that volcaniclastic sediments, ash-flow tuffs, and basalt flows of the late Miocene to Pliocene Deschutes Formation unconformably overlie the John Day Formation over large portions of the flanks. Powell Buttes lies at the western end of the Brothers Fault Zone, a major structural feature which is considered by some writers to mark the northern terminus of the Basin and Range physiographic province in the western United States.

Although several springs are present on Powell Buttes, the warmest of these is only 18°C. The lack of naturally occurring surface thermal phenomena makes the area a true "blind" geothermal anomaly. Several warm domestic water wells are present on the north, northwest, and western sides of the buttes. The highest water temperature measured in a domestic well was 33°C, in a well located on the west flank of the buttes in the zone of highest heat flow.

The Oregon Department of Geology and Mineral Industries (DOGAMI) first became interested in the Powell Buttes area during the summer of 1978, when temperatures measured in three open holes resulted in gradients in excess of 100°C km^{-1} and bottom hole temperatures as high as 37°C. Several more holes logged during the summer of 1979 confirmed the presence of a thermal anomaly along the north and west flanks of the buttes. In 1980 DOGAMI completed an extensive water sampling program and made an intensive effort to locate and log every open well in the vicinity of Powell Buttes. In the fall of 1980 DOGAMI drilled 9 heat flow holes, mostly along the west flank of the buttes.

The drilling program culminated in February 1981 with the completion of a 460-meter borehole centered in the zone of highest heat flow. In addition to the above efforts, complete Bouguer and residual gravity and aeromagnetic maps of the Powell Buttes area were completed for DOGAMI by the Oregon State University Geophysics Group.

A total of twenty-five wells and springs were sampled and analyzed during the course of the project. The waters are unusual when compared to waters from other geothermal areas in that they are relatively "clean". Total dissolved solids are low; and Cl, which is usually present in abundance in thermal waters, is nearly nonexistent. Also somewhat unusual is the presence of high amounts of trace metals such as Cu, Ba, Zn, and Sr. Minimum reservoir temperatures, calculated using Si geothermometers, are in all cases less than 100°C.

Several conclusions can be derived from the chemical analyses of the waters at Powell Buttes. First, the waters sampled were probably never much warmer than the temperature recorded during sampling. Second, because of the very low concentrations of constituents normally associated with thermal waters, the waters at Powell Buttes have not been deeply circulated. It is more likely that they have been heated conductively by a source that lies at greater depths.

Third, the waters sampled are most probably meteoric waters which have infiltrated through the buttes, the local recharge area. The high trace metal concentrations were probably acquired from zones of hydrothermal alteration as the fluids migrated down the hydrologic dip to where they were intercepted by domestic water wells.

The geophysical anomalies associated with Powell Buttes are somewhat difficult to interpret. There are large positive Bouguer and residual gravity anomalies centered over the buttes paralleling its northeast trend. Neither block faulting nor the presence of an intrusive beneath the buttes seem sufficient in themselves to provide the mass excess required to explain the large magnitude of the anomaly. It is likely that both mechanisms are in operation.

The most surprising aspect of the aeromagnetic study at Powell Buttes is the lack of an anomaly associated with the buttes, implying that either the buttes are underlain by nonsusceptible rocks, or that the rocks are very hot. Again it is probable that both mechanisms are in operation, particularly given the silicic nature of the volcanism that has occurred at Powell Buttes and the high heat flow measured on its flanks.

Since 1978, temperature gradients have been measured in 43 drill holes in the vicinity of Powell Buttes, and heat flow values have been determined for 32 of the sites. The data delineates a closed elliptical anomaly paralleling the west side of the butte. The zone of highest heat flow lies directly downslope from a large rhyolitic exogenous dome.

Although the early data collected at Powell Buttes indicated that temperature gradients in excess of 160°C km^{-1} and heat flow values in excess of 376 mWm^{-2} were present in the high heat flow zone, later data from deeper holes (particularly the 460-meter hole drilled by DOGAMI) indicate that the average heat flow in the vicinity of Powell Buttes is 125-167 mWm^{-2} and the average temperature gradient is about 80°C km^{-1}.

There are two possible explanations for the very high temperature gradients measured at shallow depths on the west side of the butte: (1) the high gradients are the result of a combination of heat flow refraction and very low thermal conductivities in the unconsolidated colluvium mantling the flanks of the buttes, and (2) there is a slow flow of warm water in a shallow aquifer beneath the zone of highest heat flow. In this second case fractures in the rhyolitic dome just east of the high heat flow zone could be acting as a conduit for thermal fluids.

There are problems with both hypotheses. Heat flow in the Powell Buttes area is conductive. There is no evidence of large-scale convective fluid movement in any of the holes in the data set, and only rarely is there any evidence of intraborehole fluid movement. In the 9 heat flow holes drilled by DOGAMI, no aquifer of the type described was encountered, and the geochemistry of the various water samples indicates that the waters have not been deeply circulated. Finally, groundwater supply in the Powell Buttes area is a serious problem. Wells are often totally dry, and those that do produce do so at rates of only 5-10 gpm. Producing wells seem to be situated along fairly narrow fracture zones, arguing against the presence of large stratigraphic aquifers. The hypothesis is still viable, however, as the flow rates in the aquifer could be extremely low and still produce the anomaly.

The temperature-depth profile at Powell Buttes has been successfully reproduced by computer using a finite difference thermal conductivity model. The problem with this model is that to account for the high temperature gradients, extremely low thermal conductivities are required for the surface layers. The conductivities are lower than can be produced with water-rock combinations alone, requiring that the pore space in the rock be only about 70% saturated; the remaining space filled with air. While certainly possible, given the arid nature of the region, the phenomenon has not been identified in other holes in east central Oregon.

Whatever mechanism is operative, it is obvious that temperatures adequate for many direct use applications can be found at relatively shallow depths in the Powell Buttes area. The temperature at 460 meters in the DOGAMI deep test (PB-1) was 56°C. Projections of the temperature gradient indicate that 80°C would be encountered at about .8 km, and 150°C at 1.7 km.

The problem is the availability of adequate fluids. Although the temperature-depth curve for PB-1 did show one small aquifer at 425 m, significant amounts of fluids were not encountered in the hole. In general, the John Day Formation and the underlying Clarno Formation are composed of large amounts of tuffaceous rocks, which are relatively impermeable.

It is clear that efforts to produce a viable low temperature resource in the Powell Buttes area must center around the location of adequate fluids. Detailed geologic mapping and geophysics, to locate fracture permeability, and the deepening of PB-1 to locate stratigraphic aquifers (probably associated with lava flows) are the most obvious steps to take in this direction. At this point in time, the PB-1 drill site has been turned over to Francana Corporation, which plans to deepen the hole sometime in the near future. Although private industry will probably continue to explore for high temperature geothermal resources, the position of Powell Buttes within piping distance of three important towns, Bend (16 km), Prineville (8 km), and Redmond (8 km), make it a viable exploration target for direct use resources. Future exploration should be aimed at deeper drilling not only at Powell Buttes but also on youthful faults known to exist in the vicinity of Bend and Redmond (e.g. see Peterson and others, 1976). Additional temperature measurement and possible drilling should be accomplished at Prineville as well. Engineering studies should be pursued to define the amount of exploration expenditure which can be justified by expected loads and end uses.

NORTHERN HARNEY BASIN

The study area is located at the northern end of a large, circular topographic depression in the central portion of eastern Oregon known as the Harney Basin (Figure 1). The major population center is the city of Burns (a population of 3,525) and the nearby community of Hines (population of 1,575). Fifteen springs and wells were sampled, four temperature logged to a depth of 800 m, and geologic maps at both the 1:62,500 and 1:24,000 scale were produced for the area. A soil mercury survey and ground magnetometer survey were also completed. All of the raw data, except the mercury and magnetometer surveys, was published in various open file reports and in one high quality colored 1:24,000 scale geologic map of the Burns area.

The northern Harney basin was a major silicic volcanic center during the late Miocene and probably during the middle Miocene as well. Major cauldron subsidence blocks formed during eruption of voluminous soda rhyolite ash-flow sheets which covered hundreds of square miles of eastern Oregon. Interfingering with the ash flows are smaller amounts of soda rhyolite lava and basaltic lava. Volcanism since about 3.0 m.y.B.P. has been dominated by eruption of small volumes of alkaline high-alumina tholeiite. Holocene eruptions of alkali basalt at Diamond Craters near the southern margin of the study area was the last volcanic activity.

Faulting in the area follows three general trends. The first is the trend of the Brothers fault zone (N25°W to N55°W), which is exhibited most strongly immediately west of Burns. These are dip-slip faults which cut 2.3 to 2.9 m.y.B.P. basaltic andesites near Burns Butte. The second trend is that of north-south to north-northwest dip-slip faults of the Basin and Range which cut all bedrock units except the Holocene basalts. Dip-slip faults at a N40°W to N50°W in the east-central part of the area are transitional between the Brothers and Basin and Range trends.

Many of the faults have evidence of some relation to strike-slip motion. This is particularly true of faults of the Brothers fault zone which, according to Lawrence (1976) may be related to right lateral wrenching at depth. A large north-south trending fault in the Soldier Creek area at the northern margin of the basin also has evidence of lateral movement. The Soldier Creek fault is notable for its large opalized breccia zones, and because the hottest geothermal well in the area (the O.J. Thomas well) occurs 3 km east of the presumed extension of this fault at the northern margin of the basin. Brown and others (1980a) conclude that the O.J. Thomas water emanates from this fault. The Soldier Creek zone loses its aeromagnetic and gravity signature at about the latitude of Hines where a west-northwest trending structure appears in geophysical maps.

Folding of bedrock units is generally in the form of broad, shallowly dipping anticlines and synclines plunging toward the center of the basin. Exceptions are sharply folded rocks adjacent to major fault zones.

The Harney Basin appears to be the result of downwarping over a broad area. Some parts of the basin may be bounded by caldera faults, but much of the northern half of the area appears to be a broad zone of subsidence requiring very little deformation at the basin boundaries. D. D. Blackwell (personal communication) has speculated that much of this broad subsidence may be due to cooling and contraction following late Miocene silicic volcanism.

Most warm springs in the Burns area are in the 22 to 28.5°C range with calculated minimum reservoir temperatures of between 70°C and 11°C. Thermal water near the Soldier Creek fault zone possesses both higher surface temperatures (71°C) and higher calculated minimum reservoir temperatures (99-139°C).

The best example of thermal water from the Soldier Creek system is the O. J. Thomas well, which is 15.3 km east-northeast of Burns. This well yielded 11,400 liters per minute (about 3,000 gpm) of 72°C water in a pump test (this was the capacity of the pump). The Harney Development well, an old oil well south of the O. J. Thomas well (14.5 km southeast of Burns), flows about 380 liters per minute (100 gpm) of 46°C to 50°C thermal water, similar in composition to the water of the O. J. Thomas water (e.g. high total dissolved solids and boron). No pump test data is available for the Harney Development well to establish its ultimate potential flow.

Four shallow (140 m to 187 m) temperature gradient wells and one deep oil well (the Poteet well 2 km east of Burns) provided the most definitive data about temperatures and aquifers in the area. The Poteet well was temperature logged to 800 m and revealed that the background gradient at Burns is about 60° C/km with an estimated heat flow of about 92 mW/m^2. The well also showed disturbances in the conductive gradient indicative of definite thermal aquifers at 210-230 m (32°C) and 550-600 m (48°C) and a possible small aquifer at about 750 m (55°C). A 187-m well at the Hines Lumber Mill encountered a 3,800 liter per minute (1,000 gpm), 27°C aquifer at 15 to 50 m. A 164-m well drilled on the Hotchkiss Ranch, about 2.4 km (1.5 m) southwest of Hines was targeted on a soil mercury anomaly and encountered a 4- to 8-liter per minute (lpm) aquifer at 126 m, a 20-lpm aquifer at 140 m, and ~20-lpm aquifer at 160 to 164 m. All of these aquifers were between 34 and 35°C and were located in ash flow tuff, loose volcanic sands, or basaltic interflow areas. Discharge rates are estimated from water blown from the well during air drilling.

Comparing the data from the above holes, it is apparent that abundant thermal water in the temperature range of 27°C to 35°C occurs at depths of 15 m to 230 m between Hines and Burns. This is also the temperature of most of the thermal springs in the area which no doubt issue from these same aquifers. Data from the Poteet well suggests that the background temperature gradient is high enough to produce this 27 to 35°C water from conductive heating at between 140 and 340 m. Water encountered in the Hines area is thus ascending from at least these depths and then flowing laterally in the layered volcanic rocks. A mapped fault at the Hotchkiss site was encountered in the drill hole and may have provided a conduit for rise of warm water there. Because the Hotchkiss site is 114 m higher in elevation than the Hines area, some water around Hines could be explained by lateral flow of water from the Hotchkiss area. The high flow rate at the Hines Lumber Mill site, however, suggests that water must be coming from other areas as well, perhaps other faults. Additional drilling will be necessary to determine the circulation pattern of these shallow aquifers at Hines. Drilling should be focused on mapped faults and probable extensions of mapped faults under the valley sediments.

The city of Burns probably has thermal aquifers at 32°C at about 210 to 230 m and at 48°C at about 550 to 600 m, based on data from the Poteet well. There is definitely abundant (380 lpm) 14°C water at Burns High School at a depth of 37 m, and an 18°C aquifer of unknown volume occurs at about 140 m at the same site. The Poteet well should be cleaned out and temperature logged below 800 m, in order to discover if other higher temperature thermal aquifers are present at depth beneath Burns. The well has a drilled depth of 1975 m. Temperatures of 100°C at about 1.5 km (5,000 ft) and 200°C at about 3.2 km (10,400 ft) would be expected beneath Burns, based on the Poteet data. There is no guarantee of fluids at these depths, however.

One way of mitigating the high cost of drilling deep at Burns for hot water would be to take advantage of possible areas of upwelling thermal water. Fault zones are often sites of upwelling. The probable southerly extension of the Soldier Creek fault between 10.5 and 14.5 km (6 to 9 mi) east of Burns apparently contains large quantities of thermal water, based on data from the O. J. Thomas well (at least 11,400 lpm, of 72°C water). Water found in this well would have to ascend from at least a depth of 1 km (3,280 ft), based on the 60° C/km Poteet gradient. If the O. J. Thomas water is from a conductively heated source at the geochemically calculated reservoir temperature (99 to 135°C), the water would have to ascend from depths of about 1.5 km to 2.0 km. This is a clear indication that a major hydrothermal circulation system must be operating east of Burns. Drilling between the O. J. Thomas well and Burns should be pursued to determine the lateral extent of the circulation system toward Burns.

Another particularly interesting site for drilling is the area approximately due east of Hines and due south of Soldier Creek, where geophysical anomalies indicate a possible intersection of the Soldier Creek structure with a west-northwest trending structure. Possible high fracture permeability in this area might allow convection of large quantities of thermal water to shallow depths.

Engineering studies should be pursued which evaluate the feasibility of drilling beneath Burns for the thermal aquifers noted in the Poteet well. Additional studies should focus on the maximum distances that resources associated with the Soldier Creek hydrothermal system could be piped. The shallow thermal aquifer at Hines should be evaluated for heat pump and cogeneration applications.

SOUTHERN HARNEY BASIN

The Harney Basin is a roughly circular basin with interior drainage to Malheur, Harney and Mud Lakes. The basin covers approximately 8,100 square miles. The small unincorporated farming communities of Crane, Princeton, and Diamond are the only population centers.

DOGAMI's study of the south Harney Basin (Figure 1) involved extensive spring sampling, gradient data accrual through the location and logging of all available open water wells, a literature search, reconnaissance mapping of eight 15' quadrangles, and the drilling of a 135 m heat flow hole at Crane School.

Thermal spring and well water geochemistry generally indicates reservoir temperatures of 100°C to 140°C by the quartz geothermometer and 100°C to 170°C by the Na-K-Ca geothermometer. Numerous thermal springs occur in the area, 22 of which were sampled for this study. The highest spring temperatures, located near Crane, were 80°C. On the basis of the chemistry, the springs can be split into two groups. The first group is centered near Crane, the second near Harney Lake. Chemical differences probably stem from the nature of the rocks these fluids are associated with at depth and subsurface residence time.

The basin was formed by regional collapse due to the eruption of voluminous ash-flow sheets from within the area. Harney Lake was one of the eruptive centers, active about 9 m.y.B.P. The last silicic volcanism occurred approximately 8 m.y.B.P., but a Holocene basaltic center, Diamond Crater, was active as recently as 15,000±2,000 years ago (Norm Peterson, 1980, personal communication, cited in Brown and others, 1980b).

The area is also in the Brothers Fault Zone, which represents the northern termination of the Basin and Range physiographic province. Basin and Range faulting occurred predominantly in the middle and late Miocene and represents east-west extension on numerous north-south trending faults. The Brothers Fault Zone trends northwesterly through the area. Fault activity associated with the Brothers Fault trend is younger than that of the Basin and Range trend in the area. The fabric of the area is predominantly northwesterly. Northwest trending faults cut the 15,000±2,000 year-old basalts of Diamond Crater (Brown and others, 1980b).

The background gradient for the south Harney Basin is 60-80°C/km, the background heat flow is 60-80 mW/m^2. These values are based on previous DOGAMI and USGS heat flow studies (Hull and others, 1977, DOGAMI 0-77-3; Sass and others, 1976) and new data from open water wells.

The deepest well logged for temperature in the area is the Poteet oil well, in the northern Harney Basin. The well is 800 m deep with a gradient of 59.8°C/km and a heat flow of 92 mW/m^2. The heat flow value is consistent with the modeling of Blackwell and others (1978) and corroborates predictions of anomalous heat flow and geothermal potential along the Brothers Fault Zone. This high-quality heat flow and gradient may be more representative of the regional background heat flow than the 60-80 mW/m^2 value, since the lower values are based on shallower measurements. Only deeper drilling will test this hypothesis adequately.

The background heat flow predicts that spring waters probably ascend from a minimum depth of one km. This indicates that hydrothermal circulation may reach at least this depth in other parts of the basin as well.

DOGAMI identified a potential geothermal resource at Crane. A heat flow hole was drilled by DOGAMI in 1981 at Crane School. The gradient was 96°C/km and the bottom hole temperature was 24.5°C at 135 m. The heat flow for the hole is approximately 148 mWm^2. Additional drilling would be needed for utilization because no large water-bearing aquifer was encountered in the hole. This gradient and heat flow are obviously very anomalous with respect to both of the above regional background estimates. It is probably necessary for background heat flow to be redistributed by convection to produce heat flow this high. Either magmatic or hydrothermal convection would suffice. It is likely that hydrothermal convection is responsible for this anomaly, since Crane is not a young volcanic center. Should this hypothesis prove correct, there could be a major hydrothermal circulation system beneath Crane. Additional shallow drilling around the Crane area should be done to determine the width of the anomaly, in order to determine its extent and to do half width calculations which can predict the depth of the anomalous heat source. Deeper drilling should then be done if the predicted drilling depths can be economically justified. Alternatively, deeperdrilling could be pursued immediately to determine if the anomaly is caused by a relatively shallow aquifer of warm water.

Anomalous geothermal areas, other than hot spring locations, were found near Coyote Buttes and west of Diamond Valley, where gradients of 130-160°C/km and 88°C/km, respectively, and heat flow of 125-155 and 146 mW/m, respectively, were found. However, population densities in these areas are too low to justify exploitation unless industrial interests decide to lcoate at these sites. In terms of risk, the existing hot springs are a better choice, since hydrothermal water is readily accessible if hot spring temperatures are adequate.

DOGAMI recommends site-specific resource evaluation of several locales within the basin. Low temperature utilization would possibly be feasible for the population center of Crane and for possible light industrial/agricultural purposes elsewhere in the basin. Methods that should be used are detailed geologic mapping at large scales; detailed sampling and analysis of thermal springs and wells to determine fluid flow direction, provenance and reservoir conditions; and a drilling program to outline thermal anomalies and test geothermal aquifers. Several intermediate-depth wells (600 m) will be required to give stratigraphic control, identify aquifers at depth and enable informative pump test data to be acquired. These steps should only be taken after engineering feasibility studies have shown that development of potential resources is economically justified.

WESTERN SNAKE RIVER PLAIN

The Western Snake River Plain, as defined in this report, includes approximately 1100 square miles of eastern Oregon located in the extreme northeastern corner of Malheur County, adjacent to the state of Idaho (Figure 1). Major population centers include Ontario (and Payette, immediately across the Snake River in Idaho) in the extreme east-central portion of the area; Vale, in the west-central part of the area; and Nyssa, in the southern part of the area.

The Snake River Plain is a broad structural downwarp which extends across southern Idaho and at its western terminus into east-central Oregon. In Oregon the downwarp is filled with a series of Pliocene-Pleistocene lacustrine and fluvial sediments (often tuffaceous) which are intercalated with a few thin olivine basalt flows. These sediments, which are over 914m (3000 ft) thick throughout most of the study area, are underlain by a thick sequence of Miocene flood basalts (the Owyhee Basalt) which are considered to be time-stratigraphic equivalents with the Columbia River Group in the Columbia Plateau and the Steens Mountain Basalt in south-central Oregon.

Hot springs are common throughout the study area, with the highest temperatures being reported for Vale Hot Springs (90^{o}C), Neal Hot Springs (88^{o}C), Deer Butte Hot Springs (79^{o}C), Baschon Well (69^{o}C), and Snively Hot Springs (57^{o}C). Nearly all of the springs are associated with normal faulting, and they appear to result from typical deep circulation systems.

The Oregon Department of Geology and Mineral Industries (DOGAMI) has gathered a considerable amount of data in the Western Snake River Plain over the last several years. The measurement of temperature gradients in open water wells has been an ongoing process since the early 1970's. In the summers of 1972 and 1973 a series of (2-3 meter) wells was drilled to investigate the possibilities of identifying geothermal anomalies by using temperature measurements from very shallow holes, and in 1975 DOGAMI drilled 5 deeper holes (62-152 m) to investigate geothermal anomalies in Cow Hollow, Willow Creek, and South Fork Jacobsen Gulch. For the present study, no new heat flow holes were drilled in the Western Snake River Plain. Instead, the emphasis was placed on spring sampling and the measurement of temperature gradients in open water wells. In addition, a detailed geologic map of the Vale East 7 1/2' quadrangle was produced. The map will be published in the summer of 1982.

A large geochemical data base, which includes all of the major hot springs in the area, now exists for the Western Snake River Plain. Geochemically the waters are typical of eastern Oregon Basin and Range fluid-dominated deep circulation systems. Calculated minimum reservoir temperatures cover a wide range, with several of the springs having at least one method of calculation resulting in a minimum temperature of greater than 150°C. The most promising of of these are Vale Hot Springs (160^{0}C), Neal Hot Springs (180^{0}), Bully Creek Warm Spring (188^{0}C), Harper Warm Spring (208^{0}C), and BLM Vine Hill well (162^{0}C).

As a result of DOGAMI efforts since the early 1970's, a considerable body of heat flow data now exists for the Western Snake River Plain. By 1980, temperature gradients had been measured in 45 holes. Additional holes, mostly in the vicinity of Vale Hot Springs, have been added since that time. These serve to give a fairly accurate picture of heat flow within the province. The average heat flow is approximately 119 mWm^{-2} and the average temperature gradient is 97.5^{0} Ckm^{-1}. The heat flow is nearly twice the worldwide average, and the temperature gradient is greater than twice the worldwide average. This is due to the insulating effect of the low thermal conductivity tuffaceous sedimentary rocks which crop out throughout the study area.

As is the case throughout much of eastern Oregon, local convective thermal anomalies are superimposed on an overall high regional heat flow. In these systems, meteoric waters penetrate to great depths and are heated by the regional geothermal gradient. When the heated waters encounter significant fracture permeability in the normal faults which cut the area, they rise rapidly with little cooling to the surface, where they emerge as hot springs.

Because of the combination of the above factors, the Western Snake River Plain has a great deal of low temperature geothermal potential. There are significant population centers, an overall high population density, and a large agricultural industry to provide loads. Because of the high regional temperature gradient ($60^{O}Ckm^{-1}$ is the minimum gradient encountered in the region), it can be expected that moderate temperature resources ($80^{O}C$-$130^{O}C$) will be encountered in the depth range 1-1.5 km. In areas where convective anomalies are present, moderate temperatures exist at depths of only a few hundred meters. Temperatures suitable for heat pump applications may be found at depths of a few tens of meters throughout the study area.

At the present time, several large-scale direct-use projects are in the operation; including greenhouses, mushroom nurseries, and an alcohol plant. The one potential problem with the development of low to moderate temperature geothermal resources in the Western Snake River Plain may be the lack of adequate fluids at depth beneath large portions of the study area. The tuffaceous sedimentary rocks which cover the area tend to be relatively impermeable. The Ore-Ida Food Comapny drilled a deep exploration hole to greater than 3000 meters in the city of Ontario; and although temperatures in excess of $175^{O}C$ were encountered at the bottom of the hole, there was no fluid production below 2000 meters. It appears that future exploration will be more concerned with locating aquifers rather than locating temperatures. The Ore-Ida well might, in fact have been successful had more attention been paid to permeability during site selection.

Vale Hot Springs is probably the best site in the area for direct-use. In a crude pump test, conducted in cooperation with the landowner, R. Butler, a shallow (30 m) well near the old swimming pool at the springs produced about 1,500 lpm (400 gpm) of 110°C (230°F) water for about ten hours. Additional drilling and pump testing around Vale Hot Springs should be done to estimate the ultimate volume and temperature of the waters. This resource could probably produce enough water to significantly offset space heating loads at the city of Vale which is within 1/4 km of the springs.

There has also been considerable high-temperature resource exploration in the area. To this point in time, private industry has concentrated its energies primarily in three areas: Bully Creek, Willow Creek, and the Cow Hollow Geothermal Anomaly. This last anomaly is a fault-controlled system extending southeastward from Vale Hot Springs, which was discovered during one of the early phases of the Oregon geothermal programs. At this time, there are plans to install a small biphase electrical generation system on a well in the Cow Hollow anomaly near Vale Hot Springs by the summer of 1982.

LAKEVIEW

The Lakeview area is located in the Basin and Range physiographic province of south-central Oregon (Figure 1). A typical Basin and Range graben-horst pair, the Goose Lake Valley on the west and the Warner Mountains on the east, make up the area. Lakeview (pop. 2,770), the only town in the region, is located in the center of the area at the foot of the Warner Range.

The geology is typical of most of the rest of the Basin and Range province in Oregon. The Goose Lake Valley is composed of unconsolidated Pleistocene to Holocene lacustrine and fluvial sedimentary deposits which are as much as 1,524 m (5,000 ft) thick in the center of the basin. The Warner Range, in the vicinity of Lakeview, is composed of volcanic and volcaniclastic rocks which range in age from Oligocene(?) to Pleistocene(?) rhyodacitic exogenous domes and flows and mafic vent complexes.

The dominant structure in the area is the essentially north-south normal fault that separates Goose Lake Valley from the Warner Mountains. It is vertical or steeply westward dipping and, where exposed in the vicinity of Lakeview, is characterized by a breccia zone as much as 50 feet in width. The earliest fault movement probably occurred in the early Pliocene, and most of the movement on the fault took place before glaciation affected the higher peaks in the Warner Range, although Pleistocene terrace material is faulted north of Lakeview.

Surface or near surface thermal phenomena are associated with this normal fault in three separate parts of the study area. The hottest is the Leach Hot Well area just north of Lakeview, where a bottom hole temperature of 112.7°C was measured in a 120-m hole. At Barry Ranch Warm Spring in the central part of the study area, a temperature of 75.7°C was measured in a 73-m hole, and at the Rockford Ranch, in the southern part of the study area, a temperature of 69.9°C was measured in a 415-m hole.

The Oregon Department of Geology and Mineral Industries' (DOGAMI) effort in the Lakeview area consisted of a limited spring sampling program, the measurement of temperature gradients in existing, open drill holes, and a nine-hole drilling program. In addition, a complete Bouguer anomaly map was completed for DOGAMI by the Oregon State University Geophysics Group.

Twenty thermal springs were sampled, and these, when combined with existing published analyses, resulted in a total of 27 analyses available for the calculation of minimum reservoir temperatures. In general, the calculated minimum reservoir temperatures fall in the 100-150°C range.

Of the nine holes drilled by DOGAMI in the Lakeview area, three were located in Hammersly Canyon adjacent to the Leach Hot Well thermal area, three were located in Bullard Canyon, immediately west of the town of Lakeview, one was near the Precision Pine Company just north of the town, one was in the town itself, and one was near Barry Ranch Hot Springs.

In addition to the nine holes drilled by DOGAMI specifically for heat flow purposes, temperature gradients were measured in 31 open water wells. The heat flow pattern which emerges is typical of the Basin and Range Province throughout the western United States. The high regional heat flow (approximately 100 mW/m^2) is modified by thermal refraction, erosion, sedimentation, and hydrologic effects. These factors interact in a complex manner, with the overall result being that higher heat flow values are typically measured in the range blocks immediately adjacent to the bounding normal faults than are measured in the adjacent valleys. Superimposed on the high regional heat flow are local, higher temperature anomalies which result from the circulation of thermal fluids up permeable zones in the normal faults. Frequently the higher temperature anomalies are localized by the intersection of cross faults with the range bounding normal faults.

The holes in the Leach Hot well area demonstrated that the actual upflow of geothermal fluids occurs within the range block, and that heat flow is at least three times the regional value for a distance of 1 1/2 km into the range. One of the holes encountered 99°C water at a depth of 45 m. A later hole drilled to 208 m by Northwest Geothermal Corporation adjacent to this hole found no increase in temperature at the deeper depth.

In the town of Lakeview itself, temperature gradients and heat flow values are lower, only about 50% greater than regional values.

It appears that the heat requirements of the town of Lakeview may possibly be satisfied with water from geothermal systems located within 8 km of the town. The Northwest Geothermal Corporation (a subsidiary of Northwest Natural Gas Company) was given a 30-year franchise by the city to build and operate a district geothermal heating system. The company has been waiting for some large year-round industrial loads or a construction subsidy before beginning construction.

In addition to low temperature uses, there are temperatures in the Lakeview area adequate for the generation of electricity using biphase technology. A 40-kw Ranking Cycle generator utilizing 80°C fluid has recently commenced operation on the Rockford Ranch.

ALVORD VALLEY

The Alvord Valley lies in the Basin and Range physiographic province of southeastern Oregon and northeastern Nevada (Figure 1). It is a north- to northeast-trending graben valley that is flanked on the west by the Steens Mountains in Oregon and the Pueblo Mountains in Nevada, and on the southeast by the Trout Creek Mountains. The valley is approximately 113 kilometers long and has a maximum width of about 16 kilometers near the Alvord Desert.

The rocks of the Steens Mountains are composed of a series of volcanic flows and volcaniclastic rocks which range in age from lower Miocene to early(?) Pliocene. The Alvord Valley is composed of a series of Pliocene-Pleistocene to Holocene unconsolidated lacustrine and fluvial deposits.

Structurally the area is dominated by the large north- to northeast-trending vertical to steeply eastward dipping normal fault which separates the Steens Mountains from Alvord Valley. Displacements on the fault are estimated to be as much as 1000 feet, most of which occurred before the onset of glaciation. The slight uplift of some Quaternary alluvial fans is an indication faulting is an ongoing process.

Surface thermal phenomena are associated with the range-bounding normal fault at Mickey Hot Springs, in the northern part of the area, at Alvord hot spring west of the Alvord Desert in the central part of the area, at Borax Lake Hot Springs in the south central portion of the area, and at Pedro Springs in the southern part of the area just west of Fields, Oregon.

The Department of Geology and Mineral Industries (DOGAMI) effort in Alvord Valley was confined to limited spring sampling and the measurement of temperature gradients in existing wells. In all, six springs were sampled and their waters analyzed. When combined with previously published data, a total of twenty-seven analyses was available for evaluation. Calculated minimum reservoir temperatures covered a wide range, with the maximums being a 330°C estimate for Mickey Hot Springs and a 252°C estimate for Alvord Hot Springs.

Due to the sparsely settled nature of the study area, there are few open holes available for the measurement of temperature gradients. The heat flow, however, appears to be typical of other parts of the Basin and Range Province in the western United States, where local convective thermal anomalies are superimposed on high regional heat flow values of approximately 100 mWm^{-2}. The convective anomalies result from the rapid ascent of thermal waters in zones of fracture permeability in the range bounding normal faults. The fracture permeability often results from the intersection of cross faults with the range-bounding normal faults. This appears to be the situation in the Alvord Valley, where previously published geophysical data indicate the presence of faults beneath Mickey Hot Springs, Alvord Hot Springs, and Borax Lake Hot Springs.

Given the sparsely settled nature of the Alvord Valley (less than 1 person per square mile), the potential for the use of low temperature geothermal fluids is not significant. Although the required temperatures and fluid flow rates are present for direct use applications, the population densities required to attract industrial users or establish heating districts are not.

This is not the case with respect to electrical generation potential. The high minimum estimated reservoir temperatures at Mickey Hot Springs and Alvord Lake Hot Springs have attracted considerable industry interest over the last few years, and exploration by the private sector is still pressing forward at the present time.

McDERMITT

The McDermitt area is located in the extreme southeast corner of Oregon (Figure 1). The town of McDermitt just across the state line in Nevada is the only population center in the area.

The McDermitt caldera was a major Miocene eruptive center. Five large overlapping collapse structures with resurgent domes and ring dikes have been identified by workers in the area. Two of the calderas partially extend into Oregon's extreme southeast corner. Volcanism centered in the area was very silicic. Rhyolites, alkali rhyolites, trachyandesites, quartz latites, dacites and ash-flow sheets of these compositions were all erupted in the area. Volcanic activity occurred between 15 and 18 m.y.B.P.

Thermal springs with recorded temperatures of 53.5^{o}C, 52^{o}C, 32^{o}C, 25^{o}C, and 35^{o}C and an artesian well flowing at 46^{o}C are associated with the caldera structures within Oregon. Geochemical analysis of the springs indicates reservoir temperatures of approximately 100-130^{o}C.

Mineral deposits of mecury, uranium, and lithium are found at the caldera margins. None of the Oregon deposits are currently being worked, but others in Nevada associated with the same McDermitt caldera structures are the largest mecury deposits in the United States and are currently in production. Chemical analyses of rocks of the area indicate rhyolitic and alkali rhyolitic magmas enriched in mecury, uranium and lithium were probably the source for subsequent mineralization by epithermal hydrothermal fluids. The highest uranium concentrations are located in rhyolitic ring dikes and domes although there are also anomalous concentrations of uranium associated with mercury deposits.

Local heat flow is greater than 100 mW/m^2 (Blackwell and others, 1978). The thermal anomaly and springs of the McDermitt area may be generated by a combination of the locally high radioactivity with the very low conductivity of the silicic pyroclastic rocks. Thermal springs may occur where faulting or fracturing has provided channelways for heated waters to rise to the surface.

Low temperature geothermal utilization in the McDermitt area has low potential due to the very low population density of the area. Distances between residences preclude formation of a heating district, and light industry is not likely to locate in an area so remote with relatively little transportation access and through-traffic. Potential utilization of thermal waters in the McDermitt area seems to be restricted to individual ranch resources and needs, unless high-temperature fluids, adequate for electrical generation, can be found. The high heat flow and faulted nature of the rocks in the area are favorable for such resources.

ACKNOWLEDGEMENTS

This paper is the culmination of a unique and rapidly disappearing geothermal research program sponsored and formulated by the United States Department of Energy (USDOE). USDOE should be given credit for their far-sighted approach to stimulating the development of the vast low-temperature geothermal resources of the United States. For the first time the small developer, who is the main user of low temperature geothermal resources, has at his disposal high quality data sets and reports which can be utilized to mitigate the high risk of exploration. In addition, this program has allowed, with its emphasis on state participation, the development of highly trained geothermal exploration and utilization teams which have served the small developers and the states in general. The state-coupled geothermal assessment has been a successful and highly rewarding project which demonstrates the efficiency of state-implemented federal programs.

SELECTED REFERENCES

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.

Brown, D. E., McLean, G. D., and Black, G. L., 1980a, Preliminary geology and geothermal resource potential of the northern Harney Basin: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-6, 52 p.

Brown, D. E., McLean, G. D., and Black, G. L., 1980b, Preliminary geology and geothermal resources of the southern Harney Basin: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-7, 90 p.

Hammond, P. E., 1980, Reconnaissance geologic map and cross-sections of southern Washington Cascade Range latitude 45°30'-47°15' N., longitude 120°45'-122°22.5' W.: Portland, Oreg., Portland State University Earth Sciences Department, scale 1:125,000.

Hull, D. A., Blackwell, D. D., Bowen, R. G., and Peterson, N. V., 1977, Heat-flow study of the Brothers fault zone, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-77-3, 43 p.

Lawrence, R. D., 1976, Strike-slip faulting terminates the Basin and Range province in Oregon: Geological Society of America Bulletin, v. 87, p. 846-850.

Peterson, N. V., Groh, E. A., and Taylor, E. M., 1976, Geology and mineral resources of Deschutes County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin, no. 89, 66 p.

Sass, J. H., Lachenbruch, A. H., Munroe, R. J., Green, G. W., and Moses, T. H., Jr., 1971, Heat flow in the western United States: Journal of Geophysical Research, v. 76, no. 26, p. 6376-6413.

STATEWIDE LOW TEMPERATURE GEOTHERMAL RESOURCE EVALUATION

FINAL REPORT

U.S. DEPARTMENT OF ENERGY

CONTRACT NO. AC06-77-ET-28369

Principal Investigator: Donald A. Hull
Department of Geology and Mineral Industries
State of Oregon

July 1979

RLO-1040

INTRODUCTION

A statewide inventory of low temperature geothermal resources - geothermal waters with a temperature of 90° C or less - was begun on July 1, 1977, by the Department of Geology and Mineral Industries(DOGAMI). The inventory consisted of two phases - the first was a compilation of chemical data on thermal springs and wells in Oregon, and the second phase was an identification of low temperature reservoirs utilizing a combination of geochemistry, heat flow, geological, and geophysical data. Phase Ia was funded by the Department of Energy (formerly ERDA) under Contract No. EG-77-C-06-1040 and completed on September 30, 1977. Phase Ib was begun on October 1, 1977, under this contract, as extended, with additional funding provided for the period October 1 - December 31, 1977. An application for an extension and additional funding of this project was submitted to ERDA (DOE) on September 14, 1977, funded on December 28, 1977, and later extended to December 31, 1978. A no-cost extension to the contract was issued by DOE on January 1, 1979, with the original completion date as specified in Article II of the contract changed to June 15, 1979. Further, the contract number was changed from EG-77-C-06-1040 to AC06-77-ET-28369 as of the above date.

Dr. Donald A. Hull, Oregon State Geologist, was the principal investigator for DOGAMI. The field studies administered by DOGAMI have been managed by its staff personnel and/or consultants. The final report was edited by Dr. Joseph F. Riccio.

WORK ELEMENTS

According to Appendix A of Contract No. EG-77-C-06-1040, DOGAMI was to conduct a preliminary statewide evaluation of low temperature geothermal resources. This study would also include interaction with the U.S. Geological Survey's (USGS) expansion of its GEOTHERM data base.

Phase Ia

Under this portion of the contract, forty-eight (48) chemical analyses of thermal waters from springs or wells in Oregon based on both field sampling and literature research by DOGAMI were submitted to the USGS for inclusion in their GEOTHERM data base. These data are included in Open File Report 0-79-3, Chemical Analyses of Thermal Springs and Wells in Oregon, authored jointly by USGS and DOGAMI. A copy of the publication is enclosed.

The locations of these thermal springs and wells as well as others previously identified by DOGAMI are shown on Geological Map Series (GMS)-10, which is an update of previously published Miscellaneous Paper 14 (1970). GMS-10 is submitted as part of DOGAMI's contractual obligation to DOE.

Phase Ib

Thirty (30) potential geothermal-field areas were identified under this part of the study and pertinent data thereon were also submitted to the USGS for their inclusion in the GEOTHERM data base. Of the above number, nine (9) definite resource areas favorable for the discovery and development of low temperature (<90° C) geothermal resources totally within Oregon and three (3) other areas that are partially in Oregon-Idaho, Oregon-Nevada, and Oregon-Washington are detailed in USGS Circular 790, Assessment of Geothermal Resources of the United States - 1978. These areas are: Belknap-Foley Hot Springs, Willamette Pass, Craig Mountain - Cove (La Grande), Glass Buttes, Northern Harney Basin, Southern Harney Basin, Alvord Desert, Lakeview, Klamath Falls, Western Snake River Basin, McDermitt, and Walla Walla. Data on these areas presented on Table 12 of Circular 790 are based on information provided to USGS by DOGAMI.

DOGAMI publication GMS-11, Preliminary Geothermal Resource Map of Oregon, scale of 1:500,000, relates the above resource areas to pertinent Pleistocene-Holocene geology, geologic structure, heat flow, and to thermal springs and wells. GMS-11 is included as a part of this report.

Special Report 4, Heat Flow of Oregon, contains extensive newly acquired heat flow and geothermal gradient data for the State of Oregon. These data are presented on a contour map of heat flow (20 m W/m^2 interval) at a scale of 1:1,000,000. Also presented in the text are maps of heat flow and temperature at a depth of 1 km for 1° x 1° intervals. Histograms and averages of geothermal gradient and heat flow for the various physiographic provinces within the State are also included. This publication is part of the final report for the Statewide Low Temperature Geothermal Resource Evaluation.

CONCLUSION

The factual data and conclusions, recommendations, or comments presented in the foregoing publications constitute the formal results of the geothermal studies carried out by DOGAMI under DOE Contract No. AC06-77-ET-28369 for the Statewide Low Temperature Resource Evaluation.

THE
UNIVERSITY
OF UTAH

DEPARTMENT OF GEOLOGY
AND GEOPHYSICS

COLLEGE OF MINES AND
MINERAL INDUSTRIES
717 MINERAL SCIENCE BLDG.
SALT LAKE CITY, UTAH 84112

December 2, 1980

MEMO

To: B. Blackett

From: Stan Evans

Enclosed is a table of analyses recently completed for the Oregon state coupled team. Please feel free to make a copy for your files and then forward the results on to George Priest.

Stan

Stan

Sample No.	Unit	Material Dated	Weight (gms).	%K	Moles/gm Ar^{40}_{Rad} ($X10^{11}$)	$\%Ar^{40}_{atm}$	Age (M.Y.)
Cougar Dam East	-	Plagioclase	6.01058	0.237	0.674	86.9	16.3±1.8
RI-112	-	Plagioclase	6.33873	0.208	0.417	64.7	11.5±0.5 *
RI-85	-	Plagioclase	2.91937	0.349	0.844	74.5	13.9±0.8 *
Foley Ridge	-	Whole Rock	2.53109	0.548	0.195	94.6	2.05±0.52
Tmw-Top	-	Whole Rock	3.01778	1.121	1.739	38.9	8.93±0.34 *
Tpb	-	Whole Rock	3.01174	0.365	0.533	61.1	8.39±0.36
STACK	-	Whole Rock	3.00758	0.540	2.090	64.7	22.2±1.0

* Provisionary dates - done on new extraction line, subject to later revision.

Constants Used:

$\lambda_\beta = 4.962 \times 10^{-10}$/yr.

$\lambda_\varepsilon = 0.581 \times 10^{-10}$/yr.

$K^{40}/K_{Tot.} = 1.167 \times 10^{-4}$ Mole/Mole

THE
UNIVERSITY
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DEPARTMENT OF GEOLOGY
AND GEOPHYSICS

COLLEGE OF MINES AND
MINERAL INDUSTRIES
717 MINERAL SCIENCE BLDG.
SALT LAKE CITY, UTAH 84112

January 28, 1980

TO: Duncan Foley

FROM: Stan Evans

Dear Duncan:

Here is the data for the Oregon rocks from the western Cascades sent by Craig White. In addition to the eight samples dated two others were not dated. CT-57 contains too much glass and carbonate to be dated accurately. CT-28 was datable but there was insufficient sample to separate the hornblende. If Craig would like the amphibole dated have him send more sample.

Sincerely,

Stan Evans

Sample No.	Unit	Material Dated	Weight (gms.)	%K	Moles/gm Ar^{40}_{Rad} ($X10^{11}$)	KAr^{40}_{atm}	Age(M.Y.)
CT-17	-	Whole rock	7.31954	0.44	0.473	71	6.24 ± 0.33
CT-22	-	" "	4.68341	0.64	0.210	90	1.90 ± 0.26
CT-32	-	" "	6.59840	1.00	0.196	80	1.13 ± 0.08
CT-41	-	" "	5.09256	2.17	1.547	59	4.10 ± 0.17
CT-51	-	" "	8.01601	0.63	0.130	90	1.20 ± 0.17
CT-52	-	" "	8.10805	0.86	0.259	82	1.74 ± 0.14
CT-59	-	" "	5.42872	1.25	2.568	34	11.8 ± 0.4
CT-68	-	" "	8.02548	0.78	0.672	58	4.99 ± 0.20

Constants Used:

$\lambda_\beta = 4.962X10^{-10}/yr.$

$\lambda_\varepsilon = 0.581X10^{-10}/yr.$

$K^{40}/K_{Tot.} = 1.167X10^{-4}$ Mole/Mole

$(\frac{Ar^{40}}{Ar^{38}})_{spike} = 0.0525$

$(\frac{Ar^{36}}{Ar^{38}})_{spike} = 0.0306$

OREGON Rocks

Sample No.	Unit	Material Dated	Weight (gms.)	%K	Moles/gm Ar^{40}_{Rad} $(X10^{11})$	$\%Ar^{40}_{atm}$	Age(M.Y.)
CT-17	-	Whole Rock	7.31954	0.44	0.458	71	6.05 $\pm$ 0.31
CT-22	-	" "	4.68341	0.64	0.217	90	1.97 $\pm$ 0.27
CT-32	-	" "	6.59840	1.00	0.185	80	1.07 $\pm$ 0.08
CT-41	-	" "	5.09256	2.17	1.524	59	4.04 $\pm$ 0.17
CT-51	-	" "	8.01601	0.63	0.111	90	1.02 $\pm$ 0.14
CT-52	-	" "	8.10805	0.86	0.239	82	1.62 $\pm$ 0.14
CT-59	-	" "	5.42872	1.25	2.566	34	11.8 $\pm$ 0.4
CT-68	-	" "	8.02548	0.78	0.639	58	4.74 $\pm$ 0.19

13 Mar 80

Craig - these numbers have been revised slightly —

Duncan

Constants Used:

$\lambda_\beta = 4.96X10^{-10}/yr.$

$\lambda_\varepsilon = 0.581X10^{-10}/yr.$

$K^{40}/K_{Tot.} = 1.167X10^{-4}$ Mole/Mole

ID F-134 (Rev. 10-79) Ref. ID 1325.1

Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

Subject:

TRANSMITTAL OF TECHNICAL PROGRESS REPORT #3
COOPERATIVE AGREEMENT NO. DE-FC07-79ET27220

To: Distribution

From: L. L. Mink, OGE
DOE-ID

Date: NOV 19 1979

Margaret A. Widmayer for

Enclosed for your information and retention is one copy of the Technical Progress Report for Cooperative Agreement No. DE-FC07-79ET27220 with the Oregon Department of Geology and Mineral Industries. If you have any questions or comments regarding this report, please contact this office.

1 Enclosure

Distribution

G. Brophy, DOE-HQ
E. Hyster, DOE-ID
D. Foley, UURI

F. M. 2.14

VICTOR ATIYEH
GOVERNOR

Department of Geology and Mineral Industries

ADMINISTRATIVE OFFICE
1069 STATE OFFICE BLDG., PORTLAND, OREGON 97201 PHONE (503) 229-5580

October 25, 1979

RECEIVED
NOV 2 1979
ENERGY & TECHNOLOGY DIVISION

Mr. Leland L. Mink
Energy and Technology Division
Idaho Operations Office, DOE
550 Second Street
Idaho Falls, Idaho 83401

Dear ~~Mr. Mink~~ Lee:

Subject: Cooperative Agreement No. DE-FC07-79ET27220; Project Status Report No. 3

1. Data compilation is underway for the low-temperature geothermal resource areas identified in Phase 1; Belknap-Foley, Willamette Pass, Craig Mountain-Cove, Glass Buttes, Lakeview, Northern and Southern Harney Basins, and Alvord. Compilation has not begun this date on Western Snake River Plain.

2. Geologic mapping is underway and in various stages of completion for Lakeview, Craig Mountain-Cove, Balknap-Foley, Northern and Southern Harney Basins, and Willamette Pass. Craig Mountain-Cove, mapped under contract to DOGAMI by Geoscience Research Consultants, has been completed. The geologic report is being written. The other areas are being mapped by DOGAMI personnel.

3. Temperature-gradient logging of "free" holes is currently underway at Lakeview and La Grande.

4. Fluid samples from available springs and wells have been collected for chemical analyses in the Lakeview and Alvord areas.

5. Chemical analyses of water samples submitted to the State DEQ laboratory obtained from Belknap-Foley, Lakeview and Willamette Pass have been completed. Evaluation of data is currently underway.

Sincerely,

Donald A. Hull
State Geologist

DAH:lk
cc J.F. Riccio

ID F-134 (Rev. 10-79) Ref. ID 1325.1

Department of Energy Idaho Operations Office 550 Second Street Idaho Falls, Idaho 83401	Subject: TRANSMITTAL OF TECHNICAL PROGRESS REPORT #3 COOPERATIVE AGREEMENT NO. DE-FC07-79ID12044

To: Distribution

From: L. L. Mink, OGE
DOE-ID
Margaret A. Widmayer for

Date: NOV 19 1979

Enclosed for your information and retention is one copy of the Technical Progress Report for Cooperative Agreement No. DE-FC07-79ID12044 with the Oregon Department of Geology and Mineral Industries. If you have any questions or comments regarding this report, please contact this office.

1 Enclosure

Distribution
- G. Brophy, DOE-HQ
- E. Hyster, DOE-ID
- D. Foley, UURI

M.2.16

VICTOR ATIYEH
GOVERNOR

Department of Geology and Mineral Industries

ADMINISTRATIVE OFFICE

1069 STATE OFFICE BLDG., PORTLAND, OREGON 97201 PHONE (503) 229-5580

October 25, 1979

RECEIVED
NOV 2 1979
ENERGY & TECHNOLOGY DIVISION

Mr. Leland L. Mink
Energy and Technology Division
Idaho Operations Office, DOE
550 Second Street
Idaho Falls, Idaho 83401

Dear Ray ~~Mr. Min~~k:

Subject: Cooperative Agreement No. DE-FC07-79ID12044; Technical Progress Report No. 3

1. Drilling of temperature-gradient holes has been underway since the latter part of September. Three holes have been completed; another should be completed this week. Drilling has not been without problems because upper portions of the holes encounter either High Cascade lavas, till or alluvium. These holes are all in the northern portion of the Willamette National Forest.

2. Geologic studies by subcontractors to DOGAMI are continuing. Currently, field work is hampered by an early snowfall.

3. Temperature-gradient profiling from "free" holes is continuing, especially those holes currently being drilled by EWEB.

Sincerely,

Donald A. Hull
State Geologist

DAH:lk
cc J. F. Riccio

Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

TO: DISTRIBUTION

FROM: M. A. WIDMAYER
Geologic Program Manager Maggie

SUBJECT: OREGON RESOURCE ASSESSMENT PROGRAM

Enclosed for review and comment is a proposal for continued funding of the Oregon State Resource Assessment Program.

Please provide all comments regarding the technical scope of the work to this office by March 24, 1980.

1 Enclosure

Distribution: G. Brophy, DOE-HQ
D. Foley, UURI
M. Reed, USGS

RESEARCH PROPOSAL

SUBMITTED TO DIVISION OF GEOTHERMAL ENERGY

U. S. DEPARTMENT OF ENERGY

RECEIVED
FEB 7 1980
GEOTHERMAL ENERGY
BRANCH

Title

LOW TEMPERATURE GEOTHERMAL RESOURCE ASSESSMENT, PHASE II

By

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
1069 State Office Building
Portland, Oregon 97201

Amount requested: $400,000

	DOE	DOGAMI	TOTAL
Fiscal 1980	$400,000	$20,450	$420,450

Starting date: May 22, 1980 through May 22, 1981

ENDORSEMENTS

Principal Investigator

Joseph F. Riccio — 2/21/80
Joseph F. Riccio — Date

Approving Administrative Official

Donald A. Hull — 2/21/80
Donald A. Hull, State Geologist — Date

CONTENTS

INTRODUCTION

During Phase I of the Western States Cooperative Direct-Heat Geothermal Program (Contract No. EG-77-C-06-1040) available data on low temperature ($\sim 20^0C < T < 90^0C$) geothermal resources were collected in Oregon. Based on review of these data, nine low-temperature resource areas were identified. During the Mt. Hood geothermal Resource Assessment project (1978), Contract No. AC06-77-ET-28369, two other low-temperature resource areas were identified: Parkdale, northeasterly of Mt. Hood, and Powell Buttes, northeast of Bend.

Phase II of the direct-heat geothermal program primarily entails the selection of specific sites, based on Phase I data, for detailed evaluation. Geological-geophysical investigations of the specific sites are to be conducted in order to select drill test locations. Sites selected will be drilled on a priority basis for reservoir confirmation and assessment. Results, including maps and reports, will be published by DOGAMI and made available to the geothermal community, governmental agencies, and the public. Development of direct heat geothermal resources should have a significant near-term impact by fulfilling, in part, the energy requirements of Oregon and the United States.

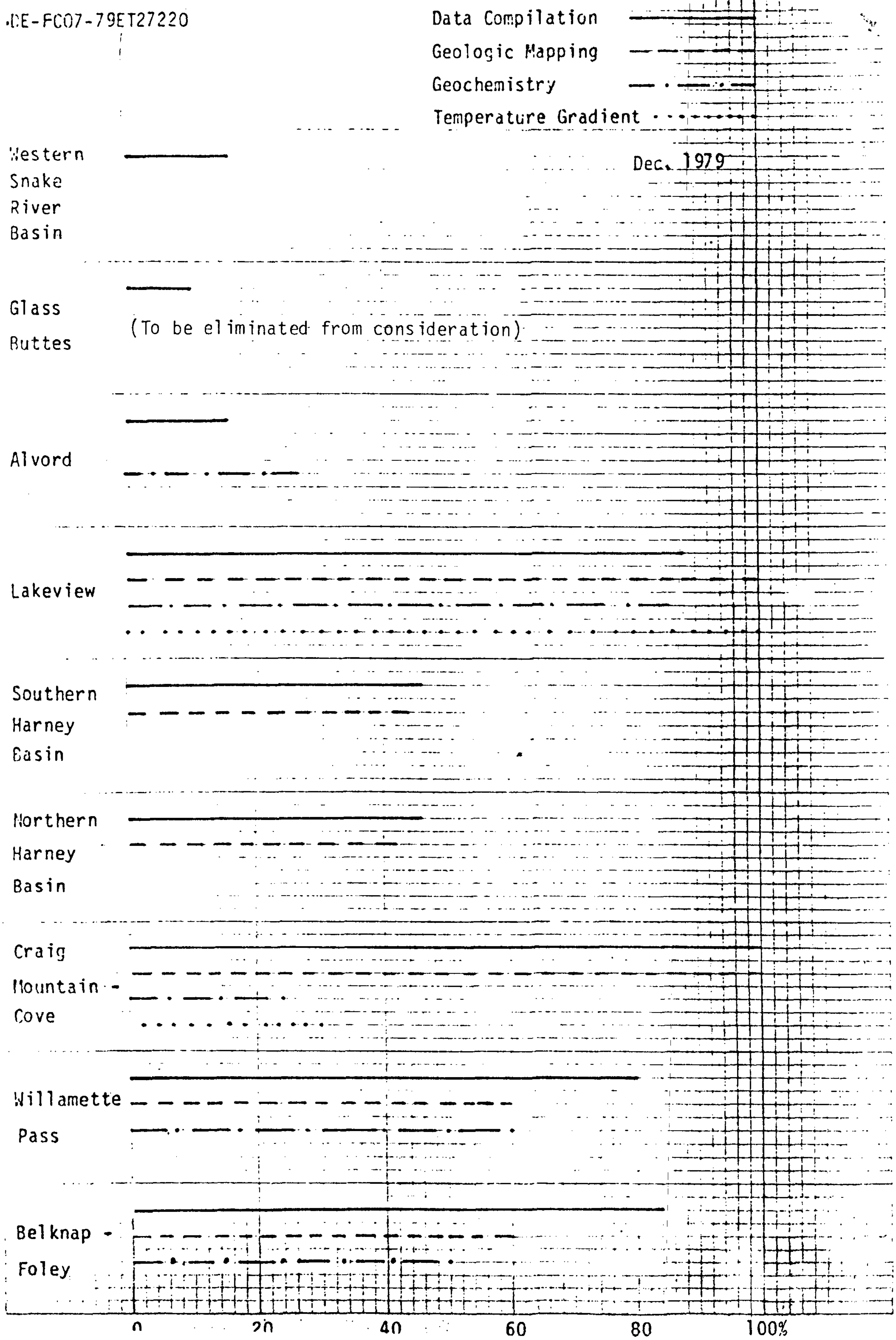
During the 1979-80 portion of the Phase II project (Contract No. DE-FC07 79ET-27220), geological-geophysical investigations have been carried out for certain low-temperature areas as shown on Figure 1 in compliance with the aforementioned contract.

It is hereby requested that the Glass Buttes area be dropped from further consideration because of existing industry involvement and that Parkdale and Powell Buttes be assimilated into the project for 1980-81. Other modifications will be treated below in the assessment plan portion of this proposal.

This proposal describes the studies necessary to continue and complete most aspects of the Phase II program, the selection of specific sites for deep test drilling and requests funds in the amount of $400,000 to continue these studies during the year of 1980-81. Summary costs by task are provided in the Budget Section of this proposal.

Not contemplated in this proposal is intermediate to deep geothermal drilling for final confirmation and assessment of promising geothermal targets such as the Lakeview area. As these areas are identified, they will continue to be brought to the attention of DOE. Future assessments should include scientific supervision by DOGAMI.

DE-FC07-79ET27220



ORGANIZATION AND MANAGEMENT PLAN

The Department of Geology and Mineral Industries (DOGAMI) is responsible under Oregon State Law for the conduct of geologic research and the regulation for the exploration and development of minerals and mineral fuels including geothermal energy. DOGAMI and its predecessor organization have been in existence since 1913. The agency has a staff of 15 geologists and engineers; a chemical, assay and spectrographic laboratory; library; cartographic facilities; and an editorial and accounting staff. These facilities will be available to the project described in this proposal at no additional cost.

DOGAMI has been engaged in continuing geothermal research, involving a variety of geological, geochemical and geophysical studies, for the past eleven years. The results of these efforts are included in the geothermal publications list included below.

The principal investigator is Dr. Joseph F. Riccio, Geothermal Specialist, DOGAMI.

Dr. Riccio, as Geothermal Development Manager for the Public Service Department, City of Burbank, California, was resonsible for the city's program of geothermal development leading to electric power production. He recently completed geological studies associated with the exploratory drilling for a geothermal deep test at the Long Valley KGRA, California. He has also contributed research and authorship to an ERDA grant, Contract No. E (0-4-1311) entitled "Site-Specific Analysis of Hybrid Geothermal/Fossil Power Plant's" which deals with the evaluation of hybrid power plants that combine geothermal energy with that of coal. While as a consultant to the State of California Energy Commission (ERCDC) he was involved with state-sponsored development of electric power plants utilizing geothermal energy for the geothermal fields in Imperial Valley, California.

He has completed the work on Phase I of the Oregon Low Temperature Geothermal Resource Assessment and the Geothermal Resource Assessment of the Mt. Hood Volcano, Oregon (Contract No. EG-77-C-06-1040); especially heat flow studies and evaluation of the exploratory holes drilled by Northwest Natural Gas Company at Old Maid Flat and Timberline.

Dr. Riccio is currently the Program Manager for DOGAMI of the Low Temperature Geothermal Resource Assessment, Phase II, 1979-80, Contract No. DE-FC-07-79ET27220 and the Geothermal Resource Assessment of the Western and Central Cascades, Contract No. DF-FC-07-79ID12044.

DOGAMI, as project manager for work in Oregon funded by the U.S. Department of Energy (DOE), will: (1) coordinate various State and Federal agencies and other organizations which may participate in this project; (2) act as liaison and coordinator between the project and other ongoing Federal and State supported geothermal projects; (3) coordinate site-specific geological-geophysical studies; (4) subcontract temperature-gradient drilling; (5) prepare and compile final maps and reports for the project. Geophysical studies, if required, will be administered by DOGAMI. Consulting geophysicists and geologists will be utilized, wherever necessary, to complement the assessment portion of this proposal.

It is anticipated that cost of site deep-test drilling, if done, is to be borne by DOE, and funds for this drilling are not provided herein. Portions of the site deep-test drilling may be managed either by DOE or DOGAMI. DOGAMI would oversee the downhole geologic logging and geologic studies associated with the site deep-test drilling.

DOGAMI will administer all phases of the low-temperature resource assessment described for which funding is herein to be made available. DOGAMI will conduct the necessary geologic studies; air-photo and imagery interpretation; temperature-gradient studies including shallow drilling (to 500 ft); and geochemical testing. DOGAMI would also manage the accounting functions inherent to this proposal.

An organization chart of DOGAMI personnel that will be utilized in the Phase II (1980-81) study is shown in Figure 2.

ORGANIZATION CHART

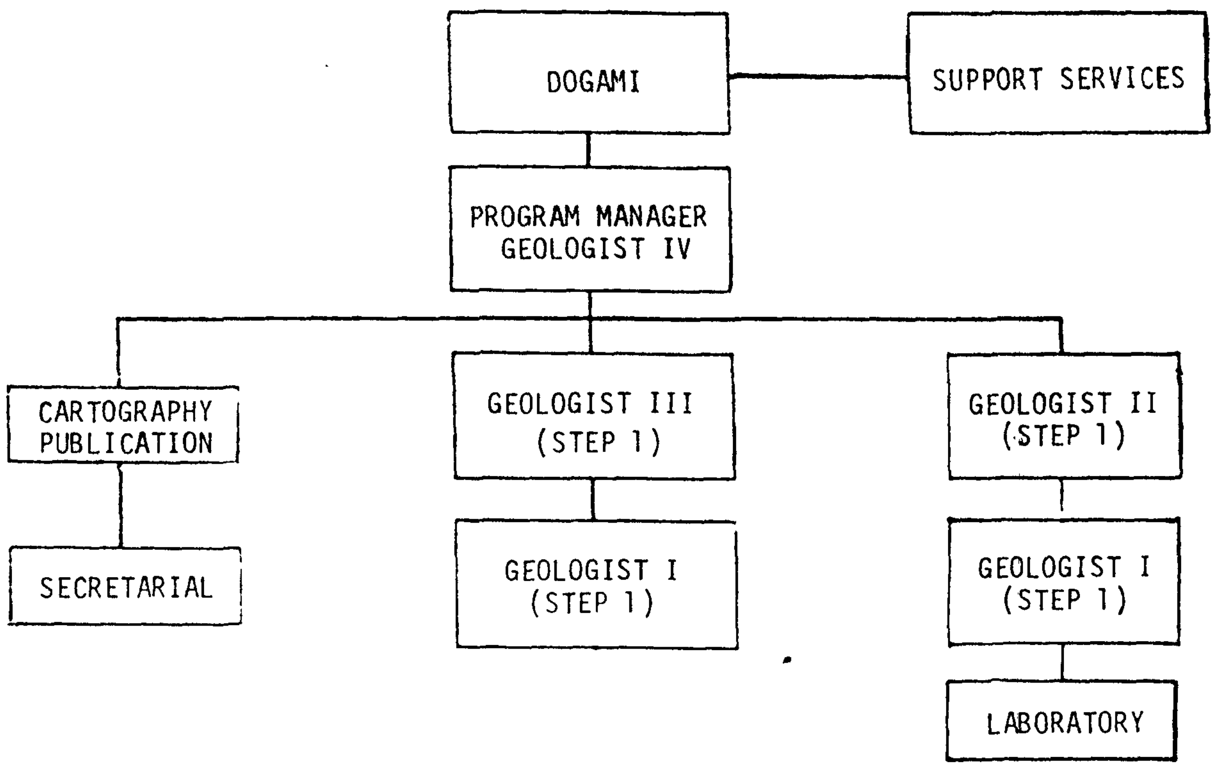


Figure 2

ASSESSMENT PLAN

Data Compilation

Geological, geophysical, geochemical, and heat flow data for the low temperature resource areas identified in Phase I (Belknap-Foley, Willamette Pass, Craig Mountain-Cove, Western Snake River Plain, Northern and Southern Harney Basins, Alvord and Lakeview) (Figure 3) are in various stages of completion and no additional funding is requested for these areas except as noted below. Funding for data compilation is required for Parkdale and Powell Buttes as well as for Walla Walla and McDermitt, the latter two being part of the original Phase I identification. Data compilation will be an ongoing process throughout the assessment period.

Geologic Mapping

Initial assessment of the additional four resource areas will consist, in part, of geologic mapping and air-photo and imagery interpretation.

A geologic map, at an appropriate scale, extending into adjacent areas, based on either field mapping or literature research-field reconnaissance, and air-photo interpretation, will be produced for each of the resource areas. The map also will depict all known major structures or trends as well as surface geothermal manifestations. Cross-sections based on available geologic data will be drawn through the resource areas.

Besides black and white, color and color IR photos, air-photo studies will involve the interpretation of SLAR, LANDSAT (ERTS), NASA U-2 and Apollo imagery, as available. Data obtained will be utilized to produce a lineament

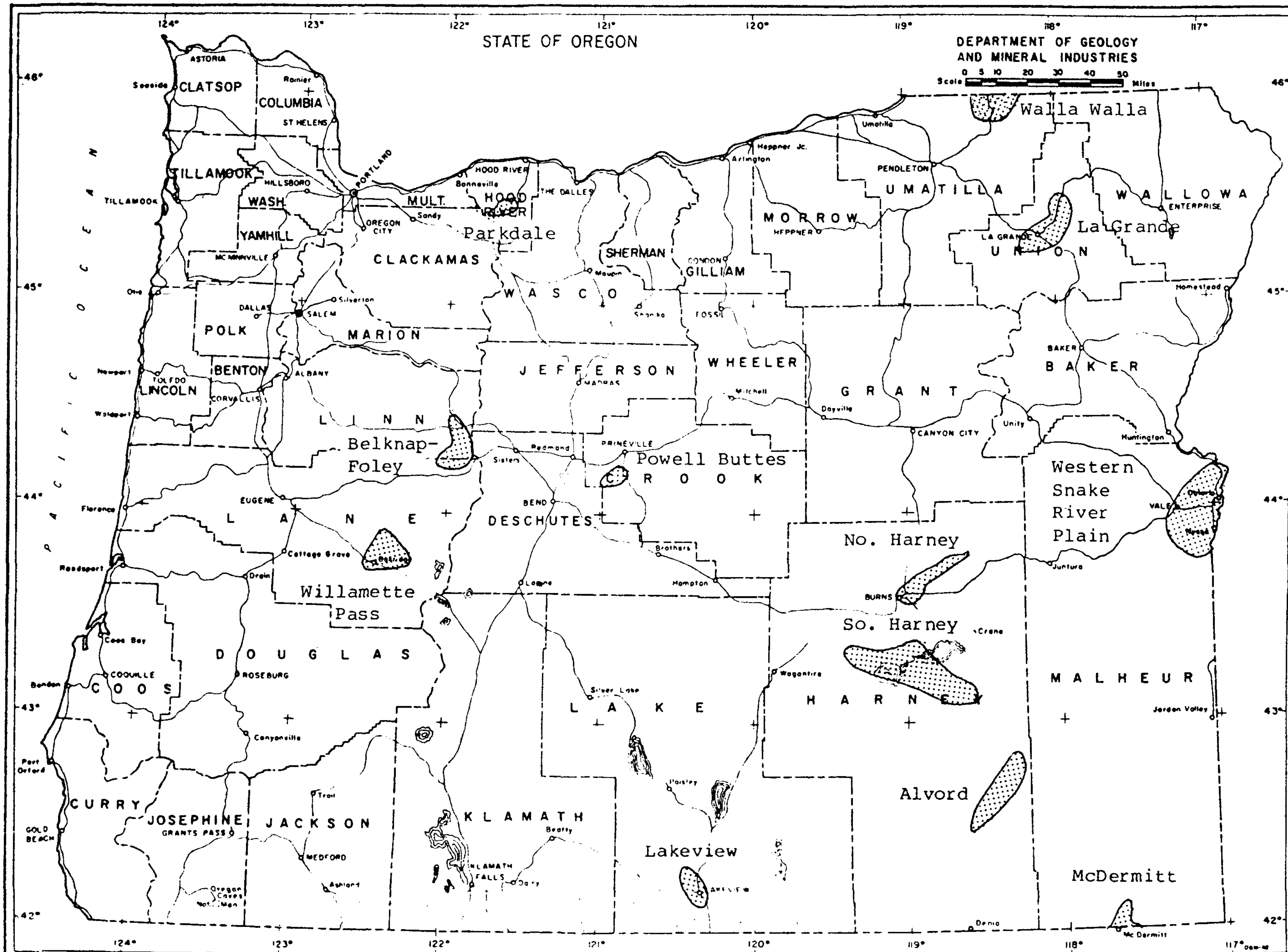


Figure 3. Index map of low temperature areas

map for each of the four resource areas. Ground-truth verification may be needed to resolve ambiguous interpretation and may be accomplished during field mapping. It is contemplated that some of this work may be done by consultants to DOGAMI.

Temperature-Gradient Study

Temperature-gradient drilling has been completed at Lakeview and La Grande, two of the resource areas previously identified. Under this present proposal, funding is requested for temperature-gradient drilling at Belknap-Foley, Willamette Pass, and Parkdale. Drilling of heat-flow holes is not contemplated for the remainder of the resource areas because of either prior industry involvement, remoteness of resource area to available markets, availability of drilling sites, or the large size of the resource area. Any drilling funds remaining after drilling of the above three resource areas will be utilized in the drilling of hole(s) in the Harney Basin.

Because the three resource areas represent varied geologic conditions, holes to be drilled will encounter materials that may vary from valley-fill sediments to volcanics of diverse types. Each area should exhibit distinct drilling characteristics with differing attendant problems. Part of the compilation process will be to better define the drillability within the respective resource areas so that loss of future drilling-completion time can be kept to an absolute minimum.

It is proposed that a minimum of four (4) up to 500-foot (152 m) deep, temperature-gradient holes be drilled in each of the three aforementioned areas. However, site conditions may dictate that a lesser or greater number of such holes be drilled. It is contemplated that the holes should not be any deeper than that expressed above, but there may be a possibility that gradient holes up to 1,000 feet may be a necessity.

Whatever "scrounge or free" holes may be located within the resource areas; i.e., water wells, oil-test wells, mineral exploratory holes, etc., temperature gradients will be measured for these holes. These data will complement that obtained from the proposed temperature-gradient holes.

Drilling projects in young volcanic environments throughout the world encounter repeated costly and time consuming difficulties. Therefore, it is felt that an exchange of ideas with others is important for the successful completion of the test holes. Funds are included herein for travel by the principal investigator or his designee to Washington, D.C., to confer with DOE drilling specialists.

Geochemistry

During the Phase I and II (1979-80) investigation, available thermal springs and wells were sampled, water analyzed, and geothermometry computed. This process will continue for the resource areas for additional wells and springs that may not have been included in the previous work by virtue of their availability. If thermal fluids are encountered in the temperature-gradient holes, samples of these fluids will be chemically analyzed and the data submitted to the U.S. Geological Survey (USGS), Menlo Park, California, for their inclusion in the GEOTHERM data base.

Site Selection

The final selection of deep test drill sites will be decided after a thorough review with appropriate USGS and DOE personnel of all geological, geochemical, and geophysical data collected for the resource areas.

Selection of precise drill sites must take into account whether surface and subsurface occupancy rights are available for lands under Federal, State, and local government ownership or control. It is not anticipated that drill sites will be located on private lands unless special arrangements can be made with the fee holders and/or lessors.

Deep Test Drilling

Use coupled drilling pvt sector

Deep test drilling should commence sometime after the second half of 1981 and therefore is not a part of the present proposal. It is possible that the selection process, based on the ongoing assessment, may eliminate identified resource areas from consideration. On the other hand, all of the areas could be drilled. Drilling of one hole per area, for example, if successful, would tend to identify a specific reservoir. However, reservoir evaluation leading to exploitation can only proceed when confirmation wells are drilled.

Funding for the actual deep test drilling, drilling and geological supervision, geophysical logging, and flow testing is not contemplated as part of this proposal and cannot be accurately forecast at the present time. It will be the subject of continuing discussions between DOE and DOGAMI.

Publication

It is envisioned that the final report would consist of the assessment portions (i.s., geologic and lineament maps, geophysical maps, data on heat flow and geochemistry, and associated text) as well as recommendations for each of the resource areas either as one compendium or as individual treatises. This decision will be predicated on the quantity of the data collected and the needs of the geothermal community.

RELATED STUDIES

A statewide inventory of low-temperature geothermal resources (Phase I); i.e., geothermal waters with a reservoir temperature of 90°C or less, was begun on July 1, 1977. The inventory, as originally planned, consisted of two parts - the first was a compilation of chemical data on Oregon's thermal springs and wells, and the second part was an inventory of low-temperature reservoirs utilizing a combination of geochemistry, heat flow data, temperature-gradient data, and geological-geophysical information.

Geochemical data obtained from the Phase I study have been sent to USGS for their inclusion in the GEOTHERM data base. The collection of low-temperature data during the Phase II (1979-80) study will be likewise submitted to USGS.

DOGAMI, under Contract No. DE-FC07-79ID12044, is currently drilling temperature-gradient holes in the Central Cascades area. This work should be completed in late 1980. Data that may relate to an understanding of the geothermal regime in the Willamette Pass and Belknap-Foley resource areas will be incorporated in the final report(s) of these two areas. Similarly data generated under Contract No. AC06-77-ET-28369 for the geothermal assessment of Mt. Hood will be utilized in the evaluation of the Parkdale area.

Because of its long-term involvement in the study of Oregon's geothermal resources, DOGAMI holds a considerable quantity of unpublished data which will be available for this project.

PATENT INFORMATION

There is no proprietary information included in this proposal and the information to be collected during the proposed study will not be confidential.

APPLICATIONS TO OTHER SPONSORS

This proposal has not been submitted to other potential sponsors and we do not plan to submit it to others in the future.

RESUMÉ AND BIBLIOGRAPHY

RESUMÉ

Joseph F. Riccio

Summary:	Technical, administrative and management experience in petroleum geology, engineering geology, hydrogeology, environmental geology, and geothermics.
Education:	University of Southern California BA 1950 Geology University of Southern California MS 1951 Geology University of Southern California Ph.D. 1965 Geology

Experience:

5/78 to Present	Oregon Department of Geology and Mineral Industries, Portland, Oregon; Geothermal Specialist. Responsible for the completion of the low-temperature resource assessment in Oregon (DOE Contract No. EG-77-C-06-1040) and the geothermal resource assessment of Mt. Hood Volcano, Oregon (DOE Contract No. EG-77-C-06-1040).
8/77 to 5/78	Consultant in California in geothermics to the State of California Energy Resources Conservation and Development Commission and to private geothermal development firms.
4/76 to 8/77	Geothermal Development Manager, Public Service Department, Burbank, California. Responsible for the city's program of geothermal development leading to electric power production. Research and author contribution to ERDA grant (Contract No. E(0-4-1311) entitled "Site-Specific Analysis of Hybrid Geothermal/Fossil Power Plants."
4/74 to 4/76	Consulting Engineering Geologist (California); Consultant to civil engineering firms, architects, land developers, and attorneys in engineering geology.
10/70 to 4/74	Consulting Engineering Geologist (Alabama); Consultant to the State of Alabama (Geological Survey) in engineering/environmental geology and hydrogeology. Staff engineering geologist, and regional geologist, Mobile District, Alabama Geological Survey.

Typical responsibilities: Hydrogeologic studies pertaining to sanitary landfill sites and land-dispodal sewage systems; deep-well disposal studies; engineering geology, and hydrogeology for several counties in South Alabama. Project Director of an environmental geology study for the U.S. Corps of Engineers entitled "Environmental Impact of the Proposed Tennessee-Tombigbee Waterway in Alabama." Project leader of an engineering/environmental geologic study for a proposed super-port and associated land-based support facilities on the Alabama Gulf Coast. Dam site geology, exploration, and reservoir studies for a proposed nuclear generating plant for the Alabama Company.

7/55 to 7/70 — Pacific Soils Engineering, Inc., California, President and Chief Engineering Geologist. Director and Supervisor of 55 employees engaged in consulting engineering geology, foundation engineering, and soil engineering.

11/53 to 6/55 — Senior Engineering Geologist (California), employed by a private consulting foundation engineering firm. Responsible for the firm's geological studies pertaining to urban, commercial, and industrial land developments.

3/52 to 7/53 — Petroleum Geologist/Engineer for an independent oil producer in California. Responsible for drilling, work-over, casing, and logging programs and completion procedures for developmental wells.

2/51 to 2/53 — Subsurface geologist for International Petroleum, Ltd. (Colómbia). Duties similar to that above plus well-site geology.

Publications

Lower Cambrian Fauna of the Marble Mountains, California: The Compass, vol. 26, no. 4, 1949.

Triloculinella, a New Genus of Foraminifera: Cont. Cushman Foundation Foram. Research, vol. I, parts 3 and 4, 1950.

The Lower Cambrian Olenellidae of the Southern Marble Mountains, California: Bull. Sou. Calif. Acad. of Sci., vol. 51, part 2, 1952.

Porosity and Permeability of some Unconsolidated Sediments: The Compass, vol. 39, no. 2, 1962.

A Geological and Geographical Appraisal of Alluvial Fans: The Compass, vol. 39, no. 2, 1962.

Origin of Adobe Clays in the Southwestern Portion of the Los Angeles Basin: in Essays in Marine Geology: Univ. Sou. Calif. Press, 1963.

Environmental Geology and Hydrology, Madison County, Alabama: Geol. Survey of Alabama, Atlas Series no. 1, 1971 (co-author).

Hydrogeology of Sanitary Landfill Sites in Alabama: Geol. Survey of Alabama Circular 71, 1972 (senior author).

Petrology and Identification of the Citronelle Formation in Alabama: Bull. Geol. Soc. America, vol. 4, no. 2, 1972, abstract (co-author).

Neogene Sediments of Mobile County, Alabama: in Recent Sedimentation along the Alabama Coast: Ala. Geol. Society, Tenth Annual Field Trip,1972 (senior author).

History of Water Supply of the Mobile Area, Alabama: Geol. Survey of Alabama, Circular 92, 1973 (senior author).

Development of a Hydrological Concept for the Greater Mobile Metropolitan-Urban Environment: Geol. Survey of Alabama Bull. 106, 1973 (senior author).

Igneous Rocks in Mobile River: Geotimes, vol. 18, no. 12, 1973 (senior author).

Use of Satellite Imagery in the Interpretation of Physiographic and Structural Features in South Alabama: Am. Assoc. Petroleum Geologists Bull., vol. 58, no. 3, 1974 (co-author).

Infrared Color Photography of the Fort Mims Site, Alabama: Jour. Ala. Archaeology, vol. 20, no. 2, 1974 (senior author).

Faulted Upper Pleistocene Marine Terrace, Palos Verdes Hills, California: Am. Assoc. Petroleum Geologists Bull., vol. 61, no. 11, 1977 (senior author).

Site Specific Analysis of Hybrid Geothermal/Fossil Power Plants: ERDA Publication, Contract No. E(0-4-1311), City of Burbank, 1977 (co-author).

Low- to Intermediate-Temperature Thermal Springs and Wells in Oregon: Oregon Department of Geology and Mineral Industries Geologic Map Series No. 10, 1978 (junior author).

Preliminary Geothermal Resource Map of Oregon: Oregon Dept. of Geology and Mineral Industries Geologic Map Series No. 11, 1978.

Geothermal Exploration in Oregon in 1978: Oregon Dept. of Geology and Mineral Industries, Oregon Geology, vol. 41, no. 3, 1979 (senior author).

Geothermal Resource Assessment of Mount Hood: U.S. Dept. Energy Contract No. AC06-77-ET-28369, Oregon Dept. of Geology and Mineral Industries, 1979 (editor and co-author).

DOGAMI GEOTHERMAL ENERGY PUBLICATIONS

1966

Bodvarsson, G., 1966, Energy and power of geothermal resources: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 28, no. 7, p. 117-124.

Groh, E.A., 1966, Geothermal energy potential in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 28, no. 7, p. 125-135.

1967

Peterson, N.V., and Groh, E.A., 1967, Geothermal potential of the Klamath Falls area, Oregon, a preliminary study: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 29, no. 11, p. 209-231.

1970

Bowen, R.G., and Peterson, N.V., 1970, Thermal springs and wells in Oregon: Oregon Department of Geology and Mineral Industries Miscellaneous Paper 14.

1972

Bowen, R.G., 1972, Geothermal gradient studies in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 34, no. 4, p. 68-71.

1973

Bowen, R.G., and Blackwell, D.D., 1973, Progress report on geothermal measurements in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 35, no. 1, p. 6-7.

1974

Bodvarsson, G., 1974, Telluric current exploration for geothermal anomalies in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 36, no. 4, p. 93-107.

Walker, G.W., 1974, Some implications of late Cenozoic volcanism to geothermal potential in the High Lava Plains of south-central Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 36, no. 7, p. 109-119.

1975

Bowen, R.G., 1975, The Cow Hollow geothermal anomaly: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 7, p. 109-121.

Bowen, R.G., 1975, Geothermal gradient data: Oregon Department of Geology and Mineral Industries Open-File Report O-75-3, 114 p.

Bowen, R.G., Blackwell, D.D., and Hull, D.A., 1975, Geothermal studies and exploration in Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-75-7, 66 p.

1975 Cont'd.

Hull, D.A., 1975, Geothermal gradient data, Vale area, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-75-4, 18 p.

1976

Bowen, R.G., Blackwell, D.D., Hull, D.A., and Peterson, N.V., 1976, Progress report on heat-flow study of the Brothers fault zone, central Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 38, no. 3, p. 39-45.

Hull, D.A., 1976, Electrical resistivity survey and evaluation of the Glass Buttes geothermal anomaly: Oregon Department of Geology and Mineral Industries Open-File Report 0-76-1, 11 p.

Hull, D.A., Bowen, R.G., Blackwell, D.D., and Peterson, N.V., 1976, Geothermal gradient data, Brothers fault zone, central Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-76-2, 24 p.

1977

Bowen, R.G., 1977, Geothermal exploration studies in Oregon: Oregon Department of Geology and Mineral Industries Miscellaneous Paper 19, 50 p.

Hull, D.A., 1977, Preliminary heat-flow map and evaluation of Oregon's geothermal energy potential: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 39, no. 7, p. 109-123.

Hull, D.A., Blackwell, D.D., Bowen, R.G., and Peterson, N.V., 1977, Heat flow study of the Brothers fault zone, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-77-3, 43 p.

Hull, D.A., Blackwell, D.D., Bowen, R.G., Peterson, N.V., and Black, G.L., 1977, Geothermal gradient data: Oregon Department of Geology and Mineral Industries Open-File Report 0-77-2, 134 p.

1978

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.

Bowen, R.G., Peterson, N.V., and Riccio, J.F., 1978, Low- to intermediate-temperature thermal springs and wells in Oregon: Oregon Department of Geology and Mineral Industries Geologic Map Series 10.

Hull, D.A., Blackwell, D.D., and Black, G.L., 1978, Geothermal gradient data: Oregon Department of Geology and Mineral Industries Open-File Report 0-78-4, 187 p.

1978 Con'd.

Oregon Department of Geology and Mineral Industries, 1978, Geophysical logs, Old Maid Flat No. 1, Clackamas County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-78-6.

1979

Riccio, J.F., 1979, Preliminary geothermal resource map of Oregon: Oregon Department of Geology and Mineral Industries Geologic Map Series 11.

Riccio, J.F., and Newton, V.C., Jr., 1979, Geothermal exploration in Oregon in 1978: Oregon Department of Geology and Mineral Industries, Oregonnn Geology, v. 41, no. 3, p. 39-46.

U.S. Geological Survey and Oregon Department of Geology and Mineral Industries, 1979, Chemical analyses of thermal springs and wells in Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-79-3, 170 p.

Riccio, J.F., 1979, Editor, Geothermal resource assessment of Mount Hood: Oregon Department of Geology and Mineral Industries Open File Report 0-79-8.

B U D G E T

PROJECT BUDGET SUMMARY

		DOE	DOGAMI
Personnel (including OPE)			
Geologist IV	12 mo. @ 0.5 FTE		$ 20,450
Geologist III	12 mo. @ 1.0 FTE	$ 27,265	
Geologist III	3 mo. @ 1.0 FTE	8,730	
Geologist II	12 mo. @ 1.0 FTE	23,855	
Geologist I	24 mo. @ 1.0 FTE	37,490	
Cartographer II	6 mo. @ 1.0 FTE	10,225	
Editor	3 mo. @ 1.0 FTE	6,390	
Travel			
500 days @ $30/day		15,000	
Transportation -	40,000 @ 7¢/mi., and 5 pickups @ $132/mo.	10,000	
Services and Supplies			
Direct material, maps, sample bags, thin sections, photos		10,000	
Drilling (Temperature-gradient)		170,000	
Water chemistry		805	
Printing		23,000	
TOTAL DIRECT COSTS		$342,760	$20,450
INDIRECT COSTS		57,240	
TOTAL		$400,000	$20,450

PROJECT TOTAL $420,450

BUDGET MATRIX - DOE FUNDING

	Task 1 Data Compilation	Task 2 Geological Mapping	Task 3 Temperature Gradient	Task 4 Geochemistry	Task 5 Publication	Total
Geologist III		$27,265				$ 27,265
Geologist III		8,730				8,730
Geologist II			$ 23,855			23,855
Geologist I	$ 9,373	9,373	9,372	$ 9,372		37,490
Cartographer II					$10,225	10,225
Editor					6,390	6,390
Travel		10,000	15,000			25,000
Direct Material	1,000	1,000	4,000	3,000	1,000	10,000
Drilling			170,000			170,000
Water Chemistry				805		805
Printing					23,000	23,000
Indirect Costs	1,733	9,413	37,111	2,201	6,782	57,240
TOTAL	$12,106	$65,781	$259,338	$15,378	$47,397	$400,000

GEOLOGY AND MINERAL INDUSTRIES

OVERHEAD

PERSONNEL

Z6320 Director 60,360
Z3064 Deputy Director 53,424
Z0010 Administrative Assis. 28,272
Z0051 Business Manager 39,816
C0101 Accounting Clerk 19,368
C3006 STD SCNTFC-TECH TR. (80%) 7,747

210,924

OPE 20.3% 42,817

Total Personnel 251,391

SERVICE AND SUPPLIES (PROGRAM 1 BB)

(1) Instate and Reg. Travel 16,809
(2) Out-of-State Travel 3,363
(3) Office Expenses
a) Phone (6 of 17 phones) (excluding proj.) 4,200
b) Shuttle Mail 5,016
c) Central Stores 1,944
d) Copier 3,936
(4) Fiscal Control 12,664
(8) Attorney General 1,388
(9) Insurance 1,961
(11) Housing and Grounds (670 x 62 x 24) 9,970

Total Services and Supplies 61,272

Total Overhead 312,603

Total Budget, Minus Overhead 1,867,625

Overhead Rate 16.7%

GEOLOGY AND MINERAL INDUSTRIES

OPE

Indirect Overhead OPE		15%
sick leave		
vacation		
other		
Direct Overhead OPE		27%
FICA	6.1	
FERS	16.2	
Other	4.7	
Health Ins.		
Life Ins.		
Dental Ins.		
SAIF		
ERB		
Misc		
TOTAL		42%

THE UNIVERSITY OF UTAH

DEPARTMENT OF GEOLOGY AND GEOPHYSICS
COLLEGE OF MINES AND MINERAL INDUSTRIES
717 MINERAL SCIENCE BLDG.
SALT LAKE CITY, UTAH 84112

August 28, 1980

MEMORANDUM

To: Bob Blackett

From: Stan Evans

Here are three dates that were done for Craig White of the Oregon team. Please forward them on to him.

Sincerely,

Stan

SE/li

enclosure

Sample No.	Unit	Material Dated	Weight (gms).	%K	Moles/gm Ar^{40}_{Rad} ($X10^{11}$)	$\%Ar^{40}_{atm}$	Age (M.Y.)
CT-8	-	Whole Rock	2.08904	1.291	5.756	22.3	25.5±0.8
CT-62	-	Whole Rock	2.81221	1.063	0.293	89.4	1.59±0.21
CT-64	-	Whole Rock	3.00691	0.897	1.533	66.3	9.83±0.46

Constants Used:

$\lambda_{\beta} = 4.962 \times 10^{-10}$/yr.

$\lambda_{\varepsilon} = 0.581 \times 10^{-10}$/yr.

$K^{40}/K_{Tot.} = 1.167 \times 10^{-4}$ Mole/Mole

Bob

UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

EARTH SCIENCE LABORATORY
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108
TELEPHONE 801-581-5283

August 28, 1980

Mr. Dave Brown
Oregon Dept. of Geology
and Mineral Industries
1069 State Office Building
Portland, Oregon 97201

Dear Dave,

Enclosed is a tabulation of data pertaining to K-Ar age dates of certain rock samples from your geothermal program. Stan Evans has indicated that one of the dates is a provisional date, as shown, arrived at from newly installed equipment. Although he intends to perform 10 to 20 more extractions on the sample, any error should be only ±1 or 2%.

If you have any questions, please call.

Sincerely,

Bob

Robert E. Blackett
Geologist

REB:ls

Enclosure

Sample No.	Unit	Material Dated	Weight (gms).	%K	Moles/gm Ar^{40}_{Rad} ($X10^{11}$)	$\%Ar^{40}_{atm}$	Age (M.Y.)
* SH-4	Jackass Butte	Plagioclase	5.01785	0.43	1.247	32.2	16.7 ± 0.6
SH-12	?	Whole Rock	3.53915	0.265	0.134	89.5	2.91 ± 0.38

* Provisionary date - extraction done on newly calibrated line.

Constants Used:

$\lambda_\beta = 4.962 \times 10^{-10}/yr.$

$\lambda_\varepsilon = 0.581 \times 10^{-10}/yr.$

$K^{40}/K_{Tot.} = 1.167 \times 10^{-4}$ Mole/Mole

VICTOR ATIYEH
GOVERNOR

Department of Geology and Mineral Industries
ADMINISTRATIVE OFFICE
1069 STATE OFFICE BLDG., PORTLAND, OREGON 97201 PHONE (503) 229-5580

May 21, 1980

Duncan Foley
Earth Science Lab
University of Utah
Research Institute
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

Dear Duncan:

Sar - 15-16 m.y. - if my dim memory serves right. D.

Enclosed are three samples of Miocene Western Cascade rocks. These were collected in the Cougar Reservoir area near McKenzie Bridge, Oregon. K-Ar data on these samples should help to define the age of the top and bottom of the "Sardine Series" in this area and the age of a major N-S fault which appears to be associated with the hot springs systems.

Thin sections and xeroxed copies of petrographic descriptions are enclosed. Sample numbers and locations are as follows:

Sample #	Rock Type	Location
Cougar Dam East	basaltic andesite	N 44° 7' 43", W 122° 14' 18"
RI - ~~[illegible]~~ 112	basaltic andesite	N 44° 6' 30", W 122° 16' 58"
RI - 85	hornblende-bearing dacite ash flow	N 44° 7' 40", W 122° 16' 15"

If you have any questions about these samples, please do not hesitate to call myself or Joe Riccio.

Sincerely,

George R. Priest

George R. Priest

Encl.

GRP/bh

VICTOR ATIYEH
GOVERNOR

Department of Geology and Mineral Industries
ADMINISTRATIVE OFFICE
1069 STATE OFFICE BLDG., PORTLAND, OREGON 97201 PHONE (503) 229-5580

May 21, 1980

Duncan Foley
Earth Science Lab
University of Utah
Research Institute
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

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Sincerely,

George R. Priest

George R. Priest

Encl.

GRP/bh

THE
UNIVERSITY
OF UTAH

DEPARTMENT OF GEOLOGY
AND GEOPHYSICS
COLLEGE OF MINES AND
MINERAL INDUSTRIES
717 MINERAL SCIENCE BLDG.
SALT LAKE CITY, UTAH 84112

June 3, 1980

MEMO

To: Duncan Foley

From: Stan Evans

Dear Duncan:

Here are six dates for the Oregon people. Samples OM-5, 49, 520 and BF-5 were submitted by Dave Brown, samples Bullard 1 and 2 were submitted by Joe Riccio. I am now indicating more significant figures for %K and argon numbers. This is done only to allow the dates given to be calculated from the K and argon numbers in the table. Really all I am showing is the number of significant figures I'm carrying thru my age calculations.

Sincerely,

Stan Evans

Stan Evans

jcm

Sample No.	Unit	Material Dated	Weight (gms).	%K	Moles/gm Ar^{40}_{Rad} ($X10^{11}$)	$\%Ar^{40}_{atm}$	Age (M.Y.)
OM-5	-	Plagioclase	5.03912	0.340	1.2644	65.6	21.3 ± 1.0
OM-49	Basalt	Whole Rock	3.07859	0.755	2.2824	53.1	17.3 ± 0.7
OM-520	-	Plagioclase	5.00452	0.511	1.6673	66.7	18.7 ± 0.9
BF-5	Basalt	Whole Rock	3.05013	0.755	1.2232	66.4	9.31 ± 0.44
Bullard-1	-	Whole Rock	0.74802	3.362	14.448	28.5	24.6 ± 0.8
Bullard-2	-	Plagioclase	4.27471	0.515	2.4485	36.9	27.2 ± 0.9

Constants Used:

$\lambda_{\beta} = 4.962 \times 10^{-10}$/yr.

$\lambda_{\varepsilon} = 0.581 \times 10^{-10}$/yr.

$K^{40}/K_{Tot.} = 1.167 \times 10^{-4}$ Mole/Mole

UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

EARTH SCIENCE LABORATORY
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108
TELEPHONE 801-581-5283

June 9, 1980

Mr. Dave Brown
Oregon Dept. of Geology and
Mineral Industries
1069 State Office Bldg.
Portland, OR 97201

Dear Dave;

Please find enclosed, a copy of a memo and attached information pertaining to rock samples that were submitted by yourself and Mr. Joe Riccio for age dating.

Should you have any questions concerning these data, please call.

Sincerely,

Robert E. Blackett

Robert E. Blackett
Geologist

REB/hb

enclosures

THE
UNIVERSITY
OF UTAH

DEPARTMENT OF GEOLOGY
AND GEOPHYSICS
COLLEGE OF MINES AND
MINERAL INDUSTRIES
717 MINERAL SCIENCE BLDG.
SALT LAKE CITY, UTAH 84112

June 3, 1980

MEMO

To: Duncan Foley

From: Stan Evans

Dear Duncan:

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Sincerely,

Stan Evans

Stan Evans

jcm

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BF-5	Basalt	Whole Rock	3.05013	0.755	1.2232	66.4	9.31 ± 0.44
Bullard-1	-	Whole Rock	0.74802	3.362	14.448	28.5	24.6 ± 0.8
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$K^{40}/K_{Tot.} = 1.167 \times 10^{-4}$ Mole/Mole

VICTOR ATIYEH
GOVERNOR

Department of Geology and Mineral Industries
ADMINISTRATIVE OFFICE
1069 STATE OFFICE BLDG., PORTLAND, OREGON 97201 PHONE (503) 229-5580

June 26, 1980

Dr. Duncan Foley
Earth Science Laboratory
University of Utah Research Institute
420 Chipeta Way, Suite 120
Salt Lake City, Utah 94108

Dear Duncan:

Enclosed are four samples from the Alvord Desert that I would like dated. Sampling data are as follows:

AD-3 NW¼ NW¼ sec. 18, T. 34 S., R. 34 E.

AD-4 SW¼ SW¼ sec. 7, T. 37 S., R. 34 E.

AD-5 NW¼ NE¼ sec. 29, T. 36 S., R. 33 E.

AD-5 NW¼ NW¼ sec. 20, T. 37 S., R. 34 E.

Thin sections for this material will be forwarded in the immediate future.

If you have any questions concerning these samples please call me. How are our other age dates coming along?

Sincerely,

Joe

Joseph F. Riccio
Geothermal Programs Manager

JFR:lk
Encl.

Duncan

Department of Geology and Mineral Industries

ADMINISTRATIVE OFFICE

1069 STATE OFFICE BLDG., PORTLAND, OREGON 97201 PHONE (503) 229-5580

May 21, 1980

Duncan Foley
Earth Science Lab
University of Utah
Research Institute
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

Dear Duncan:

Stan - 15-16 my - if my dim memory serves right? D.

Enclosed are three samples of Miocene Western Cascade rocks. These were collected in the Cougar Reservoir area near McKenzie Bridge, Oregon. K-Ar data on these samples should help to define the age of the top and bottom of the "Sardine Series" in this area and the age of a major N-S fault which appears to be associated with the hot springs systems.

Thin sections and xeroxed copies of petrographic descriptions are enclosed. Sample numbers and locations are as follows:

Sample #	Rock Type	Location
Cougar Dam East	basaltic andesite	N 44° 7' 43", W 122° 14' 18"
RI - ~~48~~ 112	basaltic andesite	N 44° 6' 30", W 122° 16' 58"
RI - 85	hornblende-bearing dacite ash flow	N 44° 7' 40", W 122° 16' 15"

If you have any questions about these samples, please do not hesitate to call myself or Joe Riccio.

Sincerely,

George R. Priest

George R. Priest

Encl.

GRP/bh

Duncan

Department of Geology and Mineral Industries
ADMINISTRATIVE OFFICE
1069 STATE OFFICE BLDG., PORTLAND, OREGON 97201 PHONE (503) 229-5580

VICTOR ATIYEH
GOVERNOR

May 21, 1980

Duncan Foley
Earth Science Lab
University of Utah
Research Institute
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

Dear Duncan:

Enclosed are three samples of Miocene Western Cascade rocks. These were collected in the Cougar Reservoir area near McKenzie Bridge, Oregon. K-Ar data on these samples should help to define the age of the top and bottom of the "Sardine Series" in this area and the age of a major N-S fault which appears to be associated with the hot springs systems.

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If you have any questions about these samples, please do not hesitate to call myself or Joe Riccio.

Sincerely,

George R. Priest

George R. Priest

Encl.

GRP/bh

CRAIG WHITE
2306 COWLS CT.
McMINNVILLE, OR 97128

March 31, 1980

Dear Duncan,

Here are three more samples for K/Ar dating. They are all from the Cascades and have possible age ranges as follows:

CT-8	Basaltic flow	20 to 30 m.y.
CT-62	Basaltic flow	2 to 7 m.y.
CT-64	Dioritic dike	5 to 15 m.y.

Sample CT-8 is from the same unit as a previous sample I sent you that Stan Evans rejected because of high glass and carbonate content. I think this one is better, but, because it is the oldest unit in the area, it is difficult to get clean samples. I would like him to try to get what he can out of this rock as I have no other dates for this unit.

Thanks very much.

Best wishes,

CRAIG

1306

UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

EARTH SCIENCE LABORATORY
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108
TELEPHONE 801-581-5283

September 4, 1980

Mr. Craig White
2306 Cowls CT.
McMinnville, Oregon 97128

Dear Mr. White,

Enclosed is a list of age dates for rock samples submitted to us on March 31, 1980.

If you should have any questions concerning these data, please call.

Sincerely,

Robert E. Blackett

Robert E. Blackett
Geologist

RB/cw
encls

Sample No.	Unit	Material Dated	Weight (gms).	%K	Moles/gm Ar^{40}_{Rad} ($X10^{11}$)	$\%Ar^{40}_{atm}$	Age (M.Y.)
CT-8	-	Whole Rock	2.08904	1.291	5.756	22.3	25.5±0.8
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Constants Used:

$\lambda_{\beta} = 4.962 \times 10^{-10}$/yr.

$\lambda_{\varepsilon} = 0.581 \times 10^{-10}$/yr.

$K^{40}/K_{Tot.} = 1.167 \times 10^{-4}$ Mole/Mole

Sample No.	Unit	Material Dated	Weight (gms).	%K	Moles/gm Ar^{40}_{Rad} (X10^{11})	$\%Ar^{40}_{atm}$	Age (M.Y.)
Cougar Dam East	-	Plagioclase	6.01058	0.237	0.674	86.9	16.3±1.8
RI-112	-	Plagioclase	6.33873	0.208	0.417	64.7	11.5±0.5 *
RI-85	-	Plagioclase	2.91937	0.349	0.844	74.5	13.9±0.8 *
Foley Ridge	-	Whole Rock	2.53109	0.548	0.195	94.6	2.05±0.52
Tmw-Top	-	Whole Rock	3.01778	1.121	1.739	38.9	8.93±0.34 *
Tpb	-	Whole Rock	3.01174	0.365	0.533	61.1	8.39±0.36
STACK	-	Whole Rock	3.00758	0.540	2.090	64.7	22.2±1.0

* Provisionary dates - done on new extraction line, subject to later revision.

Constants Used:

$\lambda_\beta = 4.962 \times 10^{-10}$/yr.

$\lambda_\varepsilon = 0.581 \times 10^{-10}$/yr.

$K^{40}/K_{Tot.} = 1.167 \times 10^{-4}$ Mole/Mole

UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

EARTH SCIENCE LABORATORY
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108
TELEPHONE 801-581-5283

December 3, 1980

Mr. George Priest
Department of Geology and
Mineral Industries
1069 State Office Building
Portland, Oregon 97201

Dear Mr. Priest:

Enclosed is a table of analyses recently completed for certain rock samples from the Oregon State Coupled Program. The analyses and age determinations were done by Stan Evans at the Department of Geology and Geophysics, University of Utah.

If you have any questions, please call.

Sincerely,

Robert E. Blackett

Robert E. Blackett
Geologist

REB:gm

enclosure

Sample No.	Unit	Material Dated	Weight (gms).	%K	Moles/gm Ar^{40}_{Rad} ($X10^{11}$)	$\%Ar^{40}_{atm}$	Age (M.Y.)
Cougar Dam East	-	Plagioclase	6.01058	0.237	0.674	86.9	16.3±1.8
RI-112	-	Plagioclase	6.33873	0.208	0.417	64.7	11.5±0.5 *
RI-85	-	Plagioclase	2.91937	0.349	0.844	74.5	13.9±0.8 *
Foley Ridge	-	Whole Rock	2.53109	0.548	0.195	94.6	2.05±0.52
Tmw-Top	-	Whole Rock	3.01778	1.121	1.739	38.9	8.93±0.34 *
Tpb	-	Whole Rock	3.01174	0.365	0.533	61.1	8.39±0.36
STACK	-	Whole Rock	3.00758	0.540	2.090	64.7	22.2±1.0

* Provisionary dates - done on new extraction line, subject to later revision.

Constants Used:

$\lambda_\beta = 4.962 \times 10^{-10}$/yr.

$\lambda_\varepsilon = 0.581 \times 10^{-10}$/yr.

$K^{40}/K_{Tot.} = 1.167 \times 10^{-4}$ Mole/Mole

RESEARCH PROPOSAL

SUBMITTED TO DIVISION OF GEOTHERMAL ENERGY

U. S. DEPARTMENT OF ENERGY

Title

LOW TEMPERATURE GEOTHERMAL RESOURCE ASSESSMENT, PHASE III

By

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
1069 State Office Building
Portland, Oregon 97201

Amount requested: $300,000

	DOE	DOGAMI	TOTAL
Fiscal 1981	$300,000	$12.230	$312,230

Starting date: April 1, 1981 through April 1, 1982

E N D O R S E M E N T S

Principal Investigator

George R. Priest ____ 2/6/81

George R. Priest ____ Date

Approving Administrative Official

John D. Beaulieu ____ 2/6/81

Donald A. Hull, State Geologist ____ Date

INTRODUCTION

During Phase I of the Western States Cooperative Direct-Use Geothermal Program (Contract No. EG-77-C-06-1040) available data on low temperature ($20^{o}C$ - $90^{o}C$) geothermal resources were collected in Oregon. Based on review of these data, nine low-temperature resource areas were identified (Fig. 1). During the Mt. Hood Geothermal Resource Assessment project (1978), Contract No. AC06-77-ET-28369, three other low-temperature resource areas were identified: Parkdale, northeasterly of Mt. Hood, Powell Buttes, northeast of Bend, and the Corbett-Camp Collins area, 9.6 km (6.0 mi) east of Portland (Fig. 1).

Phase II of the direct-heat geothermal program primarily entailed the selection of specific sites, based on Phase I data, within the nine resource areas for detailed evaluation. Geological-geophysical investigations of the specific sites were conducted in order to select drill test locations. Sites were drilled on a priority basis for reservoir confirmation and assessment. Results, including maps and reports, were published by DOGAMI on an open-file basis and made available to the geothermal community, governmental agencies, and the public. Development of direct-use geothermal resources will have a significant near-term impact by fulfilling, in part, the energy requirements of Oregon and the United States.

This proposal describes the studies necessary to continue and complete most aspects of the Phase II program, and to consolidate and synthesize available data with the view of developing a coherent interim statement of, the geothermal potential of the State of Oregon. Summary costs by task are provided in the Budget Section of this proposal.

Not contemplated in this proposal is intermediate to deep geothermal drilling for final confirmation and assessment of promising geothermal

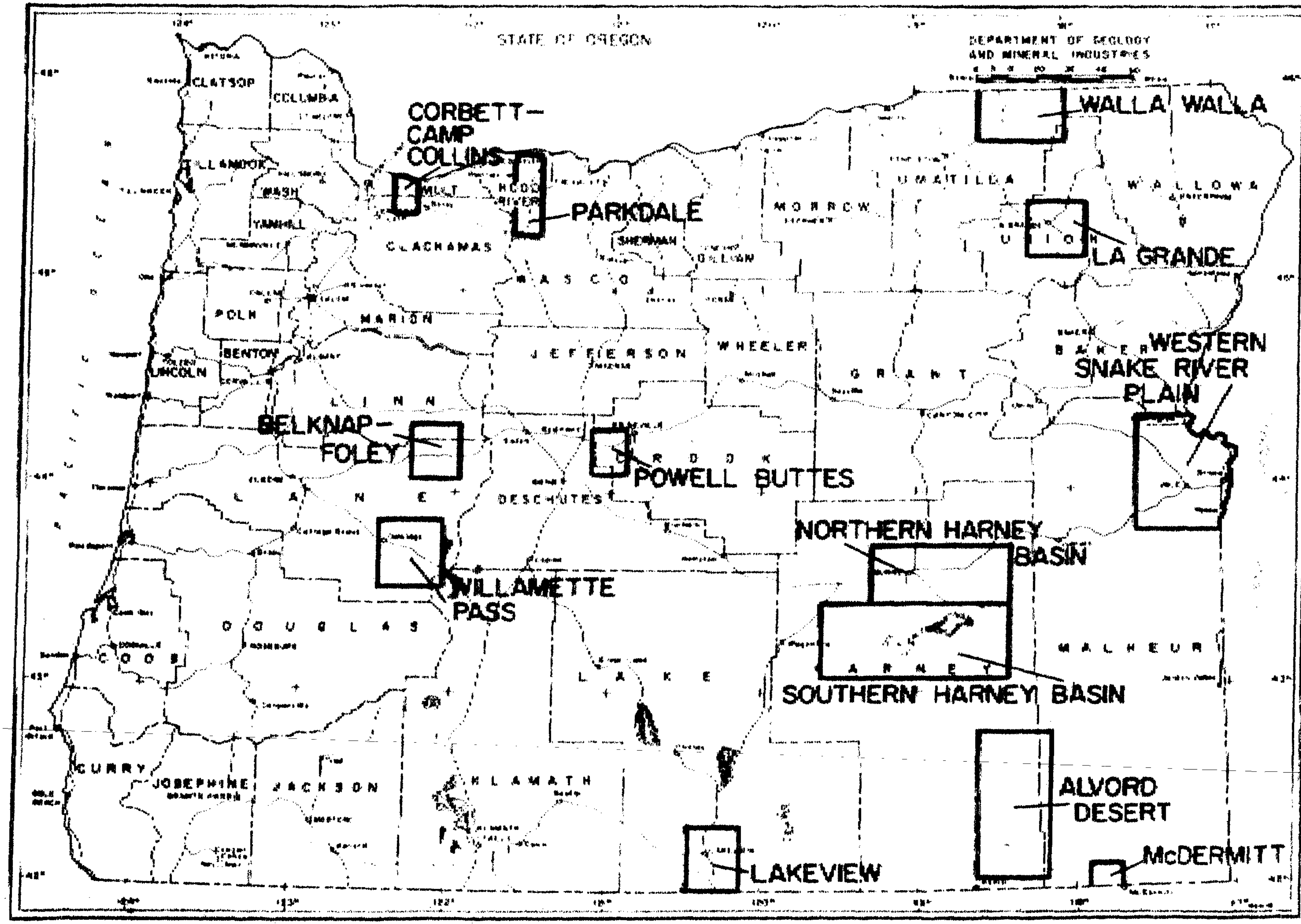


Figure 1: Map showing location of study area.

targets such as the Lakeview area. As these areas are identified, they will continue to be brought to the attention of DOE.

The thrust of the current proposal is to emphasize low cost data and sample collection statewide and to formulate an up-to-date revised geothermal assessment for the State of Oregon which includes a measure of the resource constrained by geologic parameters and a set of conceptual geothermal models to priority systems in the state. Phase III, this study, draws upon the regional data developed in previous studies, integrates the earlier Cooperative and Western Cascades efforts into one coherent study, and focuses attention on discrete resource areas in Oregon.

ASSESSMENT PLAN

Task 11 - Geologic Map Refinement

Tasks 1-10 have been undertaken under previous phases of this study program.

Geologic maps, at an appropriate scale, will be refined for the Northern Harney Basin, Parkdale, Western Snake River Plain, and, if time permits, the Lakeview area (Fig. 1). The maps will depict all known major structures or trends as well as surface geothermal manifestations. Cross-sections based on available geologic data will be drawn through the resource areas.

Besides black and white, color and color IR photos, air-photo studies will involve the interpretation of SLAR, LANDSAT (ERTS), and NASA U-2 as available. Ground-truth verification will resolve ambiguous interpretations and will complement the conceptual synthesis work defined in Task 15. Geophysical profiles perpendicular to structure may be used to better define faulting beneath alluvium in basins, if detailed geological work and existing geophysical data are not definitive.

Task 12 - Statewide Reconnaissance

Effort to acquire additional information on the location, temperature, water samples, flow data, and chemistry of thermal springs and wells of the State of Oregon will be enhanced in this study and will include emphasis on the south-central Cascades, Basin and Range province, structural basins of the Columbia Plateau and the Portland-Clackamas River area. These data will be included in existing DOGAMI and GEOTHERM data base files and updates of the geothermal map base of Oregon.

Task 13 - Assessment of the Corbett-Camp Collins Area

Initial assessment of the Corbett-Camp Collins area near Portland will be pursued by detailed temperature gradient measurement and water analysis of all existing springs and wells and drilling of shallow (152 m) temperature gradient wells. In addition, reconnaissance geologic mapping and lineament analysis will be completed. All data will be included in existing DOGAMI and GEOTHERM data base files and updates of the geothermal map base of Oregon.

Task 14 - Summary Assessment of Geothermal Resources

Geothermal models will be developed from the data, and specific development steps will be recommended for each study area. The product of this task will be detailed assessment reports incorporating all relevant data for priority areas that have high potential. A general summary report covering all areas studied will also be completed. These reports will guide statewide resource assessment and will provide a basis for evaluating or planning exploration ventures by either government or the private sector.

Task 15 - Publication

The deliverables of this effort include the following:

Task 11 - Various in-house geologic map revisions

Task 12 - Spring and well data in GEOTHERM

Task 13 - Assessment of the Corbett-Camp Collins area

Task 14 - Summary Assessment reports

Publications contemplated in this investigation include:

Report of geothermal gradient data

Special Papers on high priority resource areas

Special Paper summarizing the geothermal resource potential of all of the study areas

Geologic maps of priority areas

BUDGET SUMMARY

Personnel		
Geologist III ($3207 x 10 x 1.0 FTE x 1.08)	$34,634	
Geologist III ($3207 x 10 x 1.0 FTE x 1.08)	34,634	
Geologist II ($2775 x 10 x 1.0 FTE x 1.08)	29,968	
Geologist II ($2775 x 10 x 1.0 FTE x 1.08)	29,968	
Cartographer ($2281 x 10 x 0.5 FTE x 1.08)	12,317	
Chemist ($2910 x 1.0 x 1.0 FTE x 1.08)	3,143	
Editor ($2775 x 10 x 0.5 FTE x 1.08)	14,984	
Subtotal		$159,648
Services and Supplies		
Travel		
400 days @ 39.45/day per diem	5,780	
40,000 mi @ 12¢/mi	4,800	
400 days @ 9.50/day for vehicle	3,800	
Idaho Falls or Salt Lake and return (4 trips)	2,200	
K-Ar dates, thin sections, chemical analyses	5,000	
Direct supplies (maps, negatives, photos, reagents, etc.)	5,842 $42?	
Printing	20,000	
Subtotal		$ 57,422
Subcontracts		
Geophysical profiles	10,000	
Drilling	30,000	
Subtotal		$ 40,000
Subtotal		$257,070
Indirect costs @ 16.7%		42,930
TOTAL		$300,000

BUDGET MATRIX - DOE FUNDING

	Task 11 Map Refinement	Task 12 Statewide Recon.	Task 13 Corbett Drilling	Task 14 Summary Assessment	Task 15 Printing & Report Prep.	Total
Personnel						
Geologist III	$17,317	-	-	$17,317	-	$ 34,634
Geologist III	-	-	$17,317	17,317	-	34,634
Geologist II	-	$29,968	-	-	-	29,968
Geologist I	15,000	14,968	-	-	-	29,968
Cartographer	-	-	-	-	$12,317	12,317
Chemist	-	3,143	-	-	-	3,143
Editor	-	-	-	-	14,984	14,984
Services and Supplies						
Travel	11,790	11,790	2,000	1,000	-	26,580
Age dates, etc.	5,000	-	-	-	-	5,000
Supplies	1,000	2,842	1,000	-	1,000	5,842
Printing	-	-	-	-	20,000	20,000
Subcontracts						
Gravity profiles	10,000	-	-	-	-	10,000
Drilling	-	-	30,000	-	-	30,000
Subtotal	$60,107	$62,711	$50,317	$35,634	$48,301	$257,070
Indirect Costs	10,038	10,472	8,403	5,951	8,066	42,930
TOTAL	$70,145	$73,183	$58,720	$41,585	$56,367	$300,000

GEOLOGY AND MINERAL INDUSTRIES

OVERHEAD

PERSONNEL

26320 Director	60,360	
23064 Deputy Director	53,424	
20010 Administrative Assis.	28,272	
20051 Business Manager	39,816	
00101 Accounting Clerk	19,568	
03006 STD [illegible] (.[illegible])	7,747	
		210,924
OPE 20.3%		42,817
Total Personnel		251,391

SERVICE AND SUPPLIES (PROGRAM [illegible])

(1) Instate and Leg. Travel	16,809	
(2) Out-of-State Travel	5,365	
(3) Office Expenses		
a) Phone (6 of 17 phones) (excluding proj.)	4,[illegible]	
b) Shuttle [illegible]	5,[illegible]	
c) Central Stores	1,944	
d) Copier	3,936	
(4) Fiscal Control	12,664	
(8) Attorney General	1,386	
(9) Insurance	1,961	
(11) Housing and Grounds (67[illegible])	5,570	
Total Services and Supplies		61,272
Total Overhead		312,603
Total Budget, Minus Overhead		1,367,625
Overhead Rate		16.7%

GEOLOGY AND MINERAL INDUSTRIES

OPE

Indirect Overhead OPE			15%
sick leave			
vacation			
other			
Direct Overhead OPE			27%
FICA		6.1	
PERS		16.2	
Other		4.7	
	Health Ins.		
	Life Ins.		
	Dental Ins.		
	SAIF		
	ERB		
	Misc		
		TOTAL	42%

S.M.U.

Introduction

This budget includes time for technicians during data-generation at S.M.U., as well as time for Dave Blackwell and his assistants to train our personnel in the use of new equipment this summer. In addition, time is included for Dave Blackwell to write heat-flow reports for specific sites and regions.

Budget

Personnel:

WORK AT S.M.U.		
Dave Blackwell (0.1 F.T.E. for 9 mo).	4,410	
John Steel (0.45 F.T.E. for 10 mo).	8,757	
Bob Spafford (0.375 F.T.E. for 12 mo)	7,425	
Secretary (0.375 F.T.E. for 12 mo).	3,458	
Laboratory Technician (0.5 F.T.E. for 9 mo)	4,500	
SUBTOTAL	28,550	
Benefits (10%)	2,855	
FIELD WORK IN OREGON		
Dave Blackwell (1.0 F.T.E. for 1 mo).	4,666	
John Steel (1.0 F.T.E. for 1 mo).	3,892	
Field Assistant (1.0 F.T.E. for 2 mo)	1,900	
SUBTOTAL	10,458	
Benefits (10%)	1,046	
TOTAL SALARIES & BENEFITS		42,909
Travel & Per Diem.		11,350
Supplies (50% on-campus, 50% off-campus)		4,000
Computer time.		6,000
Overhead - on-campus work (40%).		15,762
Overhead - off-campus work (23.4%)		5,816
TOTAL		$85,837

STATE OF OREGON
1859
VICTOR ATIYEH
GOVERNOR

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

May 25, 1982

Susan Prestwitch
U.S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

Dear Susan:

Enclosed is a grant proposal for publication of several unpublished data sets developed under U.S.D.O.E. cooperative agreements over the last few years. Most of this data has been made available only in open-files of the raw data sets without any adequate interpretation. This grant would allow high-quality interpretive reports to be published.

It is particularly crucial that funds be made available for data generated during the 1982 field season. If no time and funds are made available, even preparation of crude open-file reports will not be possible, since the current Cooperative Agreement No. DE-FC07-79ID12044 ends September 30, 1982 and no provision is made for publication of these reports in the final task description (Task 11, Amendment No. A007).

7/21

Dunc:
Have a look at the attached when you have a chance.
Your reaction?
Vitto

Sincerely,

George R. Priest

George R. Priest
Geothermal Specialist

7/15/82 Review with D. Foley.
Question: Should more money be provided to cover what should have been published as part of existing contracts? This proposal asking for $167,254 - Holy Cow! - My gut reaction was "horse feathers".
[illegible]

RESEARCH PROPOSAL

SUBMITTED TO THE UNITED STATES DEPARTMENT OF ENERGY

Title

SUMMARY PUBLICATION OF GEOTHERMAL RESEARCH IN OREGON

By

State of Oregon
Department of Geology and Mineral Industries
1005 State Office Building
Portland, Oregon 97201
(503) 229-5580

Time Period

October 1, 1982 through October 31, 1983

Amount Requested

$ 167,254.44

ENDORSEMENTS

Donald A. Hull
Donald A. Hull
State Geologist

6/1/82
Date

George R. Priest
George R. Priest
Principal Investigator

5-25-82
Date

CONTENTS

SUMMARY PUBLICATION OF GEOTHERMAL RESEARCH IN OREGON

ABSTRACT

In order to realize the full benefit of geothermal research conducted with the support of U. S. Department of Energy over the last several years, the Department has resolved to publish final summary reports on the highest quality unpublished data sets in Oregon. The end result will be special papers on the regional heat flow of Oregon, the geothermal resources of Ashland, Oregon, the geothermal resources of Eastern Oregon, and the geology and geothermal resources of the Eugene-Denio lineament in the Cascades of Oregon. The estimated total cost for the project is $167,254.44. Thirteen months will be required for completion, beginning October 1, 1982 and ending October 31, 1983.

INTRODUCTION

The Oregon Department of Geology and Mineral Industries (DOGAMI) has, for the last 15 years, conducted extensive geologic and geophysical research aimed at defining the geothermal resources of Oregon. For the last five years this research was part of a United States Department of Energy (USDOE) program of geothermal resource assessment.

The USDOE program consisted of two cooperative agreements entitled "Geothermal Resource Assessment of the Western and Central Cascades" (No. DE-FC07-79ID12044) and "Low Temperature Geothermal Resource Assessment - Phase II" (No. DE-FC07-79FT27220).

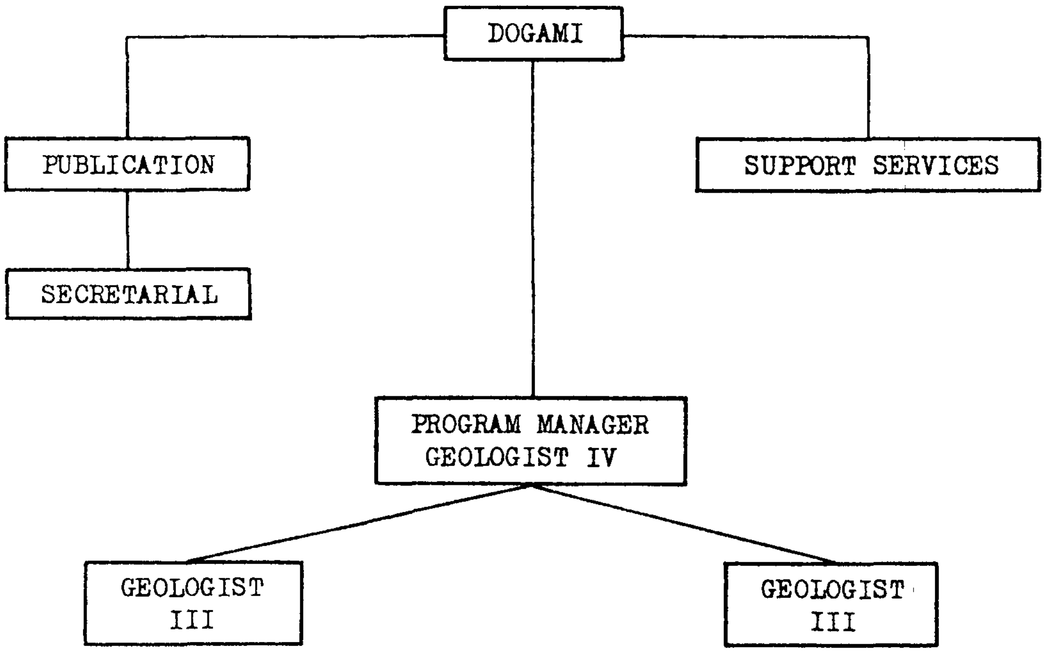
The USDOE program originally required publications which would have summarized the five-year effort. Owing to various factors, no funding for these summary publications became available. The result is a large body of data on both low and possible high-temperature geothermal resources which has never been summarized in high-quality, interpretive publications.

Specific high-quality data sets for which no funds are available for published summary reports include:

1. The Ashland (Figure 1) geothermal drilling project (in progress).
2. Geologic mapping and geothermal gradient drilling in the Eugene-Denio lineament (Figure 1) in the Cascades (to be completed during the summer of 1982).
3. Drilling and geologic mapping of low-temperature geothermal resource areas (Figure 1) of Eastern Oregon (completed).
4. Regional heat flow in Oregon from data sets developed since 1978 (publication date of the last heat flow summery).

This proposal would allow preparation of summary reports covering these data sets.

ORGANIZATION CHART



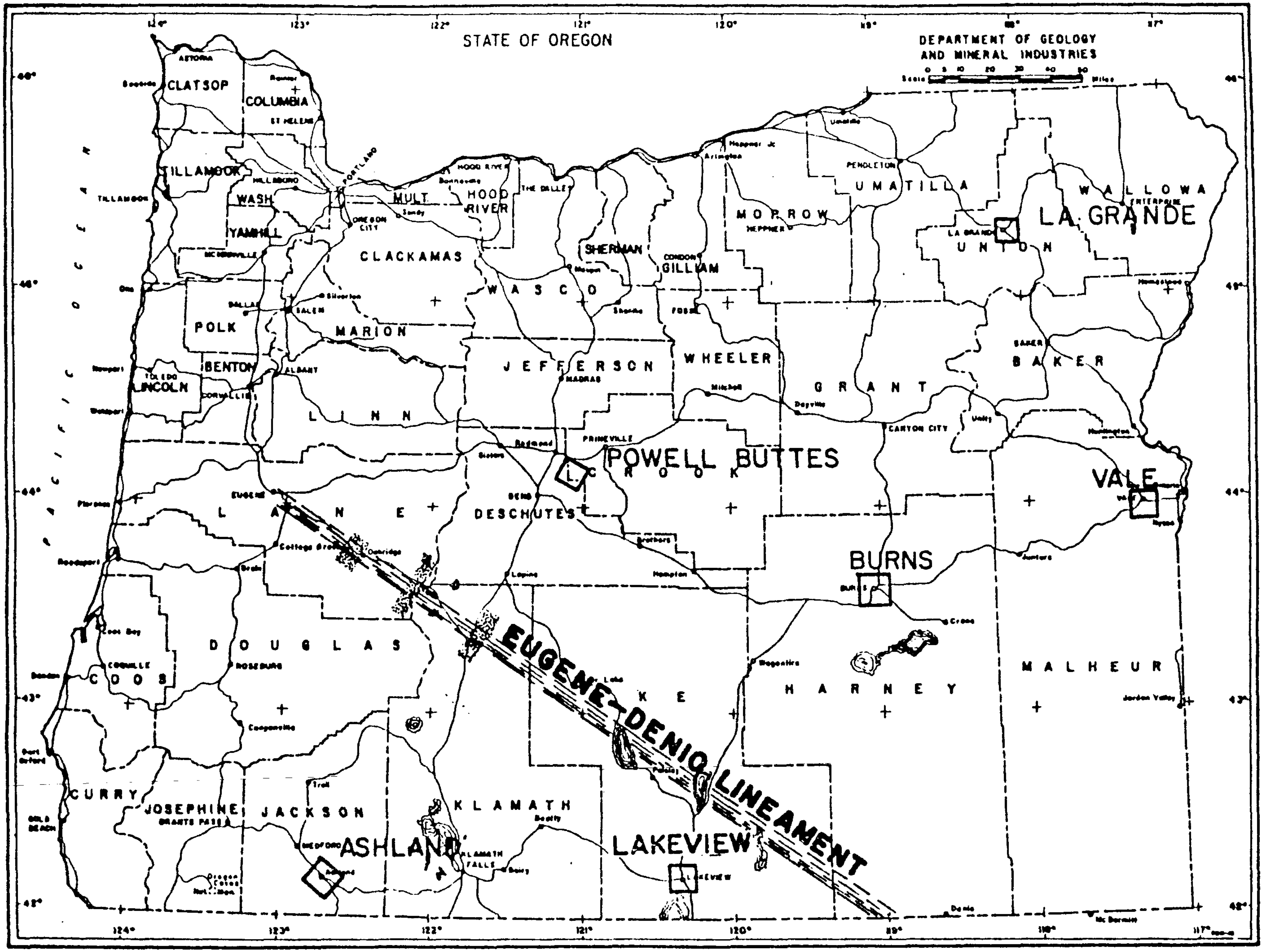


Figure 1. Location map showing major study areas with data sets in need of final publication. Shaded boxes are areas of detailed geologic mapping which will be summarized in the Eugene-Denio study.

SUMMARY PUBLICATION

Objective

The objective of this project will be to make available to the public the Department's final conclusions regarding the quality and best methods of exploitation of recently investigated geothermal resource areas. The ultimate result will be an increase in both the amount and success of geothermal exploration and development in Oregon.

Work Plan

Existing geologic mapping and temperature gradient information will be used to develop geothermal system models for the following areas (see Figure I for locations):

1. Ashland
2. The Eugene-Denio lineament in the Cascades.
3. Eastern Oregon geothermal resource areas with emphasis on Powell Buttes, Burns, La Grande, Vale, and Lakeview.

Data from these areas and new temperature gradient data from ongoing statewide scrounge will be summarized in an updated special paper on regional heat flow in Oregon. Heat flow analysis will be conducted by Dr. David D. Blackwell of Southern Methodist University. The special heat flow paper will analyze the best exploration techniques and ultimate geothermal resource potential for each major heat flow province within the state.

Deliverables

1. A DOGAMI Special Paper on the low-temperature geothermal resources of Ashland.

2. A DOGAMI Special Paper on the Eugene-Denio lineament in the Cascades. Two geologic maps will be included: one of the Willamette Pass area and one of the Walker Rim.

3. A DOGAMI Special Paper on the geothermal resources of Eastern Oregon with chapters on Powell Buttes, Burns, La Grande, Vale, and Lakeview.

4. A DOGAMI Special Paper on the heat flow of Oregon.

Schedule

October 1, 1982 through December 31, 1982: final compilation of geologic mapping and heat flow analysis of temperature data.

January 1, 1983 through March 31, 1983: report writing and preliminary typing and drafting.

April 1983: peer review of manuscripts and maps.

May 1983: final revisions of manuscripts and maps.

June 1, 1983 through October 31, 1983: final editing, drafting and printing of the special papers.

PATENT INFORMATION

There is no proprietary information included in this proposal and the information to be collected during the proposed study will not be confidential.

APPLICATIONS TO OTHER SPONSORS

This proposal has not been submitted to other potential sponsors and we do not plan to submit it to others in the future.

RESUMÉ

GEORGE R. PRIEST

Home Address

10710 S.W. Ponderosa Place
Tigard, Oregon 97223
(503) 620-6438

Business Address

Oregon Department of Geology and Mineral Industries
1069 State Office Building
Portland, Oregon 97201
(503) 229-5580

Personal Information

Birth date: 7-14-49
Height: 5' 9"; weight: 150 lbs.
Spouse: Barbara J. Priest

Education

B.S., Geology, Oregon State University, Corvallis, Oregon, 6-6-71
M.S., Geology, University of Nevada, Reno, Nevada, 8-15-74
Ph.D., Geology, Oregon State University, Corvallis, Oregon, 8-15-79

Industrial Experience

Geologist 4, Geothermal Specialist, Oregon Department of Geology and Mineral Industries, 11-1-80 to present (Dr. Donald A. Hull, supervisor).

Geologist 3, Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, Oregon 97201, 9-3-79 to 10-31-80 (Dr. Joseph Riccio, supervisor).

Geothermal Exploration Geologist, Chevron Resources Company, P.O. Box 3722, San Francisco, California 94119, 6-20-79 to 9-15-79 (Jim Salveson, supervisor).

Consulting Geologist, to Hanna Mining Company, Coastal Mining Division, 388 W. 2550 S., Salt Lake City, Utah 84115, 3-20-78 to 3-23-78; 3-27-78 (Wade Hodges, supervisor).

Geochemist, Lawrence Livermore Laboratory, P.O. Box 808, Livermore, California 94550, 7-5-77 to 9-7-77 (Dr. Kevin K. Knauss and Dr. Terry L. Steinborn, supervisors).

Exploration Geologist, Cyprus Mines Corporation, S. 400 Jefferson Street, Suite 161; Spokane, Washington 99204, 7-25-74 to 9-15-75 (Dr. E.A. Schmidt, supervisor).

Consulting Geologist; to Mr. Bruce Miller, consulting exploration geologist, Geology Department, University of Nevada, Reno, Nevada 89502, 7-1-74 to 7-6-74.

Consulting Geologist, Project Manager, for Dr. D.B. Slemmons, Geology Department, University of Nevada, Reno, Nevada 89502, 11-73 to 3-74.

Engineering Geologist, Woodward-Clyde and Associates, Berkeley, California; 5 days 1-74 (Alfred Ringa, supervisor).

Exploration Geologist, Phelps Dodge Corporation, Reno, Nevada 89502, 6-15-72 to 9-15-72 (Robert Ludden, supervisor).

Academic Experience

Assistant Professor, Portland State University, Department of Earth Sciences, Portland, Oregon 97207, 9-15-78 to 6-15-79 (Dr. Marvin H. Beeson, Department Chairman).

Teaching Assistant, five years, including the following subjects:

- Physical geology (2.0 academic years)
- Historical geology (0.5 academic years)
- Structural geology (0.5 academic years)
- Photogrammetry (0.5 academic years)
- Mineralogy (3.0 academic years)

Description of Industrial Work

Geologist 4 - Oregon Department of Geology and Mineral Industries: Supervisor for geothermal division; responsible for formulating and carrying out geothermal research and resource evaluation studies.

Geologist 3 - Oregon Department of Geology and Mineral Industries: Managed the Western Cascades geothermal drilling program for the State of Oregon. Supervised two employees and a drill crew in a Department of Energy geothermal research program. Did detailed mapping and sampling throughout the Western Cascades and originated and wrote grant proposals for further research in the Western Cascades.

Geothermal exploration - Chevron Resources Company: Completed a detailed geologic map of approximately 60 square miles of the Beowawe KGRA. In mapping this complex area, intersecting Basin and Range faults in Paleozoic and Tertiary rocks were dealt with. All structural and stratigraphic data were utilized to develop a model for the geothermal system in order to site deep drill holes. A geologic field assistant was supervised and trained during the investigation.

Consulting Geologist - Hanna Mining Company: Assisted the Hanna Mining Company in their efforts to explore two major epithermal, bonanza gold districts in central Nevada. Instructed a number of their western region geologists in the interpretation of complex volcanic textures and field relationships in these two heavily altered areas. After completion of the field project, a brief report on the potential use of trace and major-element modelling in exploration for hydrothermal ore deposits was submitted.

Geochemist - Lawrence Livermore Laboratory: Performed basic research on the origin of uranium ore deposits by a complex dissolution, alpha-spectrometric method which allowed determination of uranium and thorium-series-isotope activities. The aim of the project was to determine whether soluble uranium ions were moving out of uraniferous granitic rocks of NE Washington by testing for secular equilibrium between parent ^{238}U and daughter ^{230}Th. This work was performed under the guidance of Dr. Kevin K. Knauss. A publication on these data should be forthcoming in the near future.

While assisting Dr. Terry L. Steinborn, was introduced to the latest experimental stream-sampling techniques for uranium exploration. Became familiar with both water and sediment techniques of sampling and analysis.

Exploration Geologist - Cyprus Mines Corporation: Responsible for managing several mineral exploration drilling and mapping projects in varied geologic terranes in Nevada, California, Washington, and Montana. While working with Cyprus Mines Corporation, hundreds of feet of diamond drill core and rotary drill chips were logged, and claim and magnetometric surveys conducted. Dealt with various Federal regulatory agencies and supervised reclamation of numerous drill sites.

Consulting Geologist to Mr. Bruce Miller: Assistance was requested in running a resistivity survey over a small hydrothermal zinc prospect owned by Mr. Miller. Became familiar with this unusual type of ore deposit and the resistivity technique in the course of this work.

Consulting Geologist to Dr. D.B. Slemmons: Worked for five months on a project to evaluate regional targets for siting of nuclear reactors in northwestern Nevada. This study was contracted to Dr. Slemmons by Sierra Pacific Power.

Forty thousand square miles of NW Nevada were evaluated for presence of active and potentially active faults, utilizing high aerial and ERTS photography, as well as helicopter reconnaissance. Produced about 60% of the raw data for the hazard maps and supervised seven other part-time air-photo analysts who generated the balance of the information. Responsible for all phases of the study, including quality control, and assisted Dr. Slemmons in compilation of the final report.

Engineering Geologist - Woodward-Clyde and Associates: During employment with Dr. Slemmons (above) a leave of absence was granted to assist Woodward-Clyde and Associates in meeting an urgent deadline. Compiled a large body of published geological maps located along a major Canadian-United States natural gas pipeline route. Responsible for translating the geologic information from these maps into nontechnical and engineering terminology for planning purposes.

Exploration Geologist - Phelps Dodge Corporation: During a summer's work with Cyprus Mines Corporation, was initially responsible for helping to supervise drilling and claim-surveying operations on a large mesothermal "porphyry" copper prospect in central Nevada. In the course of logging hundreds of feet of diamond drill core across the contact of the quartz monzonite source, became intimately familiar with contrasting regional metamorphic and metasomatic alteration assemblages associated with these important copper ore bodies.

In the latter part of the summer, was involved in regional reconnaissance of several important bonanza gold districts in central Nevada. Utilizing both four-wheel drive vehicles and helicopters; assisted in compilation of alteration-mineralization maps of the Rawhide, Round Mountain and Manhattan gold districts. Also conducted similar evaluations of adjacent scheelite and molybdenum deposits in the Rawhide district.

Description of Academic Work

Experienced as a teaching assistant for many freshman-level physical and historical geology laboratories as well as junior-level structural geology and photogrammetry laboratory classes. Principal laboratory teaching, however, has been in the fields of crystallography, mineralogy and lithology. These courses were principal responsibilities as a doctoral candidate for three years at Oregon State University.

During the last term at Oregon State University a survey course in basic geology was taught to 150 non-geology majors. As an assistant professor at Portland State University during the 1978-1979 academic year had responsibility for teaching courses in mineralogy-crystallography, general geology, economic geology, igneous and metamorphic petrology, lithology, as well as graduate-level volcanology and igneous petrology.

Instructional Goals

An integrated approach to instruction is believed in. Every course should provide both practical application and theoretical justification of the lecture subjects.

In pursuit of this method, an effort has been made consistently to provide quantitative evaluation of all lecture topics where such data are available and within comprehension. Practical applications of theoretical concepts from a background in mineral exploration and volcanologic research are also used.

In addition, an attempt is made to teach basic geologic skills in every course, if at all possible. The ability to recognize rocks and minerals in hand specimens and interpretation of geologic features in the field are considered to be of paramount importance to every earth science student.

Goals in university teaching will be to teach both undergraduate and graduate-level courses in igneous petrology, especially volcanic petrology. Qualified to teach economic geology at both the undergraduate and graduate level and will be willing also to teach undergraduate mineralogy, crystallography, and igneous and metamorphic petrology-petrography.

Research Interests

Wish to use fundamental geochemical principles to solve problems in planetary science. Interest is mainly in the application of trace element geochemistry to problems in high-temperature geochemistry and volcanic stratigraphy.

An integrated, field-laboratory approach should be used in the solution of earth science problems. In pursuit of this ideal an endeavor has been made to cast all geochemical work in a framework of sound field geologic knowledge.

Industrial Interests

Interest lies mainly in geothermal and uranium exploration research; also very interested in practical exploration for geothermal energy, particularly in young volcanic terranes. Other fields of considered employmnnt are environmental geology and mineral exploration.

Geophysics

Resistivity and magnetometric surveys of base metal exploration targets have been run and evaluated. Also interpreted magnetic and gravity anomaly maps in terms of structural geology.

Mineral and Rock Identification

Able to identify a large variety of minerals utilizing ore microscopy, petrography, X-ray diffraction, and hand sample analysis. Three years of mineralogical laboratory teaching have greatly improved ability to identify minerals and rocks in hand specimens.

Mapping Experience

Able to map in the field and on air photos in all types of geologic terrane. Both detailed, large scale (1:1,200) and broad, small scale (1:62,500) geologic maps in volcanic, intrusive, metamorphic, and sedimentary terranes have been completed.

Active fault maps utilizing the fault evaluation system of Woodward-Clyde and Associates have also been produced and evaluated. During graduate-level course work in engineering geology, land-use-planning maps were produced which evaluated a large field area for slope stability; foundation and waste disposal characteristics of soil; absolute slope; sources of aggregate; active faults; water availability; and flooding potential.

Geochemical Analysis

Three slightly different X-ray fluorescence techniques for major and trace element analysis of whole rocks have been used. A variety of trace and major elements by both radiochemical and instrumental neutron activation have also been determined. During work at the Lawrence Livermore laboratory wet chemical separation techniques have been used to separate U and Th isotopes to determine absolute isotopic concentration and activity via alpha-spectroscopy.

George R. Priest

THESIS RESEARCH

Thesis title: Geology and geochemistry of the Little Walker volcanic center, east-central California.

Description of the Problem and the Attack:

The Little Walker volcanic center is a major latitic ash-flow center located in east-central Sierra Nevada, California, about 17 km WNW of Bridgeport, California. It was the source of the voluminous welded and non-welded quartz-latite tuffs of the Eureka Valley Tuff about 9.5 m.y. ago. These ash flows cover about 4,000 square kilometers of the Sierras and probably had a total volume of at least 60 cubic kilometers before erosion.

It was the aim of the thesis study to accurately locate the margins of a large caldera inferred to be present at the center, and evaluate the economic potential of mineralized areas. To accomplish these two objectives, the writer has mapped about 304 square kilometers of the Little Walker center in varying degrees of detail and geochemically analyzed numerous lavas which were erupted before, during, and after the major ash-flow eruptions. Chemical analyses were obtained by X-ray fluorescence and neutron activation methods.

Using phenocryst mineralogy and major element data for whole rock specimens, numerous least-squares mixing models have been tested, using remote-batch computer methods. Viable fractionation models obtained from the mixing calculations have then been tested with the trace element data using surface equilibrium Rayleigh fractionation models.

To obtain information about the source rock which may have been partially melted to produce the parental magmas of the center, numerous fractional fusion and batch melting calculations have been obtained for various potential source mineralogies, using geochemically reasonable eutectic and cotectic melting proportions. Such calculations are chiefly constrained by the trace element data and can be used to infer the probable trace element composition and mineralogy of the source rock, as well as the degree of partial melting which may have produced the parental magmas.

Geochemical traverse sampling and mapping of widespread epithermal alteration of the western half of the center provided the means of evaluating its gold-silver potential. Assistance in evaluation of the gold-silver mineralization was provided by support from the Freeport Mining Company, Reno, Nevada. A subsidiary study of uranium resources focused attention on the viability of the uraniferous volcanic rocks as primary and secondary sources of uranium. Trace element data from the volcanic units and from stream samples provided the basis for this part of the study.

Thesis Advisors: * Head Advisor ** Informal Advisor

*Dr. Edward M. Taylor, Department of Geology, Oregon State Univ., Corvallis, OR
Dr. William H. Taubeneck, " " "
Dr. E. Julius Dasch, " " "
Dr. Keith F. Oles, " " "
Dr. Roman A. Schmitt, Department of Nuclear Chemistry, Oregon State University, Corvallis, OR 97331
**Dr. Donald C. Noble, Department of Geology and Geologic Engineering, Michigan Technological University, Houghton, MI 49931

Publications

Priest, G.R., 1978, Phenocryst-groundmass distribution coefficients for some intermediate lavas of the Little Walker volcanic center, Mono County, California. In manuscript, 11 p.

___________, 1978, Trace and major element evidence for the origin of quartz latite and aluminous low-Mg latite: Oregon Acad. Sci. Proc. v. 14, p. 154-155.

___________, Latites, quartz latites: in Fairbridge, R. and Green, J., eds., Volcanoes and volcanology: Dowden, Hutchinson and Ross, Inc., publishers, in press, 5 p.

___________, Noble, D.C., Bowman, H.R., Geochemistry of a potassic volcanic center, Little Walker center, Mono County, California: in manuscript, 10 p.

___________, Noble, D.C., and Dickinson, W.R., Geologic evolution of the Little Walker volcanic center, Mono County, California: in manuscript, 20 p. + map at 1:24,000.

___________, Noble, D.C., Bowman, H.R., Hebert, A.J., and Wollenberg, H.A., 1975, Eruptive and geochemical evolution of the Little Walker volcanic center: California Division of Mines and Geology, California Geology, v. 28, no. 5, p. 106.

___________, Bowman, H.R., Hebert, A.J., Silberman, M.L., Street Jr., K., and Noble, D.C., 1974, Eruptive history and geochemistry of the Little Walker volcanic center, east-central California. A progress report: Geol. Soc. America Abs. with Programs, v. 6, p. 237.

___________, Riccio, J., Woller, N., Gest, D., and Pitts, S., 1980, Heat flow along the High Cascade-Western Cascade transition zone, Oregon: Oregon Acad. Sci. Proc., v. 16, in press.

Personal References

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STATE OF OREGON

DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

GEOTHERMAL ENERGY PUBLICATIONS

1966

Bodvarsson, G., 1966, Energy and power of geothermal resources: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 28, no. 7, p. 117-124.

Groh, E.A., 1966, Geothermal energy potential in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 28, no. 7, p. 125-135.

1967

Peterson, N.V., and Groh, E.A., 1967, Geothermal potential of the Klamath Falls area, Oregon, a preliminary study: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 29, no. 11, p. 209-231.

1969

Godwin, L.H., and Peterson, N.V., 1969, Geothermal energy, in Mineral resources of Oregon: Oregon Department of Geology and Mineral Industries Bulletin 64, p. 299-304.

1970

Bowen, R.G., and Peterson, N.V., 1970, Thermal springs and wells in Oregon: Oregon Department of Geology and Mineral Industries Miscellaneous Paper 14 (listed on back of location map, scale 1:1,000,000).

1971

Bowen, R.G., 1971, Geothermal activity in 1970: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 33, no. 1, p. 16-18.

1972

Bowen, R.G., 1972, Geothermal activity in 1971: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 34, no. 1, p. 12-15.

Bowen, R.G., 1972, Geothermal gradient studies in Oreogon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 34, no. 4, p. 68-71.

1973

Bowen, R.G., 1973, Geothermal activity in 1972: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 35, no. 1, p. 4-5.

Bowen, R.G., and Blackwell, D.D., 1973, Progress report on geothermal measurements in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 35, no. 1, p. 6-7.

1974

Bodvarsson, G., 1974, Telluric current exploration for geothermal anomalies in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 36, no. 4, p. 93-107.

1974 (continued)

Bowen, R.G., 1974, Geothermal activity in 1973: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 36, no. 1, p. 9-11.

Walker, G.W., 1974, Some implications of late Cenozoic volcanism to geothermal potential in the High Lava Plains of south-central Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 36, no. 7, p. 109-119.

1975

Bowen, R.G., 1975, Geothermal activity in 1974: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no.1, p. 9-10.

Bowen, R.G., 1975, Geothermal gradient data: Oregon Department of Geology and Mineral Industries Open-File Report O-75-3, 114 p.

Bowen, R.G., 1975, Geothermal power, in Proceedings of the Citizens' Forum on Potential Future Energy Sources, Portland, Oreg., January 17, 1974: Oregon Department of Geology and Mineral Industries Miscellaneous Paper 18, p. 43-50.

Bowen, R.G., and Blackwell, D.D., 1975, The Cow Hollow geothermal anomaly: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 7, p. 109-121.

Bowen, R.G., Blackwell, D.D., and Hull, D.A., 1975, Geothermal studies and exploration in Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-75-7, 66 p.

Couch, R.W., French, W., Gemperle, M., and Johnson, A., 1975, Geophysical measurements in the Vale, Oregon, geothermal resource area: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 8, p. 125-129.

Hull, D.A., 1975, Geothermal gradient data, Vale area, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-75-4, 18 p.

Hull, D.A., 1975, Geothermal studies in the Vale area, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 6, p. 104-106.

Larson, K., and Couch, R.W., 1975, Preliminary gravity maps of the Vale area, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 8, p. 138-142.

1976

Bowen, R.G., Blackwell, D.D., Hull, D.A., and Peterson, N.V., 1976, Progress report on heat-flow study of the Brothers fault zone, central Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 38, no. 3, p. 39-45.

Hull, D.A., 1976, Electrical resistivity survey and evaluation of the Glass Buttes geothermal anomaly: Oregon Department of Geology and Mineral Industries Open-File Report O-76-1, 11 p.

Hull, D.A., Bowen, R.G., Blackwell, D.D., and Peterson, N.V., 1976, Geothermal gradient data, Brothers fault zone, central Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-76-2, 24 p.

Hull, D.A., and Newton, V.C., 1976, Geothermal activity in 1975: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 38, no. 1, p. 10-17.

1977

Bowen, R.G., Blackwell, D.D., and Hull, D.A., 1977, Geothermal exploration studies in Oregon: Oregon Department of Geology and Mineral Industries Miscellaneous Paper 19, 50 p.

Hull, D.A., Bowen, R.G., Blackwell, D.D., and Peterson, N.V., 1977, Preliminary heat-flow map and evaluation of Oregon's geothermal energy potential: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 39, no. 7, p. 109-123.

Hull, D.A., Blackwell, D.D., Bowen, R.G., and Peterson, N.V., 1977, Heat-flow study of the Brothers fault zone, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-77-3, 43 p.

Hull, D.A., Blackwell, D.D., Bowen, R.G., Peterson, N.V., and Black, G.L., 1977, Geothermal gradient data: Oregon Department of Geology and Mineral Industries Open-File Report 0-77-2, 134 p.

Hull, D.A., and Newton, V.C., 1977, Geothermal activity in 1976: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 39, no. 1, p. 7-15.

Wimer, R.D., LaMori, P.N., and Grant, A.D., 1977, Potential environment issues related to geothermal power generation in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 39, no. 5, p. 73-91.

1978

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.

Bowen, R.G., Peterson, N.V., and Riccio, J.F., 1978, Low- to intermediate-temperature thermal springs and wells in Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-10 (listed on back of location map, scale 1:1,000,000).

Couch, R.W., Gemperle, M. and Connard, G., 1978, Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-9, scale 1:125,000.

Hull, D.A., Blackwell, D.D., and Black, G.L., 1978, Geothermal gradient data: Oregon Department of Geology and Mineral Industries Open-File Report 0-78-4, 187 p.

Newton, V.C., and Hull, D.A., 1978, Geothermal Energy in 1977: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 40, no. 1, p. 8-16.

Oregon Department of Geology and Mineral Industries, 1978, Geophysical logs, Old Maid Flat #1, Clackamas County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-78-6, 2 p., 7 logs.

Pitts, G.S., and Couch, R.W., 1978, Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-8, scale 1:125,000.

1979

Riccio, J.F., ed., 1979, Geothermal resource assessment of Mount Hood: Oregon Department of Geology and Mineral Industries Open-File Report 0-79-8, 273 p., 5 maps.

Riccio, J.F., 1979, Preliminary geothermal resource map of Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-11, scale 1:500,000.

Riccio, J.F., and Newton, V.C., 1979, Geothermal exploration in Oregon in 1978: Oregon Department of Geology and Mineral Industries, Oregon Geology, v. 41, no. 3, p. 39-46.

U.S. Geological Survey and Oregon Department of Geology and Mineral Industries, 1979, Chemical analyses of thermal springs and wells in Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-79-3, 170 p.

Wollenberg, H.A., Bowen, R.G., Bowman, H.R., and Strisower B., 1979, Geochemical studies of rocks, water, and gases at Mt. Hood, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-79-2, 57 p.

1980

Brown, D.E., Black, G.L., and McLean, G.D., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Craig Mountain-Cove area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-4.

Brown, D.E., Black, G.L., and McLean, G.D., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Powell Buttes area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-8.

Brown, D.E., McLean, G.D., and Black, G.L., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the northern Harney Basin, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-6.

Brown, D.E., McLean, G.D., and Black, G.L., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the southern Harney Basin, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-7.

Brown, D.E., McLean, G.D., and Black, G.L., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Western Snake River Plain, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-5.

Brown, D.E., McLean, G.D., Priest, G.R., Woller, N.M., and Black, G.L., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Belknap-Foley area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-2.

Brown, D.E., McLean, G.D., Woller, N.M., and Black, G.L., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Willamette Pass area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-3.

1980 (continued)

Geoscience Research Consultants, 1980, Geologic linears of the northern part of the Cascade Range, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 12, 25 p.

MacLeod, T., and Hill, J. (Logging Geologists, R.F. Smith Corporation), 1980, Engineering and air and mud drilling data of DOGAMI geothermal exploratory well Old Maid Flat 7A: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-11, 16 p.

Oregon Department of Geology and Mineral Industries (Hull, D.A., principal investigator), 1980, Progress report on activities of the low-temperature resource assessment program 1979-1980: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-14, 79 p.

Peterson, N.V., and Brown, D.E., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Alvord Desert area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-10.

Peterson, N.V., Brown, D.E., and McLean, G.D., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Lakeview area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-9.

White, C. 1980, Geology and geochemistry of Mt. Hood volcano: Oregon Department of Geology and Mineral Industries Special Paper 8, 26 p.

White, C., 1980, Geology of the Breitenbush Hot Springs quadrangle, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 9, 26 p.

1981

Oregon Department of Geology and Mineral Industries, 1981, Geophysical logs, Old Maid Flat Well 7A, pt. 1: Oregon Department of Geology and Mineral Industries Open-File Report 0-81-2A.

Oregon Department of Geology and Mineral Industries, 1981, Geophysical logs, Old Maid Flat Well 7A, pt. 2: Oregon Department of Geology and Mineral Industries Open-File Report 0-81-2B.

BUDGET SUMMARY

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

Personnel		
Geologist III ($2,400/mo. x 12 x 2) +O.P.E. (Salary x 1.45)	$ 57,600.00	$ 83,520.00
Services and Supplies		
Travel		
Air fare to and from Southern Methodist University, Dallas, Texas (1 trip at $600/fare for D. D. Blackwell and one geologist III)	$ 1,200	
Air fare to Idaho Falls for contract consultations (2 trips at $250/fare for the supervisor and DOGAMI budget officer)	1,000	
2 man-months at $40 per diem x 20 days/mo.	1,600	
Direct supplies (computer output devices; map bases)	7,000	
Computer software and processing time	3,000	
Printing, editing and drafting		
Ashland Special Paper	5,000	
Eastern Oregon Special Paper	10,000	
Eugene-Denio Special Paper	12,000	
Heat Flow	4,000	
Subtotal		$ 44,800.00
Subcontract		
David D. Blackwell (camera-ready heat flow paper and heat flow analysis for other special papers).		$ 15,000.00
Subtotal		143,320.00
Indirect Costs @16.7%		23,934.44
TOTAL		$ 167,254.44

GEOLOGY AND MINERAL INDUSTRIES

OPE

Indirect Overhead OPE		15%
sick leave		
vacation		
other		
Direct Overhead OPE		30%
FICA	6.65%	
PERS	17.20%	
Other	6.15%	
Health Ins.		
Life Ins.		
Dental Ins.		
SAIF		
ERB		
Misc.		
	TOTAL	45%

EXHIBIT C

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

GENERAL AND ADMINISTRATIVE EXPENSE

PERSONNEL

Z6320	Director	$ 60,360	
Z3064	Deputy Director	53,424	
Z0010	Administrative Assistant	28,272	
Z0051	Business Manager	39,816	
C0101	Accounting Clerk	19,368	
C3006	Student Scient-Tech. Train.	7,747	
			$ 208,987
OPE			42,424
	Total Personnel		$ 251,411

SERVICES AND SUPPLIES (PROGRAM 1 BB)

(1)	In-state and reg. travel	16,809	
(2)	Out-of-state travel	3,363	
(3)	Office expenses		
	a) Phone (6 of 17 phones, excl.proj.)	4,200	
	b) Shuttle mail	5,016	
	c) Central Stores	1,944	
	d) Copier	3,936	
(4)	Fiscal control	12,664	
(8)	Attorney General	1,388	
(9)	Insurance	1,961	
(11)	Housing and grounds (670 x 62 x 24)	9,970	
	Total Services and Supplies		61,251
	Total overhead		312,662
	Total budget, minus overhead		$ 1,867,625
	Overhead rate		16.7%

July 1, 1981

Circa May 82, guesses CAR

FINAL TECHNICAL REPORT

OREGON LOW TEMPERATURE RESOURCE ASSESSMENT PROGRAM

by

George R. Priest, Gerald L. Black, and Neil M. Woller, Oregon Department of Geology and Mineral Industries

7/21

Dunc:

This report, the pubs listed and the state map constitute satisfaction of the 79ET27220 deliverables requirement per SMP. I have 2 additional copies.
(They need an editor - several typos)

Carl.

TABLE OF CONTENTS

ABSTRACT

Numerous low-temperature hydrothermal systems are available for exploitation throughout the Cascades and eastern Oregon. All of these areas have heat flow significantly higher than crustal averages and many thermal aquifers. In northeastern Oregon low temperature geothermal resources are controlled by regional stratigraphic aquifers of the Columbia River Basalt Group at shallow depths and possibly by faults at greater depths. In southeastern Oregon most hydrothermal systems are of higher temperature than those of northeastern Oregon and are controlled by high-angle fault zones and layered volcanic aquifers. The Cascades have very high heat flow but few large population centers. Direct use potential in the Cascades is therefore limited, except possibly in the cities of Oakridge and Ashland, where load may be great enough to stimulate development. Absence of large population centers also inhibits initial low temperature geothermal development in eastern Oregon. It may be that uses for the abundant low temperature geothermal resources of the state will have to be found which do not require large nearby population centers. One promising use is generation of electricity from freon-based biphase electrical generators. These generators will be installed on wells at Vale and Lakeview in the summer of 1982 to evaluate their potential use on geothermal waters with temperatures as low as 80° C (176° F).

It is clear also that the low temperature geothermal resources identified here and others like them elsewhere in the state must be viewed in a broader context which considers the very favorable geologic setting for geothermal potential in general. Thus, low temperature resources identified today really constitute part of a data base which may lead to the discovery of a larger temperature resource base tomorrow, technology and economics permitting.

INTRODUCTION

This report is the summary and conclusions of an investigation of low-temperature (20 to 90° C) geothermal resources begun May 23, 1979 by the Oregon Department of Geology and Mineral Industries (DOGAMI) with support from the United States Department of Energy (USDOE) under Cooperative Agreement No. DE-FC07-79ET27220. The report summarizes low-temperature resource assessment data generated for the following project areas (Figure 1):

1. Corbett-Moffett
2. Parkdale
3. Milton-Freewater
4. La Grande (Craig Mountain-Cove area)
5. Belknap-Foley Hot Springs
6. Willamette Pass
7. Powell Buttes
8. Northern Harney Basin
9. Southern Harney Basin
10. Western Snake River Plain
11. Lakeview
12. Alvord Desert
13. McDermitt

Raw data and preliminary conclusions for these areas are included in the following published DOGAMI reports and maps and will not be included here:

1. Heat flow of Oregon: Special Paper 4, 1978, includes 1 map.
2. Geothermal gradient data for Oregon: Open-File Report 0-78-4, 1978.
3. Chemical analyses of thermal springs and wells in Oregon: Open-File Report 0-79-3, 1979.
4. Geology of the La Grande area, Oregon: Special Paper 6, 1980, includes 1 map.
5. Preliminary geology and geothermal resource potential of the Belknap-Foley area: Open-File Report 0-80-2, 1980, includes 1 map.

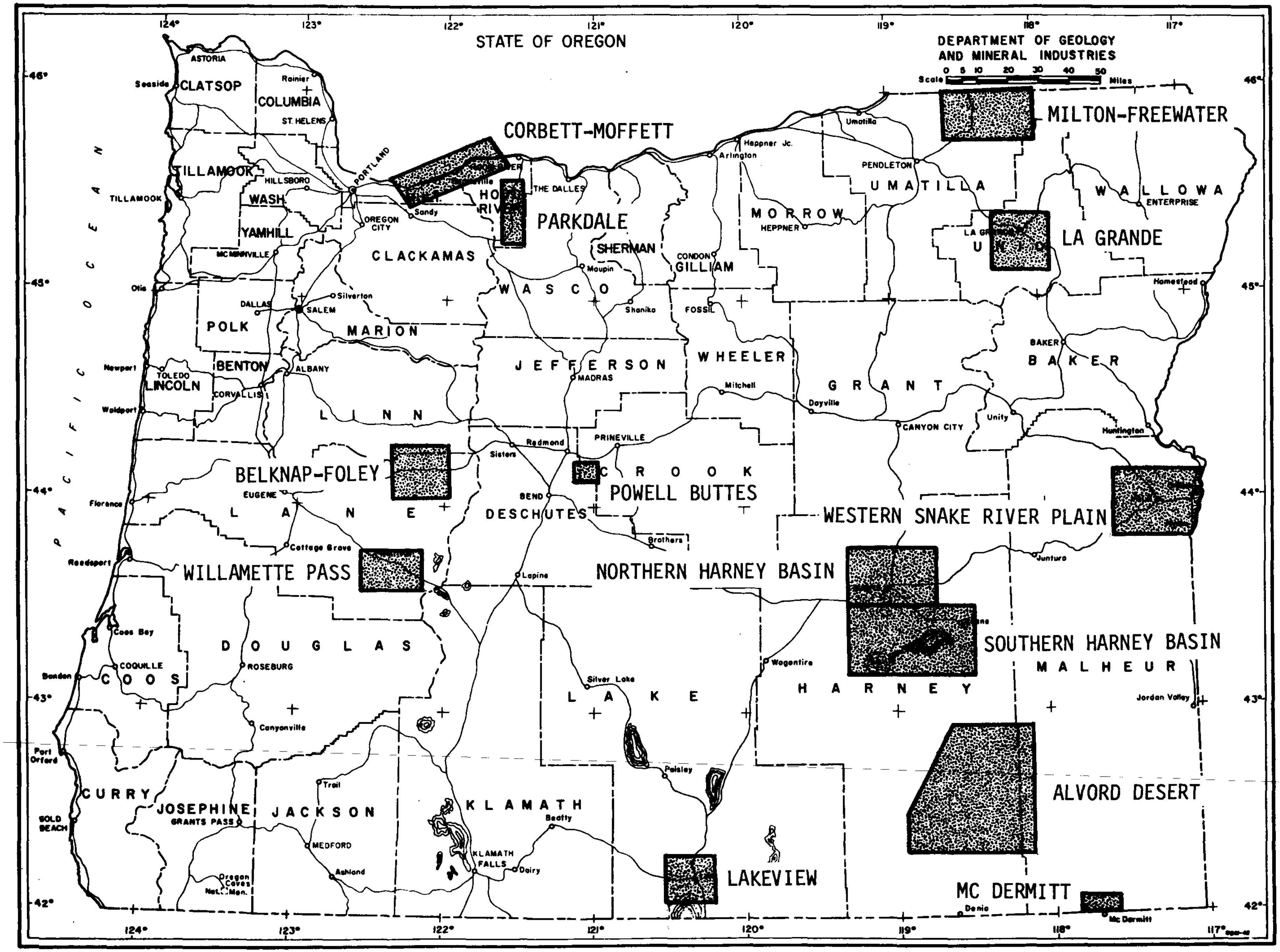

Figure 1. Location of project areas.

-5-

6. Preliminary geology and geothermal resource potential of the Willamette Pass area: Open-File Report 0-80-3, 1980, includes 1 map.
7. Preliminary geology and geothermal resource potential of the Craig Mountain Cove area: Open-File Report 0-80-4, includes 1 map.
8. Preliminary geology and geothermal resource potential of the western Snake River Plain: Open-File Report 0-80-5, 1980, includes 4 maps.
9. Preliminary geology and geothermal resource potential of the northern Harney Basin: Open-File Report 0-80-6, 1980, includes 4 maps.
10. Preliminary geology and geothermal resource potential of the southern Harney Basin: Open-File Report 0-80-7, 1980, includes 8 maps.
11. Preliminary geology and geothermal resource potential of the Powell Buttes area: Open-File Report 0-80-8, 1980, includes 1 map.
12. Preliminary geology and geothermal resource potential of the Lakeview area: Open-File Report 0-80-9, includes 2 maps.
13. Preliminary geology and geothermal resource potential of the Alvord Desert area: Open-File Report 0-80-10, 1980, includes 2 maps.
14. Progress report on activities of the low-temperature resource-assessment program 1979-80: Open File Report 0-80-14.
15. Geothermal gradient data for Oregon for 1978: Open-File Report 0-81-3A.
16. Geothermal gradient data for Oregon for 1979: Open-File Report 0-81-3B.
17. Geothermal gradient data for Oregon for 1980: Open-File Report 0-81-3C.
18. Map showing geology and geothermal resources of the southern half of the Burns 15' Quadrangle: GMS 20, in press.
19. Map showing geology and geothermal resources of the Vale East 7 1/2' Quadrangle, Oregon: GMS 21, in press.

20. Geothermal gradient data for Oregon for 1981: Open-File Report O-82-4.

The Department is continuing its resource assessment efforts in other areas throughout Oregon with concentration on the Cascades. Resource assessment data will soon be available in open file for the low-temperature resources of Ashland, Oregon when a 1982 drilling program is completed under contract DE-FC07-79ID12044. Preliminary conclusions concerning the Klamath Falls and Bend areas will also be available in an upcoming special paper on the geology and geothermal resources of the Oregon Cascades (DOGAMI Special Paper 15). A preliminary summary of this paper will be included in the conference proceedings volume for the 1982 USDOE-sponsored conference at Salt Lake City, Utah. A similar paper, aimed primarily at a summary of the data gathered at Powell Buttes, was presented in the 1981 USDOE conference at Glenwood Springs, Colorado (see DOE/ID/120-79-39, ESL-59, published by the Earth Science Laboratory, University of Utah Research Institute, Salt Lake City, Utah).

CORBETT-MOFFETT

The Corbett-Moffett area extends from Cascade Locks in the Columbia Gorge to the lower Sandy River-Troutdale area (Figure 1). Hot springs at Carson (49°C) and North Bonneville (36°C) on the Washington side, a warm well at the new site of North Bonneville (37°C) and three slightly warm springs in the Troutdale area are the main surface manifestations of the geothermal resources. These springs are in a northeast-southwest line in a distinct lineament on high altitude SLAR and ERTS imagery. The cause of this lineation and spring alignment has, as yet, not been determined.

Cascade Locks (population 835) is the largest city within the Columbia Gorge. Several smaller communities lie between Cascade Locks and Troutdale. Lumber mills at Bridal Veil and Cascade Locks and tourism are the economic bases for the population. There is also a sizable number of local residents who work at Bonneville Dam.

At the western end of the Corbett-Moffett area the population is considerably larger. Troutdale (population 5,940) and Gresham (population 33,250) are the centers of lush farming and light industrial areas. Near Troutdale, a warm artesian well at Camp Collins (23°C), a slightly anomalous spring at Corbett Quarry (18°C), and a warm spring across the Columbia River at Camas suggest that a possible resource may lie at depth.

DOGAMI undertook study of the Corbett-Moffett area under the current USDOE low-temperature grant. The aims of the study were: 1) to investigate the possibility of geothermal resources occurring on the south side of the Columbia Gorge; 2) to investigate the low-temperature manifestations at Camp Collins and Corbett Quarry; and 3) to see if the main source of geothermal waters was: a) a deep-seated northeasterly geologic structure; b) several northwesterly or northerly cross-cutting geologic structures (such as the Lacamas Fault in the Camas area) which could cause localization of geothermal waters; or c) the deep incission of the Columbia River interacting with the regional heat flow to yield higher than ambient temperature.

DOGAMI began a vigorous spring sampling and water well "scrounge" program to identify promising sites for drilling of geothermal heat flow test holes. Although many springs were tested, only in the immediate area of Camp Collins were new thermal waters discovered. None of the thermal found in the Camp Collins area exceeded the Camp Collins well in temperature or ion/mineral content.

Six holes were drilled by DOGAMI in the Corbett-Moffett area in 1981. Locations and results are as follows:

1) Dry Creek Falls - This hole was located at the foot of the cliffs south of Cascade Locks. Although the site was over 1 mile from Cascade Locks, the site was the nearest available with the possibility of yielding good results. The gradient was 35.4° C. The gradient at this site was below the expected regional gradient. This may be due to a downflow groundwater system at the site.

2) Tanner Creek - This site is across the Columbia River from thermal anomalies at Moffett Hot Springs and North Bonneville. Hammond (1980) mapped a northwesterly fault crossing the Columbia Gorge in this area. The gradient was 77° C/km. The results at this site were slightly higher than the expected regional gradient.

   The Tanner Creek site is located close to the Bonneville Dam complex, with its fish hatchery, maintenance shops, administration buildings, and tourist facilities. However, unless still warmer waters are encountered (by either deeper drilling or striking a still higher heat flow anomaly in the same vicinity), it is not likely that low temperature utilization will be feasible in this area.

3) Corbett Quarry - located at the site of a slightly warm spring. The gradient was 29.3° C/km down to 110 m, where it became isothermal. The gradient is isothermal at approximately the same temperature as the nearby spring and is probably the product of upflow from the same source which feeds the spring.

4) Howard Canyon - This site was chosen to hit the Columbia River Basalt in an area where it may have fracture permeability. It is on the hinge of a monoclinal fold of the permeable basalts, on the projected strike of the Lacamas Fault. The gradient was 40.5° C/km. The results were consistent with heat flow modeling of the northern Oregon Cascades of Blackwell and others (1978). The gradient indicates that the site is outside of the High Cascades heat flow anomaly.

5) Sandy River - This site is also in the trend of the Lacamas Fault which has been mapped in southern Washington. It is also across the Sandy River from Camp Collins. The gradient was 42° C/km which is again consistent with regional background values outside the High Cascade heat flow anomaly.

6) Camp Collins - This hole was expected to determine the nature of the resource at nearby Camp Collins. Unfortunately, the hole had to be terminated before reaching its scheduled depth because of drilling problems and budget limitations. However, the gradient was 124° C/km to a depth of 74 m. Deeper drilling needs to be done to evaluate this extremely anomalous result.

The Camp Collins site remains attractive for investigation although no evidence of a large-scale shallow hydrothermal system was revealed which might be utilized by the nearby population center of Gresham. While it does not seem likely that other than very low-temperature resources occur in this area, based on the low gradients in adjacent wells, the very high local temperature gradient suggests that deeper drilling might have a chance of encountering higher temperature water than currently utilized at Camp Collins.

Thermal aquifers may occur in Columbia River Basalt Group (CRBG) rocks at unknown depths (perhaps 1000 m?) beneath the Gresham area, although drilling for such aquifers in the Mt. Hood area has not been successful. If water is present in CRBG at 1 km in the Gresham area, it will be at about 50° C, assuming the heating of the Camp Collins water occurs at depth within the area. Perhaps more likely is the possibility that thermal waters migrated laterally within an aquifer of the CRBG from the Cascade thermal anomaly to the east, and rose to shallow levels in the lower Sandy River area via local fracture zones associated with folding of the CRBG. This is supported by the general vertical impermeability of the volcanic pile in the Mt. Hood area, the hydrostatic head of wells penetrating the CRBG in the Camp Collins area, and the absence of young local Quaternary volcanic centers. Engineering studies should be pursued to evaluate whether further exploration for a low-temperature resource is justified. The study should take into account the probable low-temperature of the resource, high risk of finding inadequate fluid, and high costs of drilling deep wells, as well as the high potential load available.

Based on the results of the studies undertaken for this report, the best model explaining the occurrence of thermal phenomena in the Corbett-Moffett area would be the localization of low-temperature geothermal waters by the intersection of the Columbia Gorge with cross-cutting northwesterly and northerly geologic structures. Future recognition of additional geologic structures in the Columbia Gorge would merit further geothermal investigation.

PARKDALE

The Parkdale area is located at the south end of Hood River Valley (Figure 1). The area is noted for its lush farmland and orchards. Local population centers include Parkdale, Dee and Odell.

Interest in low-temperature geothermal energy in the Parkdale area is based on the existence of a warm well, a young lava flow whose estimated age is 500 years, and youthful faults to promote convective circulation that may allow thermal water from the Mt. Hood heat flow anomaly to rise to shallow depths.

Heat flow data from the area is sparse. There is an abundance of spring water and runoff available to meet most of the needs of the population and agribusiness. Those not so fortunate have found ground water at shallow depths in the valley fill of river sediments. Consequently there are few water wells drilled in the valley, and those present do not penetrate the sediments to any substantial depth.

The abundant rainfall and the permeability of the river deposits create a masking effect in which shallow cold ground water tends to conceal regional gradients in wells that do not penetrate through the shallow aquifers.

The warm well that provides the Dee Fish Hatchery with 24° C has been temperature logged by DOGAMI. The temperature log shows two shallow aquifers; one at 60 to 110 m yields water of 24.2° C, and one at 110 to 175 m yields 22° C water. Geothermetric calculations using data from geochemical analysis suggest reservoir temperatures of approximately 125° C.

DOGAMI undertook an assessment of the low-temperature geothermal resources of the Parkdale area for this report. The investigation was a three-pronged study involving geochemical water sampling, regional "scrounging" for available open wells for temperature gradient logging, and geologic mapping.

Nineteen springs were sampled in 1981. Some of the springs were located on maps and used for local water supplies. Others were located during the course of the geologic mapping project and were possibly related to structural geologic features. However, none of the sampled springs showed any geothermal component, and measured temperatures were invariable low. The lone exception was the resampled well at Dee's fish hatchery, already mentioned.

The effort to locate additional wells available for temperature logging was only moderately successful. DOGAMI's files now include a total of 15 wells in the area with temperature logs. Many of these are isothermal or have negative gradients, indicating that these wells did not penetrate through the cold water "blanket" generated by recharge from Mount Hood. Two of the 15 wells were drilled by DOGAMI in previous years for heat flow determination and encountered the same problem. The few good quality gradients that exist for the area are in the range of 25° C - 55° C/km, with a high heat flow maximum of 87 mW/m^2. However, the gradient of this well (yielding a heat flow of 87 mW/m^2), was not clear and the calculated heat flow is regarded as a maximum value.

Geologic mapping was intended to identify faulting and determine the age of the episodes. The Parkdale scarp, the fault that terminates the east side of the valley, was studied by Department staff. The major movement on the fault occurred between 2.66 ± 2.0 m.y. and 2.08 ± 0.24 m.y.B.P., with a displacement of greater than 2,000 feet. Last movement of the fault postdates 2.08 ± 0.24 m.y., making this fault one of the youngest known faults in the Oregon Cascade Range.

Although available regional gradient and spring sampling data do not indicate geothermal resources in the Parkdale area more promising than for the region in general, the identification of young faulting and the proximity to Mt. Hood suggests that further work should be done in the area. Available gradient data is not sufficient to analyze the potential adequately. Lack of a large urban population in the area probably precludes development of a district heating system, should adequate geothermal resources be found. Other, smaller-scale uses, such as the aquaculture system, already being utilized at the Dee Fish Hatchery, and food processing, might be possible on a much larger scale than currently in utilization.

MILTON-FREEWATER

The Milton-Freewater area, as defined for purposes of this report, is composed of that part of the Walla Walla Basin which lies in Oregon (Figure 1). The Walla Walla Basin is a triangular shaped area which lies astride the Oregon-Washington border approximately 30 miles (48 km) northeast of Pendleton, Oregon. The only significant population centers in Oregon are Milton-Freewater (pop. 5,110) and the small unincorporated town of Umapine. Agriculture is the main source of income for the region.

The Walla Walla Basin is a structural depression located in the Columbia Plateau physiographic province of eastern Oregon and Washington, which is composed mostly of flood basalts of the Miocene Columbia River Group. That part of the plateau located in Oregon is known as the Deschutes-Umatilla Plateau. The basin is bordered on all sides by anticlines. To the east is the northeast trending Blue Mountains Anticline, to the south the west-northwest trending Horse Heaven Anticline, to the west the north-south trending Divide Anticline, and to the north in Washington is a low east-west trending arch.

As has been previously mentioned, the Columbia Plateau is underlain by a thick sequence of Miocene tholeiitic flood basalts, the Columbia River Group. In the Walla Walla Basin, the basalts are exposed only in the bottoms of streams flowing into the basin, and on the flanks of the anticlines bordering the basin. Within the basin the basalts are covered by a series of unconsolidated Pleistocene and Holocene deposits which are as much as 650 feet (198 m) in thickness. The deposits include gravels, clays, loess, silts, siltstones, glacio-fluviatile deposits, and alluvium.

There are no surface thermal phenomena in the Walla Walla Basin. Early interest in the area was generated by rumors of warm irrigation wells, some of which were artesian at temperatures in excess of 38° C, though most fall into the range 15-27° C. The warmest wells all turned out to be located in the center of the basin near the town of Touchet, in Washington.

The Department of Geology and Mineral Industries (DOGAMI) effort in the region has been quite limited. To this date temperature gradients have been measured in only seven open water wells in Oregon, though a larger data set exists for the Washington side of the Walla Walla Basin. No well sampling program has been instigated, but limited geochemical data is available from groundwater studies which have included the Walla Walla Basin. Silica geothermometers indicate minimum reservoir temperatures in the range 100°-120° C for some of the warmer wells in the area.

Based on the limited temperature gradient data available, it appears that the heat flow averages about 55 mWm^{-2} in the Walla Walla Basin. Typical gradients are 35° Ckm^{-1} in the basalts and 50° Ckm^{-1} in the lower thermal conductivity sediments overlying the basalts.

According to ground water studies, there are major sets of aquifers in the area. The first is associated with older Pleistocene gravels. The water from wells drilled into these aquifers is typically cold and unconfined. The second is associated with flow contacts in the Columbia River Basalt. Waters from these aquifers are typically warm and artesian, and the wells commonly produce several thousand gallons per minute of water.

It is clear that there is a low-temperature resource in the Walla Walla Basin with abundant fluid and temperatures adequate for space heating and other lower temperature direct-use applications (most probably agricultural applications). The high temperatures, in most cases, result from a combination of the somewhat high regional heat flow (55 mWm^{-2}) and the insulating cap of low thermal conductivity unconsolidated sediments. Where temperatures in excess of 38° C occur, as in the Touchet area of Washington, it is probable that the fluids are derived from convection systems associated with mapped normal faults.

It appears, given the nature of the Columbia River Basalts in the Oregon portion of the Columbia Plateau, that adequate quantities of warm fluids can be obtained at any specific site. The temperature obtained in a specific well will depend primarily upon the depth drilled. Therefore, future efforts should be directed primarily toward site specific engineering studies, to determine if the resource is adequate to supply the expected load. In certain areas detailed geologic mapping and geophysical studies may be useful for locating faults. Convective systems associated with the faults could provide higher temperatures than would normally be expected at a given depth.

LA GRANDE

The La Grande area is located within the Blue Mountains physiographic province of northeastern Oregon (Figure 1). It is bordered by the Blue Mountains on the north and west, and by the Wallowa Mountains on the east. The three main population centers of La Grande (pop. 11,140), Union (pop. 2,160) and Cove (pop. 500), all lie within the Grande Ronde Valley.

The Grande Ronde Valley is a structural depression which is bordered on all sides by normal faults with displacements of several thousand feet. The floor of the valley is composed of unconsolidated Plio-Pleistocene lacustrine and fluvial sediments, landslide deposits, and alluvial fans. The bedrock making up the valley margins is composed exclusively of rocks of the Miocene Columbia River Basalt Group.

Hot springs are common throughout the study area, particularly along the southern and eastern margin of the Grande Ronde Valley. The hottest spring is the Hot Lake Resort Spring, 11.7 km southeast of La Grande, with a surface temperature of 85°C. Most of the other springs possess surface temperatures in the range 20-30°C. All of the springs are fluid-dominated deep circulation systems which are associated with the normal faults at the margins of the Grande Ronde Valley.

The Department of Geology and Mineral Industries (DOGAMI) commenced its geothermal effort in the Grande Ronde Valley in the summer of 1977 with the measurement of temperature gradients in existing water wells. In the spring of 1980 a spring sampling program was completed, and in the winter of 1979/1980 three heat flow holes were drilled in the city of La Grande. Originally 4 holes with a 152 meter (500 ft) nominal depth were scheduled, but extreme drilling problems resulted in the completion of only three holes, the deepest of which was completed to 120 m.

During the DOGAMI sampling program, twenty-five thermal springs and wells were sampled and analyzed. These, when combined with previously published data, resulted in a total of seventy-five analyses available for evaluation. It is felt that the chalcedony and 4/3B Na:K:Ca geothermometers probably give the best estimates of minimum reservoir temperature. For most of the springs and wells, these estimates fell in the range 100-125°C. The highest calculated temperatures were for those springs associated with the basin-bounding normal faults. The highest estimated minimum reservoir temperature for the Hot Lake Resort Well was 100°C.

Heat flow data for the Grande Ronde Basin is sparse, and the quality of most of the data that has been obtained is not good. Because most of the holes were measured in the unconsolidated sediments of the La Grande Basin, where the effects of refraction, sedimentation, and groundwater circulation tend to depress temperatures, the measured temperature gradients were often anomalously low or even isothermal. Of the three holes drilled by DOGAMI in the city of La Grande, one was totally useless for heat flow determinations (due to a negative temperature gradient) and there were significant problems in interpretation associated with the other two. These two holes resulted in heat flow values of 42 mWm^{-2} and 84 mWm^{-2}. Based on the total data set, the best estimate for heat flow in the Grande Ronde Valley is 60-80 mWm^{-2}, and the best gradient is $50 \pm 20°Ckm^{-1}$.

One of the DOGAMI holes, drilled adjacent to the city hospital, encountered 15-21°C water flowing at 114 lpm; a temperature and flow rate adequate for space heating applications using a heat pump.

It appears that the areas with the highest potential for the direct use of low temperature geothermal fluids are those adjacent to thermal convection systems associated with valley bounding normal faults. Of the many warm springs in the Grande Ronde Valley, those associated with the Craig Mountain fault and its extensions along the southern margin of the valley appear to be the most promising. Normal faults are also present in La Grande, and the warm water encountered in one of the DOGAMI drill holes is evidence that thermal convection anomalies may be associated with these faults. At the present time the City of La Grande is drilling a 1700-ft hole near one of the DOGAMI drill sites. Although it is being drilled primarily as a city water supply, DOGAMI will be allowed to temperature log the hole. If the temperatures are adequate, serious consideration will be given to forming a geothermal heating district to supply the many public loads in the area (three schools, city and county offices, and the Eastern State College Campus).

There is also considerable low temperature geothermal potential toward the center of the Grande Ronde Valley, where deep irrigation wells (900-1700 ft) commonly encounter large (often artesian) flow rates of several hundred to several thousand gallons per minute of water in the temperature range 19-32°C. The aquifers in these wells are the flow contacts between basalts of the Columbia River Group, and the heat is provided by the regional geothermal gradient. Although the temperatures in the wells are not particularly high, the large volumes of water available should make them an attractive economic target.

BELKNAP-FOLEY

The Belknap-Foley area is located at the eastern margin of the central Western Cascade Range of Oregon, approximately 80 km (50 mi) east of Eugene (Figure 1). McKenzie Bridge, Rainbow, and Blue River are the only towns in the study area. They are very small unincorporated communities. Because few people live in the area, there is little likelihood that a large-scale heating district could be economically installed. For this reason, no drilling was done for this study, although five temperature-gradient wells were drilled to about 150 m by the Department for regional heat flow measurement in the Cascades project (Cooperative Agreement DE-FC07-79ID12044). All hot springs were sampled and a geologic map was prepared in conjunction with both the Cascades and low-temperature projects. In addition, temperature gradients in five existing wells were measured, and a geologic map at a scale of 1:62,500 was prepared.

The geology of the area is dominated by its location at the boundary between the Western Cascades and the High Cascades. Rocks at the east margin of the area are chiefly Pliocene and younger basaltic lavas of the High Cascades, but most of the area is composed of Oligocene to Miocene lavas and tuffs characteristic of the Western Cascade physiographic province.

Although there is minor folding in rocks older than about 9 m.y.B.P., the major structures in the area are a series of north-south trending normal faults. These faults are concentrated at the High Cascade-Western-Cascade physiographic boundary at Horse Creek and the upper McKenzie River and in the South Fork of the McKenzie River at Cougar Reservoir. Rocks older than about 4 m.y. are consistently offset downward toward the east in both areas. Offset at Cougar Reservoir is at least 300 m and cumulative offset across Horse Creek is about 620 m.

The Horse Creek fault zone does not cut intracanyon lavas of the High

Cascades dated at 2.05 to 3.4 m.y.B.P. The Cougar Reservoir fault zone cuts rocks dated at 13.2 m.y. but does not cut Pleistocene gravels.

Hot springs and areas of anomalously high heat flow are associated with the north-south trending faults. The hottest springs are Belknap (86.7 to 71.0°C), Bigelow (61.0°C), and Foley (80.6°C) which are along the Horse Creek fault zone. Terwilliger Hot Springs (also called Cougar Reservoir and Rider Hot Springs) is adjacent to the Cougar Reservoir fault zone and has a temperature of between 42 and 44°C. Drilling near Terwilliger Hot Springs has shown that hydrothermal water also occurs at 150 m depth about 1/2 km east of the springs in an Oligocene(?) lava.

The most reliable geothermometric calculations for the Horse Creek fault zone group indicate reservoir temperatures in the 100 to 143°C range. Similar calculations for Terwilliger Hot Springs indicate reservoir temperatures of 95 to 103°C.

Of the five wells drilled in the Belknap-Foley area, three were located along the Horse Creek fault zone and two were adjacent to the Cougar Reservoir fault zone. Where heat flow was not obviously disturbed by nearby thermal springs, regional heat flow conforms to the pattern demonstrated by Blackwell and others (1978). Heat flow increases abruptly from values of about 70 to 83 mW/m^2 (terrain-corrected gradients of 53°C/km to 52°C/km) in the Cougar Reservoir area to about 111 to 114 mW/m^2 (terrain-corrected gradients of 71 to 74°C/km) in the Horse Creek area. The area thus lies on the transition zone between low heat flow (55 mW/m^2 or below) characteristic of the Western Cascades-Willamette Valley provinces and very high heat flow (over 100 mW/m^2) characteristic of the High Cascades province. These regional gradients and heat flow values indicate that hot springs in the area probably ascend from depths of about 1.2 to 2.0 km in the Horse Creek area and about 1.6 to 1.8 km in the Cougar Reservoir area.

The best target for furhter exploration is the Horse Creek fault zone. Drilling should be aimed at intercepting either the shallow aquifers near the hot springs or possible aquifers within the fault zone at depths appropriate for the temperatures desired. At depths of about 3 km, temperatures of about 200°C can be expected. Should fluid also be present, perhaps in fractured rocks near the fault zone, then electrical generation by direct-flash technology might be possible. Electrical generation from the hot spring waters is probably possible utilizing Rankine-cycle technology. For example, 40 kilowatts of electricity will be generated at Lakeview in the summer of 1982, using freon as a working fluid, from 80°C (176°F) water. This use, and small-scale local space heating uses near the hot springs are probably the most cost-effective means of exploiting the low-temperature resources of the area. Lack of a large population or industrial base precludes large-scale district heating systems unless it is possible to pipe thermal waters to the population centers of Springfield and Eugene. An engineering study is recommended to evaluate all of these possibilities.

WILLAMETTE PASS

The Willamette Pass area is located in the central Western Cascade Range of Oregon approximately 80 km (50 mi) southeast of Eugene, Oregon, up the Willamette River drainage (Figure 1). The only town in the area is the city of Oakridge (population of 4,300).

Because it is a significant population center a substantial effort was directed at defining geothermal resources near Oakridge. Toward that goal, a 122 m city water well was deepened to 344 m, and a 150 m temperature gradient well was drilled at a fault intersection 4 km southeast of Oakridge. A geologic map at a scale of 1:62,500 and complete sampling and temperature measurement in all available springs and wells was also completed. Eighteen water samples were analyzed and seventeen temperature gradients were measured and recalculated to heat flow. Seven of the gradients were measured in holes drilled for the Cascades project.

Rocks in the area are chiefly Oligocene(?) to late Miocene lavas and tuffs with minor Pleistocene or late Pliocene intracanyon basalt flows. The Pleistocene to late Pliocene basalts come from vents in the High Cascades to the east. The lack of youthful faulting makes the location of significant fractured rocks, which could hold thermal water, very difficult. Early Miocene tholeiitic (very iron-rich) lavas which have been mapped immediately outside of the map area near Lookout Point, may, however, be permeable. These rocks, together with buried intrusive rocks may provide the best aquifers for geothermal fluids in the area. Unfortunately, owing to the complexity of the geology of the area and the short time available for mapping, the depth to these potential reservoir rocks cannot be predicted with certainty throughout much of the area. It is highly probable, however, that neither of these rock types occur beneath Oakridge. Oakridge is located in a valley cut into rocks which appear to lie stratigraphically below the tholeiitic sequence. There is also no evidence of a major volcanic or plutonic center in or adjacent to the city. Lack of significant permeability at Oakridge is underscored by the insignificant fluid found in the 344 m city well. It is however, possible that permeability may exist in areas east of Oakridge since, as discussed below, hydrothermal fluids are obviously able to circulate enough to form warm springs in three areas within 6 to 15 km east of town. These warm springs are all in or adjacent to major faults and lineations. It is thus entirely possible that similar hydrothermal systems occur in or adjacent to unexplored faults between Oakridge and the hot spring belt. One temperature gradient well in such a fault zone at Hills Creek dam, however, did not reveal any anomalous gradients or heat flow indicative of circulating hydrothermal fluids.

Three warm spring areas occur east of Oakridge. Water is 62 to 73°C at McCredie Hot Springs, 40 to 41°C at Wall Creek Hot Springs and 30 to 44°C at Kitson Hot Springs. Most reliable geothermometric calculations for the three springs indicate possible reservoir temperatures of 112-126°C, 118-125°C, and 97-110°C, respectively.

Temperature gradient and heat flow measurements in the area show that the hot springs are in the transition zone between high (over 100mW/m^2) heat flow characteristic of the High Cascades and low (55mW/m^2 and less) heat flow characteristic of the Western Cascades and Willamette Valley. Heat flow in the hot springs belt is roughly 69 to 101 mW/m^2, with a terrain-corrected gradient of about 60°C/km. Heat flow east of the hot springs belt high as 115 mW/m^2 with terrain-corrected gradients as high as 67°C/km. West of the hot springs belt at Oakridge the heat flow is about 66 to 74mW/m^2 and the terrain-corrected gradient is between 36 to 40°C/km. Oakridge is thus on the westernmost edge of the heat flow anomaly generated by the High

Cascades. The gradients at Oakridge are, however, about half as high as gradients within the main High Cascades anomaly. The transition is very sharp, occurring over a distance of about 20 km. This is an additional reason to focus exploration as far east of Oakridge as is economically feasible.

In order to attain the reservoir temperatures calculated for the warm springs, waters would have to reach depths of about 1.0 to 1.5 km in the hot springs belt. In order to encounter similar temperatures (97-125°C) under Oakridge, meteoric water would have to circulate to depths of about 2.3 to 3.0 km. If potential circulation occurs only to 1.0 to 1.5 m at Oakridge, then water with temperatures of between about 48 and 57°C should be expected at depth. If rapid circulation of water occurs laterally from the High Cascades heat flow anomaly, then higher temperature water might be found near the city. No evidence of rapid lateral circulation has, as yet, been found.

Further exploration for low-temperature at Oakridge is warranted if potential uses can justify the capital outlay. There is a high probability that potential resources will be located at least a few km east of the city. Feasibility studies should be conducted which evaluate the viability of piping thermal water to Oakridge for various end uses. Known thermal spring areas have temperatures adequate for many uses, although the high content of dissolved salts in the water at Kitson Hot Springs may preclude many uses. Similarly high salt content was noted in the small amount of water found in the 344 m well drilled at Oakridge.

POWELL BUTTES

Powell Buttes is a large elliptically shaped topographic high located in the High Lava Plains physiographic province of east central Oregon, approximately 18 km southeast of Redmond and 29 km northeast of Bend, Oregon (Figure 1).

Powell Buttes is a volcanic vent complex composed of rhyolitic, rhyodacitic, and dacitic plugs, domes, flows, and tuffs of the Oligocene John Day Formation. Although colluvium mantles the flanks of the buttes, drill holes indicate that volcaniclastic sediments, ash-flow tuffs, and basalt flows of the late Miocene to Pliocene Deschutes Formation unconformably overlie the John Day Formation over large portions of the flanks. Powell Buttes lies at the western end of the Brothers Fault Zone, a major structural feature which is considered by some writers to mark the northern terminus of the Basin and Range physiographic province in the western United States.

Although several springs are present on Powell Buttes, the warmest of these is only 18°C. The lack of naturally occurring surface thermal phenomena makes the area a true "blind" geothermal anomaly. Several warm domestic water wells are present on the north, northwest, and western sides of the buttes. The highest water temperature measured in a domestic well was 33°C, in a well located on the west flank of the buttes in the zone of highest heat flow.

The Oregon Department of Geology and Mineral Industries (DOGAMI) first became interested in the Powell Buttes area during the summer of 1978, when temperatures measured in three open holes resulted in gradients in excess of 100°C km^{-1} and bottom hole temperatures as high as 37°C. Several more holes logged during the summer of 1979 confirmed the presence of a thermal anomaly along the north and west flanks of the buttes. In 1980 DOGAMI completed an extensive water sampling program and made an intensive effort to locate and log every open well in the vicinity of Powell Buttes. In the fall of 1980 DOGAMI drilled 9 heat flow holes, mostly along the west flank of the buttes.

The drilling program culminated in February 1981 with the completion of a 460-meter borehole centered in the zone of highest heat flow. In addition to the above efforts, complete Bouguer and residual gravity and aeromagnetic maps of the Powell Buttes area were completed for DOGAMI by the Oregon State University Geophysics Group.

A total of twenty-five wells and springs were sampled and analyzed during the course of the project. The waters are unusual when compared to waters from other geothermal areas in that they are relatively "clean". Total dissolved solids are low; and Cl, which is usually present in abundance in thermal waters, is nearly nonexistent. Also somewhat unusual is the presence of high amounts of trace metals such as Cu, Ba, Zn, and Sr. Minimum reservoir temperatures, calculated using Si geothermometers, are in all cases less than 100°C.

Several conclusions can be derived from the chemical analyses of the waters at Powell Buttes. First, the waters sampled were probably never much warmer than the temperature recorded during sampling. Second, because of the very low concentrations of constituents normally associated with thermal waters, the waters at Powell Buttes have not been deeply circulated. It is more likely that they have been heated conductively by a source that lies at greater depths.

Third, the waters sampled are most probably meteoric waters which have infiltrated through the buttes, the local recharge area. The high trace metal concentrations were probably acquired from zones of hydrothermal alteration as the fluids migrated down the hydrologic dip to where they were intercepted by domestic water wells.

The geophysical anomalies associated with Powell Buttes are somewhat difficult to interpret. There are large positive Bouguer and residual gravity anomalies centered over the buttes paralleling its northeast trend. Neither block faulting nor the presence of an intrusive beneath the buttes seem sufficient in themselves to provide the mass excess required to explain the large magnitude of the anomaly. It is likely that both mechanisms are in operation.

The most surprising aspect of the aeromagnetic study at Powell Buttes is the lack of an anomaly associated with the buttes, implying that either the buttes are underlain by nonsusceptible rocks, or that the rocks are very hot. Again it is probable that both mechanisms are in operation, particularly given the silicic nature of the volcanism that has occurred at Powell Buttes and the high heat flow measured on its flanks.

Since 1978, temperature gradients have been measured in 43 drill holes in the vicinity of Powell Buttes, and heat flow values have been determined for 32 of the sites. The data delineates a closed elliptical anomaly paralleling the west side of the butte. The zone of highest heat flow lies directly downslope from a large rhyolitic exogenous dome.

Although the early data collected at Powell Buttes indicated that temperature gradients in excess of 160°C km^{-1} and heat flow values in excess of 376 mWm^{-2} were present in the high heat flow zone, later data from deeper holes (particularly the 460-meter hole drilled by DOGAMI) indicate that the average heat flow in the vicinity of Powell Buttes is 125-167 mWm^{-2} and the average temperature gradient is about 80°C km^{-1}.

There are two possible explanations for the very high temperature gradients measured at shallow depths on the west side of the butte: (1) the high gradients are the result of a combination of heat flow refraction and very low thermal conductivities in the unconsolidated colluvium mantling the flanks of the buttes, and (2) there is a slow flow of warm water in a shallow aquifer beneath the zone of highest heat flow. In this second case fractures in the rhyolitic dome just east of the high heat flow zone could be acting as a conduit for thermal fluids.

There are problems with both hypotheses. Heat flow in the Powell Buttes area is conductive. There is no evidence of large-scale convective fluid movement in any of the holes in the data set, and only rarely is there any evidence of intraborehole fluid movement. In the 9 heat flow holes drilled by DOGAMI, no aquifer of the type described was encountered, and the geochemistry of the various water samples indicates that the waters have not been deeply circulated. Finally, groundwater supply in the Powell Buttes area is a serious problem. Wells are often totally dry, and those that do produce do so at rates of only 5-10 gpm. Producing wells seem to be situated along fairly narrow fracture zones, arguing against the presence of large stratigraphic aquifers. The hypothesis is still viable, however, as the flow rates in the aquifer could be extremely low and still produce the anomaly.

The temperature-depth profile at Powell Buttes has been successfully reproduced by computer using a finite difference thermal conductivity model. The problem with this model is that to account for the high temperature gradients, extremely low thermal conductivities are required for the surface layers. The conductivities are lower than can be produced with water-rock combinations alone, requiring that the pore space in the rock be only about 70% saturated; the remaining space filled with air. While certainly possible, given the arid nature of the region, the phenomenon has not been identified in other holes in east central Oregon.

Whatever mechanism is operative, it is obvious that temperatures adequate for many direct use applications can be found at relatively shallow depths in the Powell Buttes area. The temperature at 460 meters in the DOGAMI deep test (PB-1) was 56°C. Projections of the temperature gradient indicate that 80°C would be encountered at about .8 km, and 150°C at 1.7 km.

The problem is the availability of adequate fluids. Although the temperature-depth curve for PB-1 did show one small aquifer at 425 m, significant amounts of fluids were not encountered in the hole. In general, the John Day Formation and the underlying Clarno Formation are composed of large amounts of tuffaceous rocks, which are relatively impermeable.

It is clear that efforts to produce a viable low temperature resource in the Powell Buttes area must center around the location of adequate fluids. Detailed geologic mapping and geophysics, to locate fracture permeability, and the deepening of PB-1 to locate stratigraphic aquifers (probably associated with lava flows) are the most obvious steps to take in this direction. At this point in time, the PB-1 drill site has been turned over to Francana Corporation, which plans to deepen the hole sometime in the near future. Although private industry will probably continue to explore for high temperature geothermal resources, the position of Powell Buttes within piping distance of three important towns, Bend (16 km), Prineville (8 km), and Redmond (8 km), make it a viable exploration target for direct use resources. Future exploration should be aimed at deeper drilling not only at Powell Buttes but also on youthful faults known to exist in the vicinity of Bend and Redmond (e.g. see Peterson and others, 1976). Additional temperature measurement and possible drilling should be accomplished at Prineville as well. Engineering studies should be pursued to define the amount of exploration expenditure which can be justified by expected loads and end uses.

NORTHERN HARNEY BASIN

The study area is located at the northern end of a large, circular topographic depression in the central portion of eastern Oregon known as the Harney Basin (Figure 1). The major population center is the city of Burns (a population of 3,525) and the nearby community of Hines (population of 1,575). Fifteen springs and wells were sampled, four temperature logged to a depth of 800 m, and geologic maps at both the 1:62,500 and 1:24,000 scale were produced for the area. A soil mercury survey and ground magnetometer survey were also completed. All of the raw data, except the mercury and magnetometer surveys, was published in various open file reports and in one high quality colored 1:24,000 scale geologic map of the Burns area.

The northern Harney basin was a major silicic volcanic center during the late Miocene and probably during the middle Miocene as well. Major cauldron subsidence blocks formed during eruption of voluminous soda rhyolite ash-flow sheets which covered hundreds of square miles of eastern Oregon. Interfingering with the ash flows are smaller amounts of soda rhyolite lava and basaltic lava. Volcanism since about 3.0 m.y.B.P. has been dominated by eruption of small volumes of alkaline high-alumina tholeiite. Holocene eruptions of alkali basalt at Diamond Craters near the southern margin of the study area was the last volcanic activity.

Faulting in the area follows three general trends. The first is the trend of the Brothers fault zone (N25°W to N55°W), which is exhibited most strongly immediately west of Burns. These are dip-slip faults which cut 2.3 to 2.9 m.y.B.P. basaltic andesites near Burns Butte. The second trend is that of north-south to north-northwest dip-slip faults of the Basin and Range which cut all bedrock units except the Holocene basalts. Dip-slip faults at a N40°W to N50°W in the east-central part of the area are transitional between the Brothers and Basin and Range trends.

Many of the faults have evidence of some relation to strike-slip motion. This is particularly true of faults of the Brothers fault zone which, according to Lawrence (1976) may be related to right lateral wrenching at depth. A large north-south trending fault in the Soldier Creek area at the northern margin of the basin also has evidence of lateral movement. The Soldier Creek fault is notable for its large opalized breccia zones, and because the hottest geothermal well in the area (the O.J. Thomas well) occurs 3 km east of the presumed extension of this fault at the northern margin of the basin. Brown and others (1980a) conclude that the O.J. Thomas water emanates from this fault. The Soldier Creek zone loses its aeromagnetic and gravity signature at about the latitude of Hines where a west-northwest trending structure appears in geophysical maps.

Folding of bedrock units is generally in the form of broad, shallowly dipping anticlines and synclines plunging toward the center of the basin. Exceptions are sharply folded rocks adjacent to major fault zones.

The Harney Basin appears to be the result of downwarping over a broad area. Some parts of the basin may be bounded by caldera faults, but much of the northern half of the area appears to be a broad zone of subsidence requiring very little deformation at the basin boundaries. D. D. Blackwell (personal communication) has speculated that much of this broad subsidence may be due to cooling and contraction following late Miocene silicic volcanism.

Most warm springs in the Burns area are in the 22 to 28.5°C range with calculated minimum reservoir temperatures of between 70°C and 11°C. Thermal water near the Soldier Creek fault zone possesses both higher surface temperatures (71°C) and higher calculated minimum reservoir temperatures (99-139°C).

The best example of thermal water from the Soldier Creek system is the O. J. Thomas well, which is 15.3 km east-northeast of Burns. This well yielded 11,400 liters per minute (about 3,000 gpm) of 72°C water in a pump test (this was the capacity of the pump). The Harney Development well, an old oil well south of the O. J. Thomas well (14.5 km southeast of Burns), flows about 380 liters per minute (100 gpm) of 46°C to 50°C thermal water, similar in composition to the water of the O. J. Thomas water (e.g. high total dissolved solids and boron). No pump test data is available for the Harney Development well to establish its ultimate potential flow.

Four shallow (140 m to 187 m) temperature gradient wells and one deep oil well (the Poteet well 2 km east of Burns) provided the most definitive data about temperatures and aquifers in the area. The Poteet well was temperature logged to 800 m and revealed that the background gradient at Burns is about 60° C/km with an estimated heat flow of about 92 mW/m^2. The well also showed disturbances in the conductive gradient indicative of definite thermal aquifers at 210-230 m (32°C) and 550-600 m (48°C) and a possible small aquifer at about 750 m (55°C). A 187-m well at the Hines Lumber Mill encountered a 3,800 liter per minute (1,000 gpm), 27°C aquifer at 15 to 50 m. A 164-m well drilled on the Hotchkiss Ranch, about 2.4 km (1.5 m) southwest of Hines was targeted on a soil mercury anomaly and encountered a 4- to 8-liter per minute (lpm) aquifer at 126 m, a 20-lpm aquifer at 140 m, and $\sim$20-lpm aquifer at 160 to 164 m. All of these aquifers were between 34 and 35°C and were located in ash flow tuff, loose volcanic sands, or basaltic interflow areas. Discharge rates are estimated from water blown from the well during air drilling.

Comparing the data from the above holes, it is apparent that abundant thermal water in the temperature range of 27°C to 35°C occurs at depths of 15 m to 230 m between Hines and Burns. This is also the temperature of most of the thermal springs in the area which no doubt issue from these same aquifers. Data from the Poteet well suggests that the background temperature gradient is high enough to produce this 27 to 35°C water from conductive heating at between 140 and 340 m. Water encountered in the Hines area is thus ascending from at least these depths and then flowing laterally in the layered volcanic rocks. A mapped fault at the Hotchkiss site was encountered in the drill hole and may have provided a conduit for rise of warm water there. Because the Hotchkiss site is 114 m higher in elevation than the Hines area, some water around Hines could be explained by lateral flow of water from the Hotchkiss area. The high flow rate at the Hines Lumber Mill site, however, suggests that water must be coming from other areas as well, perhaps other faults. Additional drilling will be necessary to determine the circulation pattern of these shallow aquifers at Hines. Drilling should be focused on mapped faults and probable extensions of mapped faults under the valley sediments.

The city of Burns probably has thermal aquifers at 32°C at about 210 to 230 m and at 48°C at about 550 to 600 m, based on data from the Poteet well. There is definitely abundant (380 lpm) 14°C water at Burns High School at a depth of 37 m, and an 18°C aquifer of unknown volume occurs at about 140 m at the same site. The Poteet well should be cleaned out and temperature logged below 800 m, in order to discover if other higher temperature thermal aquifers are present at depth beneath Burns. The well has a drilled depth of 1975 m. Temperatures of 100°C at about 1.5 km (5,000 ft) and 200°C at about 3.2 km (10,400 ft) would be expected beneath Burns, based on the Poteet data. There is no guarantee of fluids at these depths, however.

One way of mitigating the high cost of drilling deep at Burns for hot water would be to take advantage of possible areas of upwelling thermal water. Fault zones are often sites of upwelling. The probable southerly extension of the Soldier Creek fault between 10.5 and 14.5 km (6 to 9 mi) east of Burns apparently contains large quantities of thermal water, based on data from the O. J. Thomas well (at least 11,400 lpm, of 72°C water). Water found in this well would have to ascend from at least a depth of 1 km (3,280 ft), based on the 60° C/km Poteet gradient. If the O. J. Thomas water is from a conductively heated source at the geochemically calculated reservoir temperature (99 to 135°C), the water would have to ascend from depths of about 1.5 km to 2.0 km. This is a clear indication that a major hydrothermal circulation system must be operating east of Burns. Drilling between the O. J. Thomas well and Burns should be pursued to determine the lateral extent of the circulation system toward Burns.

Another particularly interesting site for drilling is the area approximately due east of Hines and due south of Soldier Creek, where geophysical anomalies indicate a possible intersection of the Soldier Creek structure with a west-northwest trending structure. Possible high fracture permeability in this area might allow convection of large quantities of thermal water to shallow depths.

Engineering studies should be pursued which evaluate the feasibility of drilling beneath Burns for the thermal aquifers noted in the Poteet well. Additional studies should focus on the maximum distances that resources associated with the Soldier Creek hydrothermal system could be piped. The shallow thermal aquifer at Hines should be evaluated for heat pump and cogeneration applications.

SOUTHERN HARNEY BASIN

The Harney Basin is a roughly circular basin with interior drainage to Malheur, Harney and Mud Lakes. The basin covers approximately 8,100 square miles. The small unincorporated farming communities of Crane, Princeton, and Diamond are the only population centers.

DOGAMI's study of the south Harney Basin (Figure 1) involved extensive spring sampling, gradient data accrual through the location and logging of all available open water wells, a literature search, reconnaissance mapping of eight 15' quadrangles, and the drilling of a 135 m heat flow hole at Crane School.

Thermal spring and well water geochemistry generally indicates reservoir temperatures of 100°C to 140°C by the quartz geothermometer and 100°C to 170°C by the Na-K-Ca geothermometer. Numerous thermal springs occur in the area, 22 of which were sampled for this study. The highest spring temperatures, located near Crane, were 80°C. On the basis of the chemistry, the springs can be split into two groups. The first group is centered near Crane, the second near Harney Lake. Chemical differences probably stem from the nature of the rocks these fluids are associated with at depth and subsurface residence time.

The basin was formed by regional collapse due to the eruption of voluminous ash-flow sheets from within the area. Harney Lake was one of the eruptive centers, active about 9 m.y.B.P. The last silicic volcanism occurred approximately 8 m.y.B.P., but a Holocene basaltic center, Diamond Crater, was active as recently as 15,000±2,000 years ago (Norm Peterson, 1980, personal communication, cited in Brown and others, 1980b).

The area is also in the Brothers Fault Zone, which represents the northern termination of the Basin and Range physiographic province. Basin and Range faulting occurred predominantly in the middle and late Miocene and represents east-west extension on numerous north-south trending faults. The Brothers Fault Zone trends northwesterly through the area. Fault activity associated with the Brothers Fault trend is younger than that of the Basin and Range trend in the area. The fabric of the area is predominantly northwesterly. Northwest trending faults cut the 15,000±2,000 year-old basalts of Diamond Crater (Brown and others, 1980b).

The background gradient for the south Harney Basin is 60-80°C/km, the background heat flow is 60-80 mW/m^2. These values are based on previous DOGAMI and USGS heat flow studies (Hull and others, 1977, DOGAMI 0-77-3; Sass and others, 1976) and new data from open water wells.

The deepest well logged for temperature in the area is the Poteet oil well, in the northern Harney Basin. The well is 800 m deep with a gradient of 59.8°C/km and a heat flow of 92 mW/m^2. The heat flow value is consistent with the modeling of Blackwell and others (1978) and corroborates predictions of anomalous heat flow and geothermal potential along the Brothers Fault Zone. This high-quality heat flow and gradient may be more representative of the regional background heat flow than the 60-80 mW/m^2 value, since the lower values are based on shallower measurements. Only deeper drilling will test this hypothesis adequately.

The background heat flow predicts that spring waters probably ascend from a minimum depth of one km. This indicates that hydrothermal circulation may reach at least this depth in other parts of the basin as well.

DOGAMI identified a potential geothermal resource at Crane. A heat flow hole was drilled by DOGAMI in 1981 at Crane School. The gradient was 96°C/km and the bottom hole temperature was 24.5°C at 135 m. The heat flow for the hole is approximately 148 mWm^2. Additional drilling would be needed for utilization because no large water-bearing aquifer was encountered in the hole. This gradient and heat flow are obviously very anomalous with respect to both of the above regional background estimates. It is probably necessary for background heat flow to be redistributed by convection to produce heat flow this high. Either magmatic or hydrothermal convection would suffice. It is likely that hydrothermal convection is responsible for this anomaly, since Crane is not a young volcanic center. Should this hypothesis prove correct, there could be a major hydrothermal circulation system beneath Crane. Additional shallow drilling around the Crane area should be done to determine the width of the anomaly, in order to determine its extent and to do half width calculations which can predict the depth of the anomalous heat source. Deeper drilling should then be done if the predicted drilling depths can be economically justified. Alternatively, deeper drilling could be pursued immediately to determine if the anomaly is caused by a relatively shallow aquifer of warm water.

Anomalous geothermal areas, other than hot spring locations, were found near Coyote Buttes and west of Diamond Valley, where gradients of 130-160°C/km and 88°C/km, respectively, and heat flow of 125-155 and 146 mW/m, respectively, were found. However, population densities in these areas are too low to justify exploitation unless industrial interests decide to lcoate at these sites. In terms of risk, the existing hot springs are a better choice, since hydrothermal water is readily accessible if hot spring temperatures are adequate.

DOGAMI recommends site-specific resource evaluation of several locales within the basin. Low temperature utilization would possibly be feasible for the population center of Crane and for possible light industrial/agricultural purposes elsewhere in the basin. Methods that should be used are detailed geologic mapping at large scales; detailed sampling and analysis of thermal springs and wells to determine fluid flow direction, provenance and reservoir conditions; and a drilling program to outline thermal anomalies and test geothermal aquifers. Several intermediate-depth wells (600 m) will be required to give stratigraphic control, identify aquifers at depth and enable informative pump test data to be acquired. These steps should only be taken after engineering feasibility studies have shown that development of potential resources is economically justified.

WESTERN SNAKE RIVER PLAIN

The Western Snake River Plain, as defined in this report, includes approximately 1100 square miles of eastern Oregon located in the extreme northeastern corner of Malheur County, adjacent to the state of Idaho (Figure 1). Major population centers include Ontario (and Payette, immediately across the Snake River in Idaho) in the extreme east-central portion of the area; Vale, in the west-central part of the area; and Nyssa, in the southern part of the area.

The Snake River Plain is a broad structural downwarp which extends across southern Idaho and at its western terminus into east-central Oregon. In Oregon the downwarp is filled with a series of Pliocene-Pleistocene lacustrine and fluvial sediments (often tuffaceous) which are intercalated with a few thin olivine basalt flows. These sediments, which are over 914m (3000 ft) thick throughout most of the study area, are underlain by a thick sequence of Miocene flood basalts (the Owyhee Basalt) which are considered to be time-stratigraphic equivalents with the Columbia River Group in the Columbia Plateau and the Steens Mountain Basalt in south-central Oregon.

Hot springs are common throughout the study area, with the highest temperatures being reported for Vale Hot Springs (90°C), Neal Hot Springs (88°C), Deer Butte Hot Springs (79°C), Baschon Well (69°C), and Snively Hot Springs (57°C). Nearly all of the springs are associated with normal faulting, and they appear to result from typical deep circulation systems.

The Oregon Department of Geology and Mineral Industries (DOGAMI) has gathered a considerable amount of data in the Western Snake River Plain over the last several years. The measurement of temperature gradients in open water wells has been an ongoing process since the early 1970's. In the summers of 1972 and 1973 a series of (2-3 meter) wells was drilled to investigate the possibilities of identifying geothermal anomalies by using temperature measurements from very shallow holes, and in 1975 DOGAMI drilled 5 deeper holes (62-152 m) to investigate geothermal anomalies in Cow Hollow, Willow Creek, and South Fork Jacobsen Gulch. For the present study, no new heat flow holes were drilled in the Western Snake River Plain. Instead, the emphasis was placed on spring sampling and the measurement of temperature gradients in open water wells. In addition, a detailed geologic map of the Vale East 7 1/2' quadrangle was produced. The map will be published in the summer of 1982.

A large geochemical data base, which includes all of the major hot springs in the area, now exists for the Western Snake River Plain. Geochemically the waters are typical of eastern Oregon Basin and Range fluid-dominated deep circulation systems. Calculated minimum reservoir temperatures cover a wide range, with several of the springs having at least one method of calculation resulting in a minimum temperature of greater than 150°C. The most promising of of these are Vale Hot Springs (160^{0}C), Neal Hot Springs (180^{0}), Bully Creek Warm Spring (188^{0}C), Harper Warm Spring (208^{0}C), and BLM Vine Hill well (162^{0}C).

As a result of DOGAMI efforts since the early 1970's, a considerable body of heat flow data now exists for the Western Snake River Plain. By 1980, temperature gradients had been measured in 45 holes. Additional holes, mostly in the vicinity of Vale Hot Springs, have been added since that time. These serve to give a fairly accurate picture of heat flow within the province. The average heat flow is approximately 119 mWm^{-2} and the average temperature gradient is 97.5^{0} Ckm^{-1}. The heat flow is nearly twice the worldwide average, and the temperature gradient is greater than twice the worldwide average. This is due to the insulating effect of the low thermal conductivity tuffaceous sedimentary rocks which crop out throughout the study area.

As is the case throughout much of eastern Oregon, local convective thermal anomalies are superimposed on an overall high regional heat flow. In these systems, meteoric waters penetrate to great depths and are heated by the regional geothermal gradient. When the heated waters encounter significant fracture permeability in the normal faults which cut the area, they rise rapidly with little cooling to the surface, where they emerge as hot springs.

Because of the combination of the above factors, the Western Snake River Plain has a great deal of low temperature geothermal potential. There are significant population centers, an overall high population density, and a large agricultural industry to provide loads. Because of the high regional temperature gradient ($60^{0}Ckm^{-1}$ is the minimum gradient encountered in the region), it can be expected that moderate temperature resources ($80^{0}C$-$130^{0}C$) will be encountered in the depth range 1-1.5 km. In areas where convective anomalies are present, moderate temperatures exist at depths of only a few hundred meters. Temperatures suitable for heat pump applications may be found at depths of a few tens of meters throughout the study area.

At the present time, several large-scale direct-use projects are in the operation; including greenhouses, mushroom nurseries, and an alcohol plant. The one potential problem with the development of low to moderate temperature geothermal resources in the Western Snake River Plain may be the lack of adequate fluids at depth beneath large portions of the study area. The tuffaceous sedimentary rocks which cover the area tend to be relatively impermeable. The Ore-Ida Food Comapny drilled a deep exploration hole to greater than 3000 meters in the city of Ontario; and although temperatures in excess of $175^{0}C$ were encountered at the bottom of the hole, there was no fluid production below 2000 meters. It appears that future exploration will be more concerned with locating aquifers rather than locating temperatures. The Ore-Ida well might, in fact have been successful had more attention been paid to permeability during site selection.

Vale Hot Springs is probably the best site in the area for direct-use. In a crude pump test, conducted in cooperation with the landowner, R. Butler, a shallow (30 m) well near the old swimming pool at the springs produced about 1,500 lpm (400 gpm) of 110°C (230°F) water for about ten hours. Additional drilling and pump testing around Vale Hot Springs should be done to estimate the ultimate volume and temperature of the waters. This resource could probably produce enough water to significantly offset space heating loads at the city of Vale which is within 1/4 km of the springs.

There has also been considerable high-temperature resource exploration in the area. To this point in time, private industry has concentrated its energies primarily in three areas: Bully Creek, Willow Creek, and the Cow Hollow Geothermal Anomaly. This last anomaly is a fault-controlled system extending southeastward from Vale Hot Springs, which was discovered during one of the early phases of the Oregon geothermal programs. At this time, there are plans to install a small biphase electrical generation system on a well in the Cow Hollow anomaly near Vale Hot Springs by the summer of 1982.

LAKEVIEW

The Lakeview area is located in the Basin and Range physiographic province of south-central Oregon (Figure 1). A typical Basin and Range graben-horst pair, the Goose Lake Valley on the west and the Warner Mountains on the east, make up the area. Lakeview (pop. 2,770), the only town in the region, is located in the center of the area at the foot of the Warner Range.

The geology is typical of most of the rest of the Basin and Range province in Oregon. The Goose Lake Valley is composed of unconsolidated Pleistocene to Holocene lacustrine and fluvial sedimentary deposits which are as much as 1,524 m (5,000 ft) thick in the center of the basin. The Warner Range, in the vicinity of Lakeview, is composed of volcanic and volcaniclastic rocks which range in age from Oligocene(?) to Pleistocene(?) rhyodacitic exogenous domes and flows and mafic vent complexes.

The dominant structure in the area is the essentially north-south normal fault that separates Goose Lake Valley from the Warner Mountains. It is vertical or steeply westward dipping and, where exposed in the vicinity of Lakeview, is characterized by a breccia zone as much as 50 feet in width. The earliest fault movement probably occurred in the early Pliocene, and most of the movement on the fault took place before glaciation affected the higher peaks in the Warner Range, although Pleistocene terrace material is faulted north of Lakeview.

Surface or near surface thermal phenomena are associated with this normal fault in three separate parts of the study area. The hottest is the Leach Hot Well area just north of Lakeview, where a bottom hole temperature of 112.7°C was measured in a 120-m hole. At Barry Ranch Warm Spring in the central part of the study area, a temperature of 75.7°C was measured in a 73-m hole, and at the Rockford Ranch, in the southern part of the study area, a temperature of 69.9°C was measured in a 415-m hole.

The Oregon Department of Geology and Mineral Industries' (DOGAMI) effort in the Lakeview area consisted of a limited spring sampling program, the measurement of temperature gradients in existing, open drill holes, and a nine-hole drilling program. In addition, a complete Bouguer anomaly map was completed for DOGAMI by the Oregon State University Geophysics Group.

Twenty thermal springs were sampled, and these, when combined with existing published analyses, resulted in a total of 27 analyses available for the calculation of minimum reservoir temperatures. In general, the calculated minimum reservoir temperatures fall in the 100-150°C range.

Of the nine holes drilled by DOGAMI in the Lakeview area, three were located in Hammersly Canyon adjacent to the Leach Hot Well thermal area, three were located in Bullard Canyon, immediately west of the town of Lakeview, one was near the Precision Pine Company just north of the town, one was in the town itself, and one was near Barry Ranch Hot Springs.

In addition to the nine holes drilled by DOGAMI specifically for heat flow purposes, temperature gradients were measured in 31 open water wells. The heat flow pattern which emerges is typical of the Basin and Range Province throughout the western United States. The high regional heat flow (approximately 100 mW/m^2) is modified by thermal refraction, erosion, sedimentation, and hydrologic effects. These factors interact in a complex manner, with the overall result being that higher heat flow values are typically measured in the range blocks immediately adjacent to the bounding normal faults than are measured in the adjacent valleys. Superimposed on the high regional heat flow are local, higher temperature anomalies which result from the circulation of thermal fluids up permeable zones in the normal faults. Frequently the higher temperature anomalies are localized by the intersection of cross faults with the range bounding normal faults.

The holes in the Leach Hot well area demonstrated that the actual upflow of geothermal fluids occurs within the range block, and that heat flow is at least three times the regional value for a distance of 1 1/2 km into the range. One of the holes encountered 99°C water at a depth of 45 m. A later hole drilled to 208 m by Northwest Geothermal Corporation adjacent to this hole found no increase in temperature at the deeper depth.

In the town of Lakeview itself, temperature gradients and heat flow values are lower, only about 50% greater than regional values.

It appears that the heat requirements of the town of Lakeview may possibly be satisfied with water from geothermal systems located within 8 km of the town. The Northwest Geothermal Corporation (a subsidiary of Northwest Natural Gas Company) was given a 30-year franchise by the city to build and operate a district geothermal heating system. The company has been waiting for some large year-round industrial loads or a construction subsidy before beginning construction.

In addition to low temperature uses, there are temperatures in the Lakeview area adequate for the generation of electricity using biphase technology. A 40-kw Ranking Cycle generator utilizing 80°C fluid has recently commenced operation on the Rockford Ranch.

ALVORD VALLEY

The Alvord Valley lies in the Basin and Range physiographic province of southeastern Oregon and northeastern Nevada (Figure 1). It is a north- to northeast-trending graben valley that is flanked on the west by the Steens Mountains in Oregon and the Pueblo Mountains in Nevada, and on the southeast by the Trout Creek Mountains. The valley is approximately 113 kilometers long and has a maximum width of about 16 kilometers near the Alvord Desert.

The rocks of the Steens Mountains are composed of a series of volcanic flows and volcaniclastic rocks which range in age from lower Miocene to early(?) Pliocene. The Alvord Valley is composed of a series of Pliocene-Pleistocene to Holocene unconsolidated lacustrine and fluvial deposits.

Structurally the area is dominated by the large north- to northeast-trending vertical to steeply eastward dipping normal fault which separates the Steens Mountains from Alvord Valley. Displacements on the fault are estimated to be as much as 1000 feet, most of which occurred before the onset of glaciation. The slight uplift of some Quaternary alluvial fans is an indication faulting is an ongoing process.

Surface thermal phenomena are associated with the range-bounding normal fault at Mickey Hot Springs, in the northern part of the area, at Alvord hot spring west of the Alvord Desert in the central part of the area, at Borax Lake Hot Springs in the south central portion of the area, and at Pedro Springs in the southern part of the area just west of Fields, Oregon.

The Department of Geology and Mineral Industries (DOGAMI) effort in Alvord Valley was confined to limited spring sampling and the measurement of temperature gradients in existing wells. In all, six springs were sampled and their waters analyzed. When combined with previously published data, a total of twenty-seven analyses was available for evaluation. Calculated minimum reservoir temperatures covered a wide range, with the maximums being a 330°C estimate for Mickey Hot Springs and a 252°C estimate for Alvord Hot Springs.

Due to the sparsely settled nature of the study area, there are few open holes available for the measurement of temperature gradients. The heat flow, however, appears to be typical of other parts of the Basin and Range Province in the western United States, where local convective thermal anomalies are superimposed on high regional heat flow values of approximately 100 mWm^{-2}. The convective anomalies result from the rapid ascent of thermal waters in zones of fracture permeability in the range bounding normal faults. The fracture permeability often results from the intersection of cross faults with the range-bounding normal faults. This appears to be the situation in the Alvord Valley, where previously published geophysical data indicate the presence of faults beneath Mickey Hot Springs, Alvord Hot Springs, and Borax Lake Hot Springs.

Given the sparsely settled nature of the Alvord Valley (less than 1 person per square mile), the potential for the use of low temperature geothermal fluids is not significant. Although the required temperatures and fluid flow rates are present for direct use applications, the population densities required to attract industrial users or establish heating districts are not.

This is not the case with respect to electrical generation potential. The high minimum estimated reservoir temperatures at Mickey Hot Springs and Alvord Lake Hot Springs have attracted considerable industry interest over the last few years, and exploration by the private sector is still pressing forward at the present time.

McDERMITT

The McDermitt area is located in the extreme southeast corner of Oregon (Figure 1). The town of McDermitt just across the state line in Nevada is the only population center in the area.

The McDermitt caldera was a major Miocene eruptive center. Five large overlapping collapse structures with resurgent domes and ring dikes have been identified by workers in the area. Two of the calderas partially extend into Oregon's extreme southeast corner. Volcanism centered in the area was very silicic. Rhyolites, alkali rhyolites, trachyandesites, quartz latites, dacites and ash-flow sheets of these compositions were all erupted in the area. Volcanic activity occurred between 15 and 18 m.y.B.P.

Thermal springs with recorded temperatures of 53.5^{o}C, 52^{o}C, 32^{o}C, 25^{o}C, and 35^{o}C and an artesian well flowing at 46^{o}C are associated with the caldera structures within Oregon. Geochemical analysis of the springs indicates reservoir temperatures of approximately 100-130^{o}C.

Mineral deposits of mecury, uranium, and lithium are found at the caldera margins. None of the Oregon deposits are currently being worked, but others in Nevada associated with the same McDermitt caldera structures are the largest mecury deposits in the United States and are currently in production. Chemical analyses of rocks of the area indicate rhyolitic and alkali rhyolitic magmas enriched in mecury, uranium and lithium were probably the source for subsequent mineralization by epithermal hydrothermal fluids. The highest uranium concentrations are located in rhyolitic ring dikes and domes although there are also anomalous concentrations of uranium associated with mercury deposits.

Local heat flow is greater than 100 mW/m^2 (Blackwell and others, 1978). The thermal anomaly and springs of the McDermitt area may be generated by a combination of the locally high radioactivity with the very low conductivity of the silicic pyroclastic rocks. Thermal springs may occur where faulting or fracturing has provided channelways for heated waters to rise to the surface.

Low temperature geothermal utilization in the McDermitt area has low potential due to the very low population density of the area. Distances between residences preclude formation of a heating district, and light industry is not likely to locate in an area so remote with relatively little transportation access and through-traffic. Potential utilization of thermal waters in the McDermitt area seems to be restricted to individual ranch resources and needs, unless high-temperature fluids, adequate for electrical generation, can be found. The high heat flow and faulted nature of the rocks in the area are favorable for such resources.

ACKNOWLEDGEMENTS

This paper is the culmination of a unique and rapidly disappearing geothermal research program sponsored and formulated by the United States Department of Energy (USDOE). USDOE should be given credit for their far-sighted approach to stimulating the development of the vast low-temperature geothermal resources of the United States. For the first time the small developer, who is the main user of low temperature geothermal resources, has at his disposal high quality data sets and reports which can be utilized to mitigate the high risk of exploration. In addition, this program has allowed, with its emphasis on state participation, the development of highly trained geothermal exploration and utilization teams which have served the small developers and the states in general. The state-coupled geothermal assessment has been a successful and highly rewarding project which demonstrates the efficiency of state-implemented federal programs.

SELECTED REFERENCES

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.

Brown, D. E., McLean, G. D., and Black, G. L., 1980a, Preliminary geology and geothermal resource potential of the northern Harney Basin: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-6, 52 p.

Brown, D. E., McLean, G. D., and Black, G. L., 1980b, Preliminary geology and geothermal resources of the southern Harney Basin: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-7, 90 p.

Hammond, P. E., 1980, Reconnaissance geologic map and cross-sections of southern Washington Cascade Range latitude 45°30'-47°15' N., longitude 120°45'-122°22.5' W.: Portland, Oreg., Portland State University Earth Sciences Department, scale 1:125,000.

Hull, D. A., Blackwell, D. D., Bowen, R. G., and Peterson, N. V., 1977, Heat-flow study of the Brothers fault zone, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-77-3, 43 p.

Lawrence, R. D., 1976, Strike-slip faulting terminates the Basin and Range province in Oregon: Geological Society of America Bulletin, v. 87, p. 846-850.

Peterson, N. V., Groh, E. A., and Taylor, E. M., 1976, Geology and mineral resources of Deschutes County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin, no. 89, 66 p.

Sass, J. H., Lachenbruch, A. H., Munroe, R. J., Green, G. W., and Moses, T. H., Jr., 1971, Heat flow in the western United States: Journal of Geophysical Research, v. 76, no. 26, p. 6376-6413.

STATE: Oregon (State of)

ORGANIZATION: Dept. Geology and Mineral Industries PHONE: (503) 229-5580

PRINCIPAL INVESTIGATOR/CONTACT: George Priest, Don Hull, Dave Brown

CONTRACT NO.: DE-FC07-79ET27220 DATE: 6/15/79

EST. COMPLETION: 12/31/80 ORIGINAL AMOUNT OBLIGATED DOE: 231,491

CONTRACTOR: 25,735

TOTAL: 257,226

MODIFICATIONS:

NUMBER	DATE	DESCRIPTION	AMOUNT DOE	AMOUNT CONTRACTOR
001	6/22/79	:Increase Funding	$ 6,752	-
002	12/4/79	:Increase Funding (Publish and distribute Geologic Map #11)	$ 10,000	
003	5/22/80	:Add Tasks, Funding and Time to 5/21/81--Reporting per CR-537	$400,000	$23,865
004	6/2/81	:Revise Responsibilities, Add Tasks and Funds, T.E. to 5/21/82	$274,492	$30,499
			$922,735	$80,099
005	3/8/82	:Reduce DOE Funds	(70,000)	-
			$852,735	$80,099
		Total Cost	$932,834	

DELIVERABLE STATUS:

TASK NO.	DESCRIPTION	DATE DUE	RECEIVED
1/MOD 0	Phase I Data Compilation (Belknap-Foley, Williamette Pass, Craig Mt. Cove, Western Snake River Plain, Glass Buttes, N. & S. Harney Basins Alvord and Lakeview	9/22/80	Yes 1980
2/ " "	Geologic Mapping of 8 Areas in Task 1	12/31/80	Yes 1980
3/ " "	Temp. Grad. Study: Minimum of 4-500' Holes Each Area	9/22/80	Yes 1980
4/ " "	Geochem Analysis of Samples From Study Areas and Submission to Geotherm File	9/22/80	Yes 1980
5/MOD 3	Compile Data, Geol., Geochem., Geophys., Heat Flow: Parkdale, Walla Walla, and McDermitt Areas	5/21/81	Yes 1980
6/ " "	Geologic Map--Task 5 Areas--Lineament Map Also	"	"
7/ " "	Temp. Grad. Study: Belknap-Foley, Williamette Pass, Parkdale and Harvey Basin-Drilling as Req'd and Water Sampling	"	"

CONTRACT COMPLETION DATE: July 1, 1982

TOTAL FUNDS EXPENDED DOE: $922,735

CONTRACTOR: $ 80,999

TOTAL: $932,834

STATE: Oregon (State of) CONTRACT NO.: DE-FC07-79ET27220

DELIVERABLES STATUS (CONT'D)

TASK NO.	DESCRIPTION	DATE DUE	DATE RECEIVED
9/MOD 3	State Wide Recon. Update DOGAMI and Geotherm	5/21/81	Yes 1981
10/" "	Reporting per Revised CR-537--Publications		Yes 1981
11/MOD 4	Refine Geol. Maps for N. Harney Basin, Parkdale, W. Snake River Plain and, if Possible, Lakeview Areas	5/22/82	Yes 1982
12/" "	Add. Recon. S. Central Cascades, Basin and Range Province, Structural Basins of Columbia Plateau and Portland-Clakmas River Area	5/22/82	Yes 1982
13/" "	Assess Corbett-Camp Collins Area	"	" "
14/" "	Summary Assessment of Task 11 Areas	"	7/1/82
15/" "	State Geothermal Map W/NOAA	"	7/1/82
16/" "	Reports Per CR-537 and Geol. Maps and Reports for Task II Areas; Statewide Recon. Summary Report; Summary Report for Areas Also Studied Earlier		Yes 1982 7/1/82

Also:

See attached list of publications which cover all of the areas called out in Tasks 1 through 16, state geothermal map approved for printing July 1, 1982. Publication/Distribution expected by Mid-August 1982.

Publications list taken from "Final Technical Report, Oregon Low Temperature Resource Assessment Program", G. R. Priest, et al., published July, 1982.

INTRODUCTION

This report is the summary and conclusions of an investigation of low-temperature (20 to 90° C) geothermal resources begun May 23, 1979 by the Oregon Department of Geology and Mineral Industries (DOGAMI) with support from the United States Department of Energy (USDOE) under Cooperative Agreement No. DE-FC07-79ET27220. The report summarizes low-temperature resource assessment data generated for the following project areas (Figure 1):

1. Corbett-Moffett
2. Parkdale
3. Milton-Freewater
4. La Grande (Craig Mountain-Cove area)
5. Belknap-Foley Hot Springs
6. Willamette Pass
7. Powell Buttes
8. Northern Harney Basin
9. Southern Harney Basin
10. Western Snake River Plain
11. Lakeview
12. Alvord Desert
13. McDermitt

Raw data and preliminary conclusions for these areas are included in the following published DOGAMI reports and maps and will not be included here:

1. Heat flow of Oregon: Special Paper 4, 1978, includes 1 map.
2. Geothermal gradient data for Oregon: Open-File Report 0-78-4, 1978.
3. Chemical analyses of thermal springs and wells in Oregon: Open-File Report 0-79-3, 1979.
4. Geology of the La Grande area, Oregon: Special Paper 6, 1980, includes 1 map.
5. Preliminary geology and geothermal resource potential of the Belknap-Foley area: Open-File Report 0-80-2, 1980, includes 1 map.

6. Preliminary geology and geothermal resource potential of the Willamette Pass area: Open-File Report 0-80-3, 1980, includes 1 map.
7. Preliminary geology and geothermal resource potential of the Craig Mountain Cove area: Open-File Report 0-80-4, includes 1 map.
8. Preliminary geology and geothermal resource potential of the western Snake River Plain: Open-File Report 0-80-5, 1980, includes 4 maps.
9. Preliminary geology and geothermal resource potential of the northern Harney Basin: Open-File Report 0-80-6, 1980, includes 4 maps.
10. Preliminary geology and geothermal resource potential of the southern Harney Basin: Open-File Report 0-80-7, 1980, includes 8 maps.
11. Preliminary geology and geothermal resource potential of the Powell Buttes area: Open-File Report 0-80-8, 1980, includes 1 map.
12. Preliminary geology and geothermal resource potential of the Lakeview area: Open-File Report 0-80-9, includes 2 maps.
13. Preliminary geology and geothermal resource potential of the Alvord Desert area: Open-File Report 0-80-10, 1980, includes 2 maps.
14. Progress report on activities of the low-temperature resource-assessment program 1979-80: Open File Report 0-80-14.
15. Geothermal gradient data for Oregon for 1978: Open-File Report 0-81-3A.
16. Geothermal gradient data for Oregon for 1979: Open-File Report 0-81-3B.
17. Geothermal gradient data for Oregon for 1980: Open-File Report 0-81-3C.
18. Map showing geology and geothermal resources of the southern half of the Burns 15' Quadrangle: GMS 20, in press.
19. Map showing geology and geothermal resources of the Vale East 7 1/2' Quadrangle, Oregon: GMS 21, in press.

20. Geothermal gradient data for Oregon for 1981: Open-File Report O-82-4.

The Department is continuing its resource assessment efforts in other areas throughout Oregon with concentration on the Cascades. Resource assessment data will soon be available in open file for the low-temperature resources of Ashland, Oregon when a 1982 drilling program is completed under contract DE-FC07-79ID12044. Preliminary conclusions concerning the Klamath Falls and Bend areas will also be available in an upcoming special paper on the geology and geothermal resources of the Oregon Cascades (DOGAMI Special Paper 15). A preliminary summary of this paper will be included in the conference proceedings volume for the 1982 USDOE-sponsored conference at Salt Lake City, Utah. A similar paper, aimed primarily at a summary of the data gathered at Powell Buttes, was presented in the 1981 USDOE conference at Glenwood Springs, Colorado (see DOE/ID/120-79-39, ESL-59, published by the Earth Science Laboratory, University of Utah Research Institute, Salt Lake City, Utah).

OREGON
ET27220
[COMPLETED 7/1/82
SEE SUMMARY.]

ID FORM-182
(Rev. 10-77)

U. S. DEPARTMENT OF ENERGY

COOPERATIVE AGREEMENT

PURSUANT TO AUTHORITY OF PL 93-410, PL 93-438, PL 93-473, PL 93-577, and PL 95-91

1.a. Agreement No.
DE-FC07-79ET27220

1.b. Modification No.

2. Agreement Period
From: 5/23/79 To: 12/31/80

3. Participant Name and Address
State of Oregon
Department of Geology and Mineral Industries
1069 State Office Building
Portland, Oregon 97201

4. Participant Type
☐ Educational ☐ Nonprofit
☒ State or Local Government ☐ Profit

5. Project Title
Low Temperature Geothermal Resource Assessment - Phase II

6. Project Will Be Conducted Per
See Article II

7. Technical Reports Are Required
See Article VII

8. Principal Investigator(s) or Program Director(s) Name and Address
Donald A. Hull
State of Oregon, Department of Geology and Mineral Industries
1069 State Office Building
Portland, Oregon 97201 Telephone: 503-229-5580

9. DOE Program Officer (Name and Address)
Leland L. Mink, Energy & Technology Division, DOE-ID
550 Second Street
Idaho Falls, Idaho 83401
Telephone No. 208-526-0638

10. Accounting and Appropriation Data
89X0210.91

11. Method of Payment
☐ % At Award. % When Requested. 5% Upon Receipt of Final Report
☐ Letter of Credit ☐ Reimbursement
☒ Other (specify) See Article IV

12. Submit Vouchers, if any, to Agreements Officer Unless Otherwise Specified in this Block Director, Contracts Management Division, DOE-ID, 550 Second Street, Idaho Falls, Idaho 83401

13. Funding Sources

Source	Amount
DOE:	$ 231,491.00
Participant:	$ 25,735.00
Total Funding:	$ 257,226.00

14. Remarks:

Precontract Cost Letter	$136,000.00
This Action	95,491.00
Total	$231,491.00

15. Amount Obligated By This Action $ 95,491.00

16. DOE Issuing Office (Name and Address)
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

17. DOE Cooperative Agreements Officer
John C. Basalo 6-15-79
(Signature) (Date)
Acting Manager, for
Name (typed) C. E. Williams
Title Manager
Telephone No. 208-526-1322

18. Participant Acceptance State of Oregon Department of Geology and Mineral Industries
By Donald A. Hull 6/22/79
Signature of Authorized Official
Name (typed) Donald A. Hull
Title State Geologist

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050479
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Cooperative Agreement No. DE-FC07-79ET27220

COOPERATIVE AGREEMENT

THIS AGREEMENT, entered into the 22nd day of June 1979 (effective as of the 23rd day of May 1979), by and between the UNITED STATES OF AMERICA (hereinafter called the "Government"), acting through the DEPARTMENT OF ENERGY (hereinafter called "DOE") with its Idaho Operations Office located at 550 Second Street in Idaho Falls, Idaho 83401, and the STATE OF OREGON, DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES (hereinafter called the "Participant") located at Portland, Oregon;

WITNESSETH THAT:

WHEREAS, the Government is interested in an inventory and assessment of geothermal resources in Oregon and funded Phase I of the project under separate contract; and

WHEREAS, the Participant has submitted an unsolicited proposal and proposed to undertake Phase II of the Low Temperature Geothermal Resource Assessment and DOE desires to provide certain financial assistance for the accomplishment of such a program; and

WHEREAS, this Agreement is authorized by the Department of Energy Organization Act (Public Law 95-91), Sections 7(a)(2) and 8 of Public Law 93-577, and Sections 103(5), and 107(a) of Public Law 93-438;

NOW, THEREFORE, DOE and the Participant agree as follows:

ARTICLE I - STATEMENT OF JOINT OBJECTIVE

The direct application of geothermal energy at various sites located within Oregon can be a significant factor in the Government's efforts to achieve energy independence. The research provided for in this Agreement is important to both the Government and the Participant for estimating the potential of geothermal energy utilization and for fostering its use in Oregon.

ARTICLE II - DESCRIPTION OF RESPONSIBILITIES

The Participant is responsible to assure that the research is accomplished in a manner consistent with the provisions of this Agreement. The Participant's proposal identified as "Low Temperature Geothermal Resource Assessment, Phase II," as it may have been amended, is made a part of this Agreement by this reference; however, if there is any conflict between the content of the proposal and the content of this Agreement, the content of this Agreement governs. The following specific tasks provided for in the proposal are to be accomplished:

ARTICLE II - DESCRIPTION OF RESPONSIBILITIES (Cont'd)

Task 1 - Data Compilation

Available published geological, geophysical, geochemical, and heat flow data for the low temperature resource areas identified in Phase I (Belknap-Foley, Williamette Pass, Craig Mountain-Cove, Western Snake River Plain, Glass Buttes, Northern and Southern Harney Basins, Alvord and Lakeview (Fig. 2) will be compiled as a basis for determining which additional studies may be needed to complete the process for site selection.

Task 2 - Geologic Mapping

Initital assessment of the nine resource areas will consist, in part, of geologic mapping and air-photo and imagery interpretation.

A geologic map, at an appropriate scale, extending into adjacent areas, based on field mapping and air-photo interpretation, will be produced for each resource area. The map will also depict all known major structure or trends as well as surface geothermal manifestations. Cross-sections based on available geologic data will be drawn through the resource areas so that a three-dimensional presentation can be made.

Besides black and white, color and color infrared (IR) photos, air-photo studies will involve the interpretation of SLAR, LANDSAT (ERTS), NATA U-2 and Apollo imagery, as available. Data obtained will be utilized to produce a lineament map for each of the resource areas.

Task 3 - Temperature Gradient Study

It is currently anticipated that a minimum of four (4) 500-foot (156 m) deep, heat flow holes be drilled in each resource area. However, site conditions may dictate that a lesser or greater number of such holes be drilled. It is contemplated that the heat holes should not be any deeper than that expressed above, but there may be a possibility that intermediate depth gradient holes, up to 2,000 feet, may be a necessity.

A suite of logs will be taken in each heat flow hole including temperature, resistivity, self-potential, and natural gamma. Whatever "scrounge" holes may be located within the resource areas; i.e., water wells, oil-test wells, mineral exploratory holes, etc., temperature gradients will be measured for these holes. These data will complement that obtained from the heat flow holes.

ARTICLE II - DESCRIPTION OF RESPONSIBILITIES (Cont'd)

Two sites will be investigated during the initial term of the Agreement These include the La Grande and Lakeview areas. A third site, the Ontario area, will be studies for possible inclusion into this task.

Task 4 - Geochemistry

During the Phase I investigation, available thermal springs and wells in Oregon were sampled, water analyses determined, and geothermometry computed. This process will continue for the resource areas for additional wells and springs that may not have been included in the previous study by virtue of their availability. If thermal or saline fluids are encountered in the heat flow holes, samples of these fluids obtained by either wire-line sampling gear or drill stem testing will undergo chemical analyses and geothermometric evaluation. These data also will be submitted to the USGS, Menlo Park, California, for their inclusion in the GEOTHERM data base.

The Participant is also responsible for cost-sharing to the extent provided for in Article III, "Financial Support of the Project."

ARTICLE III - FINANCIAL SUPPORT OF THE PROJECT

A. The total estimated cost of performing the work under this Agreement is Two Hundred Fity-Seven Thousand Two Hundred Twenty-Six Dollars ($257,226.00) including One Hundred Thirty-Six Thousand Dollars ($136,000.00) authorized by pre-contract cost letter. The Participant shall be reimbursed by DOE for not more than 90% of the costs of the project determined to be allowable in accordance with Article A-I of the General Provisions entitled "Allowable Costs." The remaining 10% or more of the costs of the project so determined shall constitute the Participant's share for which it will not be reimbursed by DOE. The total cost to DOE is hereby established as Two Hundred Thirty-One Thousand Four Hundred Ninety-One Dollars ($231,491.00), and this amount is also the maximum amount of the project which is subject to reimbursement by DOE unless such maximum cost is changed in writing by the Contracting Officer.

B. In regard to any increase or decrease in the total estimated cost of this Agreement, as a result of any change in the original Statement of Work, as may be agreed upon by the parties during the term of this Agreement, the appropriate sharing of the funding, if any, of such increase or decrease shall be shared at the ratio of 90% DOE, 10% Participant, as agreed upon above.

C. The amount of funds obligated under this Agreement by DOE for the period from May 23, 1979 through December 31, 1980 is Two Hundred Thirty-One Thousand Four Hundred Ninety-One Dollars ($231,491.00). Funding for continuation of the project in future years will be provided when and if available.

ARTICLE IV - METHOD AND BASIS OF PAYMENT

A. Once each month the Participant shall submit an invoice to DOE supported by a detailed statement of current costs incurred for performance of work under this Agreement and claimed to constitute allowable costs. Allowable costs will be determined in accordance with Article A-I of Appendix A. If any of the costs included in the monthly invoice are determined to be unallowable, the invoice will be adjusted. DOE will pay invoices promptly.

B. Final payment will not be made until the Final Report is received and accepted by the Contracting Officer. In no event will the final 5% of the amount of obligated funds be paid to the Participant until DOE has received the Final Report and the Final Cost Report described in Article VII.A. of this Agreement.

ARTICLE V - TERM OF AGREEMENT

The work under the Low Temperature Geothermal Resource Assessment, Phase II project is anticipated to take several years. The Participant has submitted a proposal for funding for each of the first three years. The initial term of this Agreement is the first year from May 23, 1979 through May 22, 1980, for Tasks 1, 3 and 4 and through December 31, 1980 for Task 2. The term of this Agreement may be extended as mutually agreed upon by DOE and the Participant.

ARTICLE VI - PROJECT MANAGEMENT

A. In addition to DOE personnel, the Participant agrees to permit non-DOE personnel who are under contract with DOE, and identified from time to time by the Contracting Officer, to assist the DOE representative in performance of his duties and to have necessary access to the Participant's and major subcontractors' records pertaining to the project. DOE correspondence, if any, with subcontractors shall be routed through the Participant.

B. (1) DOE's Program Officer on this project and the person who shall be the Participant's contact for all matters pertaining to this Agreement shall be the following-named person or such other person(s) as may be designated by the Contracting Officer:

Leland L. Mink
Energy and Technology Division
Idaho Operations Office, DOE
550 Second Street
Idaho Falls, Idaho 83401
Telephone 208-526-0638

ARTICLE VI - PROJECT MANAGEMENT (Cont'd)

(2) The Participant's Project Director for the work under this Agreement will be the following person or such other person(s) as may be mutually acceptable to the parties:

Donald A. Hull
Principal Investigator
State of Oregon
Department of Geology and Mineral Industries
1069 State Office Building
Portland, Oregon 97201
Telephone 503-229-5580

C. The term "DOE" means the United States Department of Energy.

D. The term "Contracting Officer" means the person executing this Agreement on behalf of DOE, and includes his successors or any duly authorized representative of such person.

ARTICLE VII - PROJECT INFORMATION

A. All Project Information Reports, as required by DOE Uniform Contractor Reporting System, Volume 1, dated September 1978, and as indicated on the attached DOE Form CR-537, shall be submitted to the DOE Program Officer in accordance with the special instructions.

B. The Final Technical Report shall be due at the end of DOE's support for the project. DOE will advise the Participant one hundred eighty (180) days in advance of termination of support for the project and the Final Technical Report shall be due as noted in the special instructions.

C. Quarterly progress meetings will be held which the Participant is required to attend. DOE will fund travel expenses for one member of the Participant's team.

ARTICLE VIII - CHANGES AND MODIFICATIONS

Any changes or modifications to this Agreement or in the scope of work to be performed shall be made by mutual written agreement of the parties. A change may be initiated by either party to this Agreement. The Contracting Officer shall have the authority to determine what constitutes a change.

ARTICLE IX - TERMINATION

A. It is the express intent of DOE and the Participant to fund their respective cost participation for the work set forth in this Agreement.

ARTICLE IX - TERMINATION (Cont'd)

B. Notwithstanding the foregoing, it is understood that DOE or the Participant may at any time upon giving sixty (60) days prior written notice to the other party terminate this Agreement for its convenience for any reason.

C. In the event of termination, it is expected that the parties will cooperate with each other to reasonably phase out the Participant's costs and cost commitments, including cost liabilities to third parties; provided, however, that the total amount obligated by the Government under this Agreement shall not be exceeded. Moreover, upon any such termination the Participant agrees to promptly, upon DOE's request, transfer to DOE all information resulting from the work performed to the date of the termination notice.

D. In the event of termination, the Government agrees to pay the Participant all allowable costs incurred prior to receipt of the termination notice, and the Participant after receipt of the termination notice shall:

(1) Place no further orders or subcontracts for materials, services, or facilities intended to be invoiced to the Government for its contribution.

(2) Cancel all orders and subcontracts to the extent that they relate to the performance of work terminated by the Notice of Termination and intended to be invoiced to the Government for its contribution.

(3) Notwithstanding subparagraphs D.(1) and (2) above, the Participant has the right to proceed with such orders and subcontracts should it decide to continue performance of the work at its expense only.

E. After a termination, the Participant shall submit to the Contracting Officer its termination claim. Such claim shall be submitted promptly but in no event later than one (1) year from the effective date of termination unless one or more extensions in writing are granted by the Contracting Officer. Upon failure of the Participant to submit its termination claim within the time allowed, the Contracting Officer may determine, on the basis of information available to him, the amount, if any, due to the Participant by reason of the termination and shall thereupon pay to the Participant the amount so determined.

F. Costs claimed, agreed to, or determined pursuant to this article must constitute allowable costs as defined in Article A-1 of the Appendix A of this Agreement.

G. Any termination notice rendered by either DOE or the Participant shall be sent by registered mail with return receipt requested.

ARTICLE X - LIABILITY AND INDEMNIFICATION

The Government will not be liable for payment of damages for injuries to any person, or loss of life or personal property, or loss suffered or sustained and arising from the work performed under this Agreement. The Participant agrees to indemnify and save the Government harmless from any and all claims, demands, damages, actions, costs, or charges against the Government arising as the result of the above-mentioned injuries, damages, or loss, except for any such damages or claims arising out of the negligent act of the Government or its employees in the course of their official duties.

ARTICLE XI - USE OF INFORMATION

All data and information generated, derived or obtained from the activities provided for herein, and this Agreement, will be public information.

ARTICLE XII - DATE OF INCURRENCE OF COSTS

The Participant shall be entitled to reimbursement for costs incurred in an amount not to exceed One Hundred Thirty-Six Thousand Dollars ($136,000.00) on or after May 23, 1979, which, if incurred after this Agreement had been entered into, would have been reimbursable under the provisions of this Agreement.

ARTICLE XIII - ADDITIONAL AGREEMENT PROVISIONS

Appendix A, attached hereto and made a part hereof, sets forth additional general provisions of this Agreement.

Phone conversation 6/13/78
verifying budget & scope

OREGON CASCADES STUDY BY DOGAMI
REVISED COSTS 6/11/79

TASK	Job Title	FY 79 DOE proposed $ ORIGINAL	FY 79 DOE REVISED	Whole DOE COSTS 3yrs (REVISED)	Whole DOGAMI COSTS (REVISED)	FY79 DOGAMI COSTS (REVISED)	Whole total CONTRIBUTIO (REVISED)
I	Geology	107,299 fault lineament	⇓ 116,115 <20,000>	⇓ 116,115	9,523	9,523	125,638
II	Tectonic Study	20,000	20,000	34,166	-0-	-0-	34,166
III	Heat Flow Drilling	200,000	308,820 <28,000>	757,587	52,375	19,045	809,962
IV	Geochemistry	17,128	20,557	49,601	-0-	-0-	49,601
V	Publication	-0-	-0-	30,361	-0-	-0-	30,361
VI	Aero. & Gravity North	55,790	<65,107>	450,894	-0-	-0-	450,894
VII	Aero. & Gravity South	169,650	197,982	347,358	-0-	-0-	347,358
	Revised Totals	——	728,581	1,786,082	61,898	28,568	1,847,98[illegible]
	Original Totals	569,867	569,867	1,640,532	68,905	28,905	1,709,43[illegible]
	$ Changes	——	158,714	145,550	< 7,007>	< 337>	138,543

Reasons for changes in cost proposal, in order of significance:
1. Direct labor, OH, and subcontract costs higher than originally expected. All $200K went to subcontra[cts]
2. DOGAMI G&A neglected to be applied to large subcontracts (Tasks VI and III)
3. Arithmatic errors
4. Changes in DOGAMI rates from 10% and 25% to 16.7% by HEW ruling

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
A001	8/6/79		

5. ISSUED BY — CODE
U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) — CODE

7. CONTRACTOR NAME AND ADDRESS (Street, city, county, state, and ZIP Code) — CODE — FACILITY CODE
State of Oregon
Department of Geology and Mineral Industries
1069 State Office Building
Portland, Oregon 97201

8. ☐ AMENDMENT OF SOLICITATION NO. ______
DATED ______ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ET27220
DATED June 22, 1979 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS
☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.
Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:
(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS
(a) ☐ This Change Order is issued pursuant to ______
The Changes set forth in block 12 are made to the above numbered contract/order.
(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.
(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Article VIII - Changes and Modifications
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

Notwithstanding the provisions of Paragraph B of Article III, Financial Support of the Project, Article III, is hereby revised to provide as follows:

Paragraph A: The total estimated cost of performing the work under the Agreement is increased by $6,752 to a new total of $263,978. The total cost to DOE is increased by $6,752 to a new total of $238,243.

Paragraph C: The amount of funds obligated under this Agreement is hereby increased by $6,752 to a new total of $238,243.

These additional funds of $6,752 are for the procurement of supporting equipment as identified in Items 1 through 4 in the Participant's proposal dated April 3, 1979, which is hereby incorporated by reference. All such equipment is hereby defined to be Government property. These funds are not to be intermingled with existing operating funds and must be reported and billed separately.

Article A-XXI - GOVERNMENT PROPERTY is hereby added as follows:

Continued......

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 2 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR
BY Donald A. Hull (Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY J. P. Anderson (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
Donald A. Hull, State Geologist	8-20-79	J. P. Anderson	8/6/79

U.S. GOVERNMENT PRINTING OFFICE: 1967—264-008

"ARTICLE A-XXI - GOVERNMENT PROPERTY

A. The Government shall deliver to the Participant, for use in connection with and under the terms of this Agreement, the property described as Government-furnished property in this Agreement, together with such related data and information as the Participant may request and as may reasonably be required for the intended use of such property (hereinafter referred to as "Government-furnished property"). The delivery or performance dates for the supplies or services to be furnished by the Participant under this Agreement are based upon the expectation that Government-furnished property suitable for use will be delivered to the Participant at the times stated in the Schedule of this Agreement or, if not so stated, in sufficient time to enable the Participant to meet such delivery or performance dates. In the event that Government-furnished property is not delivered to the Participant by such time or times, the Contracting Officer shall, upon timely written request made by the Participant, make a determination of the delay, if any, occasioned the Participant and shall equitably adjust the estimated cost, or delivery or performance dates, or both, and any other contractual provisions affected by any such delay. In the event that the Government-furnished property is received by the Participant in a condition not suitable for the intended use, the Participant shall, upon receipt thereof, notify the Contracting Officer of such fact and, as directed by the Contracting Officer, either (i) return such property, or (ii) effect repairs or modifications. Upon completion of (i) or (ii) above, the Contracting Officer upon timely written request of the Participant shall equitably adjust the estimated cost, or delivery or performance dates, or both, and any other contractual provision affected by the return, disposition, repair or modification. The foregoing provisions for adjustment are exclusive and the Government shall not be liable for suit for breach of contract by reason of any delay in delivery of Government-furnished property or delivery of such property in a condition not suitable for its intended use.

B. (1) By notice in writing, the Contracting Officer may (i) decrease the property furnished or to be furnished by the Government under this Agreement, or (ii) substitute other Government-owned property for property to be furnished by the Government, or to be acquired by the Participant for the Government, under this Agreement. The Participant shall promptly take such action as the Contracting Officer may direct with respect to the removal shipping, and disposal of property covered by such notice.

(2) In the event of any decrease in or substitution of property pursuant to subparagraph (1) above, or any withdrawal of authority to use property provided under any other Agreement or lease, which property the Government had agreed in the Schedule to make available for the performance of this Agreement, the Contracting Officer, upon the written request of the

ARTICLE A-XXI - GOVERNMENT PROPERTY (Cont'd)

Participant (or if the substitution of property causes a decrease in the cost of performance, on his own initiative), shall equitably adjust such contractual provisions as may be affected by the decrease, substitution or withdrawal, in accordance with the procedures provided for in the "Changes" article of this Agreement.

C. (1) Title to all property furnished by the Government shall remain in the Government.

(2) Notwithstanding subparagraph (1) above, title to equipment purchased with funds available for research having an acquisition cost of less than $1,000 shall vest in the Participant upon acquisition or as soon thereafter as feasible provided that the Participant shall have obtained approval of the Contracting Officer prior to acquisition of such property.

(3) Title to equipment having an acquisition cost of $1,000 or more, purchased with funds available for the conduct of research, shall vest as set forth in the Agreement.

(4) If title to equipment is vested pursuant to (2) or (3) above, the Participant agrees that no charge will be made to the Government for any depreciation, amortization, or use charge with respect to such equipment under any existing or future Government contract or subcontract thereunder.

(5) The Participant shall furnish the Contracting Officer a list of all equipment acquired under subparagraph (2) above within ten (10) days following the end of the calendar quarter during which such equipment was received.

(6) All Government-furnished property, together with all property acquired by the Participant, title to which vests in the Government under this article is hereinafter collectively referred to as "Government property."

(7) Title to Government property shall not be affected by the incorporation or attachment thereof to any property not owned by the Government, nor shall such Government property, or any part thereof, be or become a fixture or lose its identity as personality by reason of affixation to any realty.

(8) Title to all property purchased by the Participant, for the cost of which the Participant is to be reimbursed as a direct item of cost under this Agreement and which under the

ARTICLE A-XXI - GOVERNMENT PROPERTY (Cont'd)

provisions of this Agreement is to vest in the Government, shall pass to and vest in the Government upon delivery of such property by the vendor. Title to other property, the cost of which is to be reimbursed to the Participant under this Agreement and which under the provisions of this Agreement is to vest in the Government, shall pass to and vest in the Government upon (i) issuance for use of such property in the performance of this contract, or (ii) commencement of processing or use of such property in the performance of this Agreement, or (iii) reimbursement of the cost thereof by the Government, whichever first occurs.

D. The Participant shall be directly responsible for and accountable for all Government property provided under this Agreement. The Participant shall establish and maintain a system to control, protect, preserve, and maintain all Government property. This system shall, upon request by the Contracting Officer, be submitted for review and, if satisfactory, approved in writing by the Contracting Officer. The Participant shall maintain and make available such records as are required by the approved system and must account for all Government property until relieved of responsibility therefor in accordance with the written instructions of the Contracting Officer. To the extent directed by the Contracting Officer, the Participant shall identify Government property by marking, tagging, or segregating in such manner as to clearly indicte its ownership by the Government.

E. The Government property shall, unless otherwise provided herein or approved by the Contracting Officer, be used only for the performance of this Agreement.

F. The Participant shall maintain and administer, in accordance with sound industrial practice, a program for the utilization, maintenance, repair, protection and preservation of Government property so as to assure its full availability and usefulness for the performance of this Agreement. The Participant shall take all reasonable steps to comply with all appropriate directions or instructions which the Contracting Officer may prescribe as reasonably necessary for the protection of Government property.

G. (1) The Participant shall not be liable for any loss of or damage to the Government property, or for expenses incidental to such loss or damage, except that the Participant shall be responsible for any such loss or damage (including expenses incidental thereto):

ARTICLE A-XXI - GOVERNMENT PROPERTY (Cont'd)

(i) Which results from willful misconduct or lack of good faith on the part of any of the Participant's directors or officers, or on the part of any of his managers, superintendents, or other equivalent representatives, who has supervision or direction of all or substantially all of the Participant's business, or all or substantially all of the Participant's operations at any one plant, laboratory, or separate location in which this Agreement is being performed;

(ii) Which results from a failure on the part of the Participant, due to the willful misconduct or lack of good faith on the part of any of his directors, officers, or other representatives mentioned in (i) above, (A) to maintain and administer, in accordance with sound business practice, the program for utilization, maintenance, repair, protection and preservation of Government property as required by F. above, or take all reasonable steps to comply with any appropriate written directions of the Contracting Officer under F. above, or (B) to establish, maintain and administer, in accordance with D. above, a system for control of Government property;

(iii) For which the Participant is otherwise responsible under the express terms of the article or articles designated in the schedule;

(iv) Which results from a risk expressly required to be insured under some other provisions of this Agreement, but only to the extent of the insurance so required to be procured and maintained, or to the extent of insurance actually procured and maintained, whichever is greater; or

(v) Which results from a risk which is in fact covered by insurance or for which the Participant is otherwise reimbursed, but only to the extent of such insurance or reimbursement.

Any failure of the Participant to act as provided in subparagraph (ii) above, shall be conclusively presumed to be a failure resulting from willful misconduct, or lack of good faith on the part of such directors, officers, or other representatives mentioned in subparagraph (i) above, if

ARTICLE A-XXI - GOVERNMENT PROPERTY (Cont'd)

the Participant is notified by the Contracting Officer by registered or certified mail, addressed to one of such directors, officers, or other representatives, of the Government's disapproval, withdrawal of approval, or nonacceptance of the Participant's program or system. In such event, it shall be presumed that any loss of or damage to Government property resulted from such failure. The Participant shall be liable for such loss or damage unless he can establish by clear and convincing evidence that such loss or damage did not result from his failure to maintain an approved program for system or occurred during such time as an approved program or system for control of Government property was maintained.

If more than one of the above exceptions shall be applicable in any case, the Participant's liability under any one exception shall not be limited by any other exception.

(2) The Participant shall not be reimbursed for, and shall not include as an item of overhead, the cost of insurance, or any provision for a reserve, covering the risk of loss of or damage to the Government property, except to the extent that the Government may have required the Participant to carry such insurance under any other provision of this Agreement.

(3) Upon the happening of loss or destruction of or damage to the Government property, the Participant shall notify the Contracting Officer thereof, and shall communicate with the loss and salvage organization, if any, now or hereafter designated by the Contracting Officer, and with the assistance of the loss and salvage organization so designated (unless the Contracting Officer has designated that no such organization be employed), shall take all reasonable steps to protect the Government property from further damage, separate the damaged and undamaged Government property, put all the Government property in the best possible order, and furnish to the Contracting Officer a statement of:

(i) The lost, destroyed, and damaged Government property;

(ii) The time and origin of the loss, destruction, or damage;

(iii) All known interests in commingled property of which the Government property is a part; and

ARTICLE A-XXI - GOVERNMENT PROPERTY (Cont'd)

(iv) The insurance, if any, covering any part of or interest in such commingled property. The Participant shall make repairs and renovations of the damaged Government property or take such other action as the Contracting Officer directs.

(4) In the event the Participant is indemnified, reimbursed, or otherwise compensated for any loss or destruction of or damage to the Government property, it shall use the proceeds to repair, renovate or replace the Government property involved, or shall credit such proceeds against the cost of the work covered by the Agreement, or shall otherwise reimburse the Government, as directed by the Contracting Officer. The Participant shall do nothing to prejudice the Government's right to recover against third parties for any such loss, destruction, or damage, and upon the request of the Contracting Officer's expense, furnish to the Government all reasonable assistance and cooperation (including assistance in the prosecution of suit and the execution of instruments of assignment in favor of the Government) in obtaining recovery.

H. The Government, and any persons designated by it, shall at all reasonable times have access to the premises wherein any of the Government property is located, for the purpose of inspecting the Government property.

I. Upon completion or expiration of this Agreement, or at such earlier dates as may be fixed by the Contracting Officer, the Government reserves the right to inspect and to accept or reject any Government property which has not been consumed in the performance of this Agreement, or which has not been disposed of as provided for elsewhere in this article, or for which the Participant has not otherwise been relieved of responsibility. The Participant shall make disposition of rejected items as the Contracting Officer may direct.

The proceeds of any such disposition shall be applied in reduction of any payments to be made by the Government to the Participant under this Agreement, or shall otherwise be credited to the cost of the work covered by this Agreement, or shall be paid in such other manner as the Contracting Officer may direct. Pending final disposition of such property, the Participant agrees to take such action as may be necessary, or as the Contracting Officer may direct, for the protection and preservation thereof.

J. All communications issued pursuant to this article shall be in writing."

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

PAGE 1

1. AMENDMENT/MODIFICATION NO.: A002

2. EFFECTIVE DATE: [redacted]

3. REQUISITION/PURCHASE REQUEST NO.:

4. PROJECT NO. (If applicable):

5. ISSUED BY — CODE:
U.S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) — CODE:

7. CONTRACTOR NAME AND ADDRESS (Street, city, county, state, and ZIP Code) — CODE — FACILITY CODE:
State of Oregon
Department of Geology and
Mineral Industries
1069 State Office Building
Portland, Oregon 97201

8.
☐ AMENDMENT OF SOLICITATION NO. ________
DATED ________ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ET2720
DATED 6/22/79 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ______ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegr which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AN DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegr or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ________
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Article VIII - Changes and Modifications
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

Notwithstanding the provisions of paragraph B of Article III, Financial Support of the Project, Article III, is hereby revised to provide as follows:

Paragraph A: The total estimated cost of performing the work under the Agreement is increased by $10,000 to a new total of $273,978. The total cost to DOE is increased by $10,000 to a new total of $248,243.

Paragraph C: The amount of funds obligated under this Agreement is hereby increased by $10,000 to a new total of $248,243.

These additional funds of $10,000 are for the producing and mailing of 3,000 copies of Geologic Map #11 showing the Oregon State Geothermal Resources.

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 3 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR
BY ________ (Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY J P Anderson (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print): Donald A Hull, State Geologist

16. DATE SIGNED: 12/4/79

18. NAME OF CONTRACTING OFFICER (Type or print): J. P. Anderson, Chief, Contract Administration Branch

19. DATE SIGNED: 12/6/79

30-101-01

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
A003	5/22/80		

5. ISSUED BY CODE

U. S. Department of Energy
Idaho Operations Office
550 Second St. Idaho Falls, ID 83401

6. ADMINISTERED BY (If other than block 5) CODE

7. CONTRACTOR CODE FACILITY CODE
NAME AND ADDRESS
(Street, city, county, state, and ZIP Code)

State of Oregon
Department of Geology & Mineral Industries
1069 State Office Building
Portland, Oregon 97201

8.
☐ AMENDMENT OF SOLICITATION NO. ____
DATED ____ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ET27220
DATED 6/22/79 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ____
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Article VIII - Changes and Modifications
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

1. Article II - DESCRIPTION OF RESPONSIBILITIES is revised to add the following tasks:

Task 5 - Data Compilation. Geological, geophysical, geochemical, and heat flow data for low temperature resource assessment will be collected in the Parkdale, Walla Walla, and McDermitt areas. A preliminary assessment of the area geothermal potential will be made based on all available geoscience information collected. Results of this task, including tabulation of data available for each area, interpretations of geothermal potential, and recommendations for additional assessment efforts in each area will be included in the second annual final report.

Continued....

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 3 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR
BY Donald A Hull
(Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY Nell W Fraser
(Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
Donald A. Hull State Geologist	6/10/80	Nell W. Fraser, Director Contracts Management Division	6/13/80

Task 6 - Geologic Mapping. A geologic map, at an appropriate scale, extending into adjacent areas, will be produced for each of the resource areas described in Task 5. The map will depict lithology, topography, all known or inferred structures, and the location and identification of all thermal springs, geothermal deposits, and thermal wells of the area. Cross-section based on available geologic and structural data will be drawn through the resource areas.

A lineament map will be constructed (at the same scale as the geologic map) for each area based on air-photo and LANDSAT imagery interpretations. Ground-truth verification of the lineaments will be performed. Copies of each map for each site, with accompanying description and interpretation of results, will be included in the second annual final report.

Task 7 - Temperature Gradient Study. Gradient drilling will be done in the following areas: Belknap - Foley, Willamette Pass, Parkdale and the Harvey Basin. Drilling will be limited to approximately 2,000 feet total drilling in each area. Actual number and depth of holes in any area will be at the descretion of the principal investigator. Any drilling funds remaining after drilling the Belknap-Foley and Willamette Pass resource areas will be utilized in the drilling of holes in the Parkdale and/or Harvey Basin areas. DOE review and approval of drilling subcontracts in accordance with Article A-II must be obtained prior to award.

In addition to the above-mentioned drilling program, scrounge, or free holes, located within these resource areas (water wells, oil test wells, mineral exploratory holes) will be measured for temperature gradients and water samples.

Task 8 - Geochemistry. A program of additional thermal spring and well water sampling will be conducted this year for resource areas that have not been included in previous years studies. Water samples will be analyzed, geothermometry will be computed, and these data will be submitted to the USGS GEOTHERM data base. These data will also be included in the comprehensive determination for each resource area in the second annual final report.

Task 9 - State-wide Reconnaissance. Additional effort will be made to acquire information (location, temperature measurement, water sample, flow data, etc.) on thermal springs and wells throughout the State of Oregon. These data will be included in existing DOGAMI and GEOTHERM data base files and updates of the geothermal map series of Oregon.

Task 10 - Reports and Publications. Reports will be submitted in accordance with Article VII - PROJECT INFORMATION and the revised DOE Form CR-537 attached to this Modification No. A003. The annual final report will be comprehensive of each resource area studied, tasks performed, and recommendations for each area.

Individual treatises on various resource areas will be published. Numbers of copies and general publication format will be discussed and a draft final copy of each treatise will be forwarded to DOE for review and approval prior to publication.

2. Article III - FINANCIAL SUPPORT OF THE PROJECT is revised to read as follows:

"A. The total estimated cost of performing the work under this Agreement is Six Hundred Ninety-Seven Thousand Eight Hundred Forty-Three Dollars ($697,843.00) including One Hundred Thirty-Six Thousand Dollars ($136,000.00) authorized by pre-contract cost letter. The Participant shall be reimbursed by DOE for not more than 92.9% of the costs of the project determined to be allowable in accordance with Article A-I of the General Provisions entitled "Allowable Costs." The remaining 7.1% or more of the costs of the project so determined shall constitute the Participant's share for which it will not be reimbursed by DOE. The total cost to DOE is hereby established as Six Hundred Forty-Eight Thousand Two Hundred Forty-Three Dollars ($648,243.00), and this amount is also the maximum amount of the project which is subject to reimbursement by DOE unless such maximum cost is changed in writing by the Contracting Officer.

B. In regard to any increase or decrease in the total estimated cost of this Agreement, as a result of any change in the Statement of Work, as may be agreed upon by the parties during the term of this Agreement, the appropriate sharing of the funding, if any, of such increase or decrease shall be shared at the ratio of 90% DOE, 10% Participant.

C. The amount of funds obligated under this Agreement by DOE is Six Hundred Forty-Eight Thousand Two Hundred Forty-Three Dollars ($648,243.00). Funding for continuation of the project in future years will be provided when and if available."

	DOE Share	Oregon Share	Estimated Cost
Basic Contract	$231,491	$ 25,735	$257,226
Increase per Mod A001	6,752	---	6,752
Increase per Mod A002	10,000	---	10,000
Increase per Mod A003	400,000	23,865	423,865
Total	$648,243	$ 49,600	$697,843

052080

3. Article V - TERM OF AGREEMENT is revised to read as follows:

"The work under the Low Temperature Geothermal Resource Assessment, Phase II project is anticipated to take several years. The Participant has submitted a proposal for funding for each of the first three years. The term of this Agreement is from May 23, 1979 through September 22, 1980 for Tasks 1, 3, and 4, from May 23, 1979 through December 31, 1980 for Task 2 and from May 22, 1980 through May 21, 1981 for Tasks 5, 6, 7, 8, 9, and 10."

4. Article VI - PROJECT MANAGEMENT is revised to change the Participant's Project Director to:

Joseph F. Riccio
Principal Investigator
State of Oregon
Department of Geology and Mineral Industries
1069 State Office Building
Portland, Oregon 97201

5. Article VII - PROJECT INFORMATION is revised to read as follows:

"A. All Project Information Reports, as required by DOE Uniform Contractor Reporting System, Volume 1, dated September 1978 and as shown on the revised DOE Form CR-537, attached to this Modification No. A003, shall be submitted to the DOE Program Officer in accordance with the special instructions.

B. The Final Technical Report for the first year's effort shall be submitted on or about September 22, 1980 in accordance with the special instructions. The Final Technical Report for the second year's effort shall be submitted on or about May 21, 1980, or upon contract renewal, in accordance with the special instructions.

C. Quarterly progress meetings will be held which the Participant is required to attend. DOE will fund travel expenses for one member of the Participant's team."

DOE Form CR-537
(1-78)

U. S. DEPARTMENT OF ENERGY

REPORTING REQUIREMENTS CHECKLIST

(See Instructions on Reverse)

FORM APPRO
OMB NO. 38R-0

1. IDENTIFICATION

State of Oregon

2. OBLIGATION INSTRUMENT:

DE-FC07-79ET27220

3. REPORTING REQUIREMENTS

A. PROJECT MANAGEMENT	Frequency	B. TECHNICAL INFORMATION REPORTING	Frequen
1. ☐ Management Plan		1. ☐ Notice of Energy RD&D Project (SSIE)	
2. ☐ Milestone Schedule & Status Report		2. ☒ Technical Progress Report	M
3. ☐ Cost Plan		3. ☒ Topical Report	Y
4. ☐ Manpower Plan		4. ☒ Final Technical Report	Y
5. ☒ Contract Management Summary Report	M	C. PMS/MINI-PMS	
6. ☒ Project Status Report	M	1. Cost Performance Report	
7. ☐ Cost Management Report		☐ Format 1 WBS	
8. ☐ Manpower Management Report		☐ Format 2 Functional	
9. ☐ Conference Record		☐ Format 3 Baseline	
10. ☐ Hot Line Report		☐ Format 5 Problem Analysis	
		2. ☐ Cost/Schedule Status Report	
		3. ☐ Management Control System Description	
		4. ☐ Summary System Description	
		5. ☐ WBS Dictionary	

FREQUENCY CODES:
A — As Required
C — Contract Change
F — Final (End of Contract)
M — Monthly
O — One Time (Soon After Contract Award)
Q — Quarterly
S — Semi-Annually
X — Mandatory for Delivery with Proposals/Bid
Y — Yearly or Upon Contract Renewal

4. SPECIAL INSTRUCTIONS

A.5. and A.6. - Copies are due within fifteen days after end of the calendar month.

B.2. - Copies are due within fifteen days after end of the calendar month.

B.3. - Submit 2 copies in draft forty-five days prior to completion of the yearly term. After DOE approval is received, submit copies as required on attached "Report Distribution List."

B.4. - Submit 2 copies in draft forty-five days prior to annual submission date. After DOE approval is received, submit eleven copies including one camera-ready copy.

5. ATTACHED HEREWITH:

☐ Report Distribution List ☐
☐ WBS/Reporting Category ☐

6. PREPARED BY (Signature and date):

7. REVIEWED BY (Signature and date):

ID F-129 (Rev. 08-79)
Ref. DOE 13302
(use with DOE CR-537)

U.S. DEPARTMENT OF ENERGY
IDAHO OPERATIONS OFFICE
REPORT DISTRIBUTION LIST

Contract No.

Addressees	Management Plan	Milestone Schedule & Status Report	Cost Plan	Manpower Plan	Contract Management Summary Report	Project Status Report	Cost Management Report	Manpower Management Report	Conference Record	Hot Line Report	Notice of Energy RD&D Project (SSIE)	Technical Progress Report	Topical Report	Final Technical Report	Cost Performance Report	Cost/Schedule Status Report	Management Control System Description	Summary System Description	WBS Dictionary
M. A. Widmayer, Program Manager Resource Definition Branch U.S.D.O.E. Idaho Operations Office 550 Second Street Idaho Falls, ID 83401					2	2						2	2	12					
Bob Gray U.S.D.O.E. Division of Geothermal Energy MS 3344 Federal Building 12th and Penn., N.W. Washington, D.C. 20461					2	2						2	2						
Duncan Foley UURI 420 Chipeta Way Suite 120 Salt Lake City, UT 84108					1	1						1	1						
E. G. Jones, Director Financial Management Division U. S. DOE Idaho Operations Office 550 Second Street Idaho Falls, Idaho 83401					1														

Number of Report Copies

Special Instructions

DOE FORM PR-799A (TEST)
AUGUST 1979

[MOD 3 NOTES]

DE-FC07-79ET27220
MOD A003
completed 6-20-80

U. S. DEPARTMENT OF ENERGY

PROCUREMENT/FINANCIAL ASSISTANCE REQUEST-AUTHORIZATION

1. TO: J P Anderson Chief, Contract Administration Branch

2. FROM INITIATING OFFICE: R. E. Wood, Director, Energy Technology Division

3. INITIAL: [X] UPDATE: [ ] 4. PROCUREMENT: [ ] FINANCIAL ASSISTANCE: [ ]
5. PR NUMBER: ________ 6. PR CORRECTION LETTER: _ 7. RELATED PR NUMBER: ________

ACTION IDENTIFICATION

8. TITLE: Geothermal Resource Assessment in Oregon
modification: new work, new money

9. UNSOLICITED PROPOSAL NO: ________ 10. PROJECT NO: ________ 11. CFDA NO: ________
12. PRODUCT OR SERVICE:* AG3X 13. SUPPORT SERVICES: YES [ ] NO [X] 14. CONSULTANT AWARD: YES [ ] NO [ ]
15. CONTROLLED DELIVERABLE:* A6Y 16. REPORT/DRAWING REQ: YES [X] NO [ ] IF YES, ATTACH DETAILS.
17. CLASSIFICATION OF MATERIALS/WORK: U U — UNCLASSIFIED C — CONFIDENTIAL S — SECRET T — TOP SECRET
18. GOVERNMENT PROPERTY: N F — FURNISHED P — PURCHASED N — NOT INVOLVED IF CODE F OR P, ATTACH DETAILS.

AWARD PLANNING

19. AWARD AS ORDER UNDER BIN: DE-FC07-79ET27220
20. DESIRED AWARD DATE: 05 22 80 (MONTH DAY YEAR) 21. KIND OF AWARD ACTION:* 1P 22. TYPE OF AWARD:* T IF CODE T, ATTACH DETAILS.
23. IF MULTI-YEAR AWARD, INDICATE NUMBER OF YEARS: _ 24. TYPE SOLICITATION INSTRUMENT * --
25. EXTENT OF COMPETITION:* __ IF COMPETITIVE, ATTACH TECHNICAL EVALUATION PLAN. IF NON-COMPETITIVE, ATTACH JUSTIFICATION. REF: DOE-PR 9-3.805.51 or 9-4.909(?).
26. SOURCE SELECTION PROCEDURE: 4 1 — A-E 2 — SEB 3 — OTHER 4 — NONE
27. FOR A-E, SHOW ESTIMATED CONSTRUCTION COST IN DOLLARS: ________

AWARDEE

IF COMPETITIVE, HAS LIST OF SOURCES BEEN ATTACHED? YES [ ] NO [ ] IF NON-COMPETITIVE, COMPLETE 28 - 31.
28. NAME: State of Oregon 29. ADDRESS: 1069 State Office Building
30. DIVISION: Department of Geology & Mineral Industries Portland Oregon 97201
31. GOCO/LAB: D A — GOCO/LAB B — GOCO/NON-LAB C — NON-GOCO/LAB D — NOT APPLICABLE

FINANCIAL

AWARD VALUE — DOLLAR AMOUNT
32. GOV'T SHARE 400,000
33. TOTAL 420,450
34. CONSIDERATION IN KIND, LOAN, OR LOAN GUARANTEE DATA REPORTED ON PR-799C: [ ]
35. PROJECT PERIOD: FROM 05 22 80 THRU 05 21 81

CURRENT FY FUNDS COMMITTED

36. B&R NUMBER	37. FUND CLASS	38. DOLLAR AMOUNT
AM15-10	E	400,000
________	-	________
________	-	________

39. FROM PR-799B (PART A) ________
40. TOTAL THIS PR 400,000
41. FUNDING PERIOD: FROM 05 22 80 THRU 05 21 81

42. APPROPRIATION SYMBOL: ________
43. ALLOTMENT SYMBOL: ________
44. OBJECT CLASS: ----

PROJECT MANAGER

45. NAME: M. A. Widmayer
46. SIGNATURE: Margaret A. Widmayer
47. DATE: 04 21 80 48. OFFICE CODE: ________
49. FTS TELEPHONE NUMBER: ________

PROGRAM OFFICIAL

50. NAME: R. E. Wood
51. SIGNATURE: JKD [signature]
52. DATE: 04 21 80

CERTIFYING OFFICIAL

53. NAME: F. S. Smith
I HEREBY CERTIFY THAT THE FUNDS CITED IN ITEM 40 ARE AVAILABLE.
54. SIGNATURE: ________
55. DATE __ __ __ (MONTH DAY YEAR)

* SEE BACK OF FORM FOR CODES

Sunday 4/27/80

ELIZABETH:

HERE ARE SOME things to NOTE ABOUT THIS MOD.

(1) on page 11 of proposal, DOGAMI says they plan to travel to D.C. to consult w/ DOE. This is unacceptable. If they travel anywhere, they come to DOE-ID All the drilling expertise is here. Possibly will reduce travel budget.

(2) on page 22, their printing costs seem a little high - this is related to Task 7 in the SOW to produce individual treatises. The actual # of copies of each report has not been determined yet, but it would be good to have a cost idea of how much it will cost to produce 500 copies of any one treatise. Talk WITH Roy Mink this week if you have some questions. This will help justify or reduce that \$23K cost.

(3) Budgets on pages 22 & 23 will be resubmitted. I negotiated out some costs in task 1, and had them break out dollar figures for Task 6 in the SOW. John Beulieu (sp) will provide to DOE this week ⇒ Check WITH my sec'y or Roy

to see if they've come in during my absence.

(4) I talked WITH JOE Riccio on Friday 4-25-80 about getting their "in-house" final report from last year's work. He is under the false impression that he does not have to provide one. He's confusing the notion of a formal publication and a year-end report as set out in CR-537. They agreed to the terms of the agreement last year — I'm sure they'll balk at this and demand $ to produce A year-end report. Both Roy and I can't see how coming out w/ 10 copies of a year-end report is going to bust them.

* Please clear this contractual matter up WITH them, gently, they are a fragile group to WORK WITH.

(5) If a letter to incur costs is going to be written for these guys, DOGAMI has already said that $85K would get them going.

Contract Modification to # DE-FC07-79ET 27220

STATE of OREGON

DEPARTMENT of Geology and Mineral Industries (DOGAMI)

Principal Investigator: Joseph Riccio

Period of Performance: May 22, 1980 - May 21, 1981

WAYS AND MEANS:

	DOE Share	$400,000
	Capital Equip	-0-
	DOGAMI Share	20,450
	Total	$420,450

Statement of Work

TASK 1 DATA Compilation. Geological, geophysical, geochemical, and heat flow data for low temperature resource assessment will be collected in the Parkdale, Walla Walla, and McDermitt areas. A preliminary assessment of the area geothermal potential will be made based on all available geoscience information collected. Results of this task, including tabulation of data available for each area, interpretations of geothermal potential, and recommendations for additional assessment efforts in each area will be included in a final report for Mod A001.

Task 2 Geologic Mapping. A geologic map, at an appropriate scale, extending into adjacent areas, will be produced for each of the resource areas described in Task 1. The map will depict lithology, topography, all known or inferred structures, and the location and identification of all thermal springs, geothermal deposits, and thermal wells of the area. Cross-sections based on available geologic and structural data will ~~be~~ drawn through the resource areas.

A lineament map will be constructed (at the same scale as the geologic map) for each area based on air-photo and LANDSAT imagery interpretations. Ground-truth verification of the lineaments will be performed. Copies of each map for each site, with accompanying description and interpretation of results, will be included in a final report for Mod A001.

Task 3 Temperature Gradient Study. A subcontract will be issued to perform gradient drilling in the following areas: Belknap-Foley, Willamette Pass, and the Harney Basin. Drilling will be limited to a maximum of 2000 feet ~~total~~ drilling and depth of holes in each area. Actual number of holes in any area will be at the discretion of the principal investigator. Any drilling funds remaining after drilling the above three Resource areas will be utilized in the drilling of holes in the Parkdale area.

DOGAMI will review and select a drilling subcontractor on a "best efforts," most cost-effective basis. The subcontract must obtain a technical review and approval by DOE prior to award.

In addition to the above-mentioned drilling program, and scrounge, or free holes, located within these resource areas (water wells, oil test wells, mineral exploratory holes) will be measured for temperature gradients and water samples.

Task 5 Geochemistry. A program of thermal spring and well water sampling will continue this year for resource areas that have NOT been included in previous years studies. Water samples will be analyzed, geothermometry will be computed, and these data will be submitted to the USGS GEOTHERM data base. These data will also be included in the comprehensive determination for each resource area IN the final report for Mod A001.

Task 6 State-wide Reconnaissance. A continuing effort will be MADE to acquire information (location, temperature measurement, water sample, flow data, etc) on thermal springs and wells throughout the State of Oregon. These data will be included in existing data base files and updates of the geothermal map series of Oregon.

Task 7 Reports and Publications. Reports will be prepared in accordance WITH DOE Form CR-537 (included WITHIN), to include monthly technical and management summary reports, and a final report of work conducted under Mod A001. The final report will be comprehensive of each resource area studied, tasks performed, and recommendations for each area. ¶ Funds are available in this modification for the publication of individual treatises of SOME of the Resource areas. Numbers of copies and publication format will be discussed and approved by DOE. PRIOR to publication, a draft final copy of EACH treatise will be forwarded to DOE for review and approval.

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

PAGE 1 OF 5

1. AMENDMENT/MODIFICATION NO.: A004
2. EFFECTIVE DATE:
3. REQUISITION/PURCHASE REQUEST NO.: 07-81ET27220.501
4. PROJECT NO. (If applicable):

5. ISSUED BY CODE
U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) CODE

7. CONTRACTOR CODE FACILITY CODE
NAME AND ADDRESS (Street, city, county, state, and ZIP Code)
State of Oregon
Department of Geology and Mineral Industries
1069 State Office Building
Portland, Oregon 97201

8.
☐ AMENDMENT OF SOLICITATION NO.
DATED (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ET27220
DATED 6-22-79 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)
89X0224.91 AM15100000
ID-14-91; 250 $274,492.00

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ____
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Article VII - Changes and Modifications
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

1. Article II - DESCRIPTION OF RESPONSIBILITIES is revised to add the following;

"The Participant, as project manager for work in Oregon funded by the U. S. Department of Energy (DOE), will: (1) coordinate various State and Federal agencies and other organizations which may participate in this project; (2) act as liaison and coordinator between the project and other ongoing Federal and State supported geothermal projects including but not limited to USGS, UURI, NOAA, OIT, and commercialization projects; (3) coordinate site-specific geological-geophysical studies; and (4) prepare and compile final maps and reports for the project. Geophysical studies, if required will be administered by the Participant, Consulting geophysicists and geologists will be utilized, wherever necessary to complement the assessment portion of this proposal.

---------CONTINUED--------

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 2 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR
BY Donald A Hull
(Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY William C Drake
(Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print): Donald A. Hull, State Geologist
16. DATE SIGNED: 6-2-81
18. NAME OF CONTRACTING OFFICER (Type or print): William C. Drake
19. DATE SIGNED: 10 Jun 81

30-101

☆U.S.GPO:1979-0-281-187/5001

Specific tasks to be conducted under this Modification are:

Task 11 - Geologic Reconnaissance

The Participant will refine geological maps, at an appropriate scale, for the Northern Harney Basin, Parkdale, Western Snake River Plain, and, if time permits, the Lakeview area (reference Figure 1 in proposal dated February 6, 1981). The maps will depict all known major structures or trends as well as surface geothermal manifestations. Cross-sections based on available geologic data will be drawn through the resource areas.

Besides black and white, color and color IR photos, air-photo studies will involve the interpretation of SLAR, LANDSAT (ERTS), and NASA U-2 as available. Ground-truth verification will resolve ambiguous interpretations and will complement the conceptual synthesis work defined in Task 15. Appropriate geophysical profiles perpendicular to known or inferred structures may be used to better define faulting and subsurface structures beneath alluvium in basis, if detailed geological work and existing geophysical data are not definitive.

Task 12 - Statewide Reconnaissance

The Participant will acquire additional information on the location, temperature, water samples, flow data, and chemistry of thermal springs and wells of the State of Oregon and will include emphasis on the south-Central Cascades, Basin and Range province, structural basins of the Columbia Plateau and the Portland-Clackamas River area. These data will be included in existing DOGAMI and GEOTHERM data base files and updates of the geothermal map base of Oregon.

Task 13 - Assessment of the Corbett-Camp Collins Area

The Participant will perform an initial assessment of the Corbett-Camp Collins area near Portland by detailed temperature gradient measurement and water analysis of all existing springs and wells and by drilling shallow (152 m) temperature gradient wells. Drilling will not be performed until a drilling plan has been submitted by the Participant and approved by DOE. The Participant will complete reconnaissance geologic mapping and lineament analysis. Geophysical studies, as appropriate and to the extent made possible by funding, should be conducted in this study area. All data will be included in existing DOGAMI and GEOTHERM data base files and updates of the geothermal map base of Oregon.

Task 14 - Summary Assessment of Geothermal Resources

The Participant will develop goethermal models from the data, and will recommend specific development steps for the Nothern Harney Basin, Parkdale, Western Snake River Plain, and, if appropriate, the Lakeview study areas. The products of this task will be detailed assessment reports incorporating all relevant data for these areas that have high potential.

The Participant will also complete a general summary report covering all other areas studied. This summary report will include integrations of data sets and discussions of at least the Corbett-Camp Collins, Parkdale, Walla-Walla, Southern Harney Basin and McDermitt study areas. These reports will guide statewide resource assessment and will provide a basis for evaluating or planning exploration ventures by either government or the private sector.

Task 15 - State Geothermal Map

The Participant will review data submitted to NOAA for inclusion on an updated edition of the map depicting geothermal resources of Oregon, which was produced previously in this program. Detailed editorial and content reviews of at least two proof maps will be performed, with timely communication of comments to NOAA.

Task 16 - Deliverables

The Participant will deliver the following in addition to the periodic reports required by Article VII - PROJECT INFORMATION and the DOE Form CR-537 attached to Modification No. A003:.

(a) Geologic map revisions and reports integrating new and compiled geological, geochemical, and geophysical data sets, and development of geothermal resource target models for the Northern Harney Basin, Parkdale, Western Snake River Plain areas, and if time and funding permit, the Lakeview area;

(b) A summary report detailing the results of the statewide reconnaissance program, which may, if appropriate, be part of (c) below;

(c) For those areas studied that have not been included in (a) or (b) above, or in previous reports developed under this Agreement, a summary of geological, geochemical, and geophysical data sets and developed geothermal resource target models as specified under Task 14."

2. Article III - FINANCIAL SUPPORT OF THE PROJECT is revised to read as follows:

"A. The total estimated cost of performing the work under this Agreement is One Million and Two Thousand Eight Hundred and Thirty-Four Dollars ($1,002,834.00) including One Hundred Thirty-Six Thousand Dollars ($136,000.00) authorized by pre-contract cost letter. The Participant shall be reimbursed by DOE for not more than 92% of the costs of the project determined to be allowable in accordance with Article A-I of the General Provisions entitled "Allowable Costs." The remaining 8% or more of the costs of the project so determined shall constitute the Participant's share for which it will not be reimbursed by DOE. The total cost to DOE is hereby established as Nine Hundred Twenty-Two Thousand Seven Hundred Thirty-Five Dollars ($922,735.00), and this amount is also the maximum amount of the project which is subject to reimbursement by DOE unless such maximum cost is changed in writing by the Contracting Officer.

B. In regard to any increase or decrease in the total estimated cost of this Agreement, as a result of any change in the Statement of Work, as may be agreed upon by the parties during the term of this Agreement, the appropriate sharing of the funding, if any, of such increase or decrease shall be shared at the ratio of 90% DOE, 10% Participant.

C. The amount of funds obligated under this Agreement by DOE is Nine Hundred Twenty-Two Thousand Seven Hundred Thirty-Five Dollars ($922,735.00). Funding for continuation of the project in future years will be provided when and if available.

D. No drilling costs will be incurred by the Participant or paid by DOE under this Modification No. A004 until the Participant has a DOE-approved drilling plan.

The estimated cost and share totals are summarized as follows:

	DOE Share	Oregon Share	Estimated Cost
Basic Agreement	$231,491	$25,735	$ 257,226
Inc. Per Mod. A001	6,752	-	6,752
Inc. Per Mod. A002	10,000	-	10,000
Inc. Per Mod. A003	400,000	23,865	423,865
Inc. Per Mod. A004	274,492	30,499	304,991
Total	$922,735	$80,099	$1,002,834
Percentage Share	92%	8.%	

3. Article V - TERM OF AGREEMENT is revised to add the following:

"The term for Tasks 11, 12, 13, 14 and 15 is May 22, 1981 through May 21, 1982."

4. Article VII - PROJECT INFORMATION, Paragraph B., is revised to add the following:

"The Final Technical Report and any other deliverables for the third year's effort shall be submitted on or about May 21, 1982, or upon contract renewal, in accordance with the special instructions."

Modification No. A004
DE-FC07-79ET27220

5. Article XIV - <u>DATE OF INCURRENCE OF COSTS</u> to read as follows:

"The Participant shall be entitled to reimbursement for costs incurred in an amount not to exceed $10,000 on or after May 18, 1981, which, if incurred after this modification had been entered into, would have been reimbursable under the provisions of this modification"

OREGON 79 ET 27220
MOD 5

DOE F 4600.1
(7-31)

U.S. DEPARTMENT OF ENERGY
NOTICE OF FINANCIAL ASSISTANCE AWARD
(See Instructions on Reverse)

Under the authority of Public Law 95-91, 93-410, 93-438, 93-473, 93-577 and subject to legislation, regulations and policies applicable to *(cite legislative program title)*: National Geothermal Resource Assessment Program

1. PROJECT TITLE
Low Temperature Geothermal Resource Assessment - Phase II

2. INSTRUMENT TYPE
☐ GRANT ☒ COOPERATIVE AGREEMENT

3. RECIPIENT *(Name, address, zip code, area code and telephone no.)*
State of Oregon, Dept. of Geology & Mineral Industries, 1069 State Office Building
Portland, Oregon 97201

4. INSTRUMENT NO. DE-FC07-79ET27220

5. AMENDMENT NO. A005

6. BUDGET PERIOD FROM: 5/23/79 THRU: 5/21/82

7. PROJECT PERIOD FROM: 5/23/79 THRU: 5/21/82

8. RECIPIENT PROJECT DIRECTOR *(Name and telephone No.)*
G.R. Priest

9. RECIPIENT BUSINESS OFFICER *(Name and telephone No.)*
J.D. Beaulieu

10. TYPE OF AWARD
☐ NEW ☐ CONTINUATION ☐ RENEWAL
☒ REVISION ☐ SUPPLEMENT

11. DOE PROJECT OFFICER *(Name, address, zip code, telephone No.)*
S.M. Prestwich
DOE-Idaho Operations Office (208)526-1147
550 Second St., Idaho Falls, ID 83401

12. ADMINISTERED FOR DOE BY *(Name, address, zip code, telephone No.)*
E.M. Hyster, Contracts Management Division
DOE - Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401
(208) 526-1229

13. RECIPIENT TYPE
☒ STATE GOV'T ☐ INDIAN TRIBAL GOV'T ☐ HOSPITAL ☐ FOR PROFIT ORGANIZATION ☐ INDIVIDUAL
☐ LOCAL GOV'T ☐ INSTITUTION OF HIGHER EDUCATION ☐ OTHER NONPROFIT ORGANIZATION ☐ C ☐ P ☐ SP ☐ OTHER *(Specify)*

14. ACCOUNTING AND APPROPRIATIONS DATA

a. Appropriation Symbol	b. B & R Number	c. FT/AFP/OC	d. CFA Number
89X0224.91	AM1510		

15. EMPLOYER I.D. NUMBER/SSN

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION

(1) DOE Funds Obligated This Action	$(70,000.00)
(2) DOE Funds Authorized for Carry Over	$ -0-
(3) DOE Funds Previously Obligated in this Budget Period	$922,735.00
(4) DOE Share of Total Approved Budget	$852,735.00
(5) Recipient Share of Total Approved Budget	$ 80,099.00
(6) Total Approved Budget	$932,834.00

b. CUMULATIVE DOE OBLIGATIONS

(1) This Budget Period *[Total of lines a.(1) and a.(3)]*	$ 852,735.00
(2) Prior Budget Periods	$ -0-
(3) Project Period to Date *[Total of lines b. (1) and b. (2)]*	$ 852,735.00

17. TOTAL ESTIMATED COST OF PROJECT $ 932,834.00
(This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD/AGREEMENT TERMS AND CONDITIONS
This award/agreement consists of this form plus the following:
a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreement)
b. Applicable program regulations *(specify)* National Geothermal Resource Assessment Program *(Date)* n/a
c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and ☐ B (Grants) or ☒ C (Cooperative Agreements).
d. Application/proposal dated 12/2/81, ☐ as submitted ☒ with changes as negotiated

19. REMARKS
This modification reduces the total estimated cost and DOE financial support and deobligates $70,000.00 of DOE funds with no change in the participant's share or description of responsibilities under the agreement.

20. EVIDENCE OF RECIPIENT ACCEPTANCE
Donald A Hull 3/1/82
(Signature of Authorized Recipient Official) *(Date)*
Donald A. Hull
(Name)
State Geologist
(Title)

21. AWARDED BY
William C. Drake 3/8/82
(Signature) *(Date)*
William C. Drake
(Name)
Contracting Officer
(Title)

Amendment No. A005
DE-FC07-79ET27220

1. Article III - FINANCIAL SUPPORT OF THE PROJECT is revised to read as follows:

"A. The total estimated cost of performing the work under this Agreement is Nine Hundred Thirty-Two Thousand Eight Hundred and Thirty-Four Dollars ($932,834.00) including One Hundred Thirty-Six Thousand Dollars ($136,000.00) authorized by pre-contract cost letter. The Participant shall be reimbursed by DOE for not more than 91.4% of the costs of the project determined to be allowable in accordance with Article A-I of the General Provisions entitled "Allowable Costs." The remaining 8.6% or more of the costs of the project so determined shall constitute the Participant's share for which it will not be reimbursed by DOE. The total cost to DOE is hereby established as Eight Hundred Fifty-Two Thousand Seven Hundred Thirty-Five Dollars ($852,735.00), and this amount is also the maximum amount of the project which is subject to reimbursement by DOE unless such maximum cost is changed in writing by the Contracting Officer.

B. The amount of funds obligated under this Agreement by DOE is Eight Hundred Fifty-Two Thousand Seven Hundred Thirty-Five Dollars ($852,735.00).

The estimated cost and share totals are summarized as follows:

	DOE Share	Oregon Share	Estimated Cost
Basic Agreement	$231,491	$25,735	$257,226
Inc. Per Mod. A001	6,752	-	6,752
Inc. Per Mod. A002	10,000	-	10,000
Inc. Per Mod. A003	400,000	23,865	423,865
Inc. Per Mod. A004	274,492	30,499	304,991
Dec. Per Mod. A005	(70,000)	-	(70,000)
Total	$852,735	$80,099	$932,834
Percentage Share	91.4%	8.6%"	

H3-1931H

OREGON
REPORT SUMMARY

INTRODUCTION

This report is the summary and conclusions of an investigation of low-temperature (20 to 90° C) geothermal resources begun May 23, 1979 by the Oregon Department of Geology and Mineral Industries (DOGAMI) with support from the United States Department of Energy (USDOE) under Cooperative Agreement No. DE-FC07-79ET27220. The report summarizes low-temperature resource assessment data generated for the following project areas (Figure 1):

1. Corbett-Moffett
2. Parkdale
3. Milton-Freewater
4. La Grande (Craig Mountain-Cove area)
5. Belknap-Foley Hot Springs
6. Willamette Pass
7. Powell Buttes
8. Northern Harney Basin
9. Southern Harney Basin
10. Western Snake River Plain
11. Lakeview
12. Alvord Desert
13. McDermitt

Raw data and preliminary conclusions for these areas are included in the following published DOGAMI reports and maps and will not be included here:

1. Heat flow of Oregon: Special Paper 4, 1978, includes 1 map.
2. Geothermal gradient data for Oregon: Open-File Report 0-78-4, 1978.
3. Chemical analyses of thermal springs and wells in Oregon: Open-File Report 0-79-3, 1979.
4. Geology of the La Grande area, Oregon: Special Paper 6, 1980, includes 1 map.
5. Preliminary geology and geothermal resource potential of the Belknap-Foley area: Open-File Report 0-80-2, 1980, includes 1 map.

6. Preliminary geology and geothermal resource potential of the Willamette Pass area: Open-File Report 0-80-3, 1980, includes 1 map.
7. Preliminary geology and geothermal resource potential of the Craig Mountain Cove area: Open-File Report 0-80-4, includes 1 map.
8. Preliminary geology and geothermal resource potential of the western Snake River Plain: Open-File Report 0-80-5, 1980, includes 4 maps.
9. Preliminary geology and geothermal resource potential of the northern Harney Basin: Open-File Report 0-80-6, 1980, includes 4 maps.
10. Preliminary geology and geothermal resource potential of the southern Harney Basin: Open-File Report 0-80-7, 1980, includes 8 maps.
11. Preliminary geology and geothermal resource potential of the Powell Buttes area: Open-File Report 0-80-8, 1980, includes 1 map.
12. Preliminary geology and geothermal resource potential of the Lakeview area: Open-File Report 0-80-9, includes 2 maps.
13. Preliminary geology and geothermal resource potential of the Alvord Desert area: Open-File Report 0-80-10, 1980, includes 2 maps.
14. Progress report on activities of the low-temperature resource-assessment program 1979-80: Open File Report 0-80-14.
15. Geothermal gradient data for Oregon for 1978: Open-File Report 0-81-3A.
16. Geothermal gradient data for Oregon for 1979: Open-File Report 0-81-3B.
17. Geothermal gradient data for Oregon for 1980: Open-File Report 0-81-3C.
18. Map showing geology and geothermal resources of the southern half of the Burns 15' Quadrangle: GMS 20, in press.
19. Map showing geology and geothermal resources of the Vale East 7 1/2' Quadrangle, Oregon: GMS 21, in press.

20. Geothermal gradient data for Oregon for 1981: Open-File Report O-82-4.

The Department is continuing its resource assessment efforts in other areas throughout Oregon with concentration on the Cascades. Resource assessment data will soon be available in open file for the low-temperature resources of Ashland, Oregon when a 1982 drilling program is completed under contract DE-FC07-79ID12044. Preliminary conclusions concerning the Klamath Falls and Bend areas will also be available in an upcoming special paper on the geology and geothermal resources of the Oregon Cascades (DOGAMI Special Paper 15). A preliminary summary of this paper will be included in the conference proceedings volume for the 1982 USDOE-sponsored conference at Salt Lake City, Utah. A similar paper, aimed primarily at a summary of the data gathered at Powell Buttes, was presented in the 1981 USDOE conference at Glenwood Springs, Colorado (see DOE/ID/120-79-39, ESL-59, published by the Earth Science Laboratory, University of Utah Research Institute, Salt Lake City, Utah).

(OREGON)
CASCADES
file

79 ID 12044
(#2 OF 2 CONTRACTS)

JUL 20 1979

RECEIVED
JUL 1979
GEOTHERMAL ENERGY BRANCH

State of Oregon
Department of Geology and Mineral Industries
1069 State Office Building
Portland, Oregon 97201

Attention: Donald A. Hull

Subject: COOPERATIVE AGREEMENT NO. DE-FC07-79ID12044

Gentlemen:

We are enclosing three copies of the above-subject Cooperative Agreement which have been signed on behalf of DOE. If satisfactory to you, please have the three copies signed by an authorized official, and then return two fully executed copies to this office. The third fully executed copy is for your retention.

All consultant agreements and subcontracts in excess of $10,000 must be submitted to this office for review and approval prior to execution.

Please complete two copies of the attached Form DOE 538 and return to this office for submission to the Oak Ridge Technical Information Center. Reports should be numbered in accordance with the attached instructions.

J. P. Anderson, Chief of the Contract Administration Branch, and his designee, T. A. Hart, will administer this Cooperative Agreement, and all questions should be directed to Ms. Hart on telephone 208-526-1912.

Very truly yours,

Original signed by
R. E. Simonds

R. E. Simonds, Director
Contracts Management Division

CM

Enclosures:
As stated

bcc w/encl:
L. L. Mink
J. P. Anderson
Mary Parks

CNB	CAB	M	CM
KRHastings:mh	JPAnderson	CEWilliams	RESimonds
L. rson			
7/			

ID FORM-182
(Rev. 10-77)

U. S. DEPARTMENT OF ENERGY

COOPERATIVE AGREEMENT

PURSUANT TO AUTHORITY OF PL 93-410, PL 93-438, PL 93-473, PL 93-577, and PL 95-91

1 a. Agreement No.
DE-FC07-79ID12044

1 b. Modification No.

2. Agreement Period
From: May 23, 1979 To: July 30, 1980

3. Participant Name and Address
State of Oregon
Department of Geology and Mineral Industries
1069 State Office Building
Portland, Oregon 97201

4. Participant Type
- ☐ Educational
- ☐ Nonprofit
- ☒ State or Local Government
- ☐ Profit

5. Project Title
Geothermal Resource Assessment of the Western and Central Cascades, Oregon

6. Project Will Be Conducted Per
See Article II

7. Technical Reports Are Required
See Article VII

8. Principal Investigator(s) or Program Director(s) Name and Address
Donald A. Hull
State of Oregon, Department of Geology and Mineral Industries
1069 State Office Building
Portland, Oregon 97201 Telephone: 503-229-5580

9. DOE Program Officer (Name and Address)
Leland L. Mink, Energy & Technology Division, DOE-ID
550 Second Street
Idaho Falls, Idaho 83401
Telephone No. 208-526-0638

10. Accounting and Appropriation Data
89X0210.91

11. Method of Payment
- ☐ % At Award, % When Requested, 5% Upon Receipt of Final Report
- ☐ Letter of Credit ☐ Reimbursement
- ☒ Other (specify) See Article IV

12. Submit Vouchers, if any, to Agreements Officer Unless Otherwise Specified in this Block Director, Contracts Management Division, DOE-ID, 550 Second Street, Idaho Falls, Idaho 83401

13. Funding Sources

Source	Amount
DOE:	$ 662,447.00
Participant:	$ 30,472.00
Total Funding:	$ 692,919.00

14. Remarks:

Precontract Costs	$200,000.00
Post-Award Costs	462,447.00
	$662,447.00

15. Amount Obligated By This Action: $ 662,447.00

16. DOE Issuing Office (Name and Address)
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

17. DOE Cooperative Agreements Officer

_______________ (Signature) _______ (Date)

Name (typed) _______________

Title _______________

Telephone No. _______________

18. Participant Acceptance

By _______________
Signature of Authorized Official

Name (typed) _______________

Title _______________

TABLE OF CONTENTS

Cooperative Agreement No. DE-FC07-79ID12044

COOPERATIVE AGREEMENT

THIS AGREEMENT, entered into the ________ day of ________________ 1979 (effective as of the 23rd day of May 1979), by and between the UNITED STATES OF AMERICA (hereinafter called the "Government"), acting through the DEPARTMENT OF ENERGY (hereinafter called "DOE") with its Idaho Operations Office located at 550 Second Street in Idaho Falls, Idaho 83401, and the STATE OF OREGON, DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES (hereinafter called the "Participant") located at Portland, Oregon;

WITNESSETH THAT:

WHEREAS, the Government is interested in a geothermal resource assessment of the Cascades in Oregon; and

WHEREAS, the Participant has submitted an unsolicited proposal and proposed to undertake such an assessment and DOE desires to provide certain financial assistance for the accomplishment of such a program; and

WHEREAS, this Agreement is authorized by the Department of Energy Organization Act (Public Law 95-91), Sections 7(a)(2) and 8 of Public Law 93-577, and Sections 103(5) and 107(a) of Public Law 93-438;

NOW, THEREFORE, DOE and the Participant agree as follows:

ARTICLE I - STATEMENT OF JOINT OBJECTIVE

The direct application of geothermal energy at various sites located within Oregon can be a significant factor in the Government's efforts to achieve energy independence. The research provided for in this Agreement is important to both the Government and the Participant for estimating the potential of geothermal energy utilization and for fostering its use in Oregon.

ARTICLE II - DESCRIPTION OF RESPONSIBILITIES

The Participant is responsible to assure that the research is accomplished in a manner consistent with the provisions of this Agreement. The Participant's proposal identified as "Geothermal Resource Assessment of the Western and Central Cascades, Oregon," as it may have been amended, is made a part of this Agreement by this reference; however, if there is any conflict between the content of the proposal and the content of this Agreement, the content of this Agreement governs. The following specific tasks provided for in the proposal are to be accomplished:

ARTICLE II - DESCRIPTION OF RESPONSIBILITIES (Cont'd)

Task 1 - Geology and Lineament Study

This is a one year effort entirelv funded in the first year for $116,115.00. The work scope will be composed of:

a. Two areas in the Cascades have been identified for study during 1979. Geologic mapping, fault analysis and geothermal resource evaluation will be conducted at both sites. The two sites will be the upper Clackamas River Valley, and the upper portions of the Molalla and Little North Santiam Rivers. In addition to geologic mapping, funding is approved for radiometric age dating of rocks from the study area. Age dating techniques will include K/Ar and Ar^{40}/Ar^{39} methods as outlined in the proposal. Craig M. White of the Department of Geology of University of Oregon will conduct this work.

b. The lineament study will include examination various low angle and high space photographic surveys of the central western Cascades of Oregon in order to identify and verify major structures such as faults and lineaments. The product will be a series of lineament maps of 36 x 96 mile project area approximately bordered by 120°45' and 122°30'W. Longitude and 43°30' and 45°N. Latitude. Staff members of DOGAMI will conduct this work.

c. As stated in attachment 3 of the proposal, five items of work will be conducted and will include:

   1) A comparative mapping study of mines, tectonic structures, breccias and hydrothermal alteration versus plutonic and volcanic rock distribution.

   2) K-Ar age determination of plutonic and hydrothermal minerals.

   3) Study and sythesis of the petrochemistry of the plutonic and volcanic host rocks.

   4) Study of the distributions and variations of:

      (a) alteration and metallic minerals of hydrothermal origin,

      (b) trace elements in stream sediments and plutonic and volcanic host rocks.

   DOGAMI staff members will conduct this work.

ARTICLE II - DESCRIPTION OF RESPONSIBILITIES (Cont'd)

Task 2 - Tectonic Framework Study

A one year tectonics study has been proposed for a total funding of $34,167.00 and will include a detailed study of the nature and extent of tertiary rotation and deformation of rocks in the western Cascades. In addition the study will focus on the probable location of continental and oceanic plate boundaries in the area of the Coast Range and the western Cascades. Sampling of basalt flows at sites (as outlined in the proposal) in the western Cascades will be accomplished and the samples will be sent to Stanford University for cryogenic magnetometer analysis. Dr. Alan Cox of the Department of Geophysics at Stanford University will conduct this effort. The end product of this effort will be a report describing, in detail the tectonic framework of the western Cascades region.

Task 3 - Thermal Gradient Drilling Study

A three year thermal gradient study has been proposed for a total funding of $729,680.00. The first year effort $228,626, has been approved several holes will be drilled over an eight week period beginning approximately August 1, 1979. A suite of geophysical logs will be taken in each heat flow hole including temperature, resistivity, self-potential, and natural gamma. In addition to the drilling program, any previously existing wells (water wells, oil-test wells, mineral exploratory holes, etc.) will be tested for temperature gradients. The end product of this effort will be a report and heat flow interpretation maps of the western and central Cascades Region in Oregon. Staff members of DOGAMI will supervise the drilling subcontracts and will be responsible for the geophysical measurements, interpretations, report, and maps.

Task 4 - Geochemistry

A three year proposed effort for a total of $53,128. The first year phase of work has been approved for $20,557. The work will include sampling of thermal springs and wells in the study area for water analysis and geothermometry studies. The data will be submitted to the USGS, Menlo Park, California, for inclusion in the GEOTHERM data base file. The staff members of DOGAMI will conduct this work.

Task 5 - Publications

No effort during first year.

ARTICLE II - DESCRIPTION OF RESPONSIBILITIES (Cont'd)

Task 6 - A Gravity Survey in the Northern Oregon Cascades

This is a proposed three year effort; the first year workscope has been approved for $65,000. The work to be conducted will include a gravity survey in the area between 44°15' and 45°45'N. Latitude and 121°00' and 122°30' W. Longitude. The product of this study will be a series of Bouguer anomaly maps at a 1:125,000 scale, and a report describing the study and conclusions. Dr. Richard W. Couch, Associate Professor in Geophysics, Oregon State University, will conduct this study. Equipment purchased under this task will include a plotter interface system, as outlined in the proposal.

Task 7 - Aeromagnetic and Gravity Measurements, Southern Cascades

This is a proposed 4 year effort, the first year work scope has been approved for $197,982. The work will include an aeromagnetic survey and a gravity survey in the region between 42° and 43°N Latitude and 121° and 122°30'W. Longitude. The studies will determine the relatively large scale lithologic disturbances and near surface structures in the southern Cascades. The products of this study will be a map of the structural findings and a report describing the study and conclusions. Dr. Richard W. Couch, Associate Professor of Geophysics, School of Oceanography, Oregon State University, will conduct this work.

The Participant is also responsible for cost-sharing to the extent provided for in Article III, "Financial Support of the Project."

ARTICLE III - FINANCIAL SUPPORT OF THE PROJECT

A. The total estimated cost of performing the work under this Agreement is Six Hundred Ninety-Two Thousand Nine Hundred Nineteen Dollars ($692,919.00). The Participant shall be reimbursed by DOE for not more than 95% of the costs of the project determined to be allowable in accordance with Article A-I of the General Provisions entitled "Allowable Costs." The remaining 5% or more of the costs of the project so determined shall constitute the Participant's share for which it will not be reimbursed by DOE. The total cost to DOE is hereby established as Six Hundred Sixty-Two Thousand Four Hundred Forty-Seven Dollars ($662,447.00), and this amount is also the maximum amount of the project which is subject to reimbursement by DOE unless such maximum cost is changed in writing by the Contracting Officer.

B. In regard to any increase or decrease in the total estimated cost of this Agreement, as a result of any change in the original Statement of Work, as may be agreed upon by the parties during the term of this

ARTICLE III - FINANCIAL SUPPORT OF THE PROJECT (Cont'd)

Agreement, the appropriate sharing of the funding, if any, of such increase or decrease shall be shared at the ratio of 95% DOE, 5% Participant, as agreed upon above.

C. The amount of funds obligated under this Agreement by DOE for the period from May 23, 1979 through July 30, 1980 is Six Hundred Sixty-Two Thousand Four Hundred Forty-Seven Dollars ($662,447.00). Funding for continuation of the project in future years will be provided when and if available.

ARTICLE IV - METHOD AND BASIS OF PAYMENT

A. Once each month the Participant shall submit an invoice to DOE supported by a detailed statement of current costs incurred for performance of work under this Agreement and claimed to constitute allowable costs. Allowable costs will be determined in accordance with Article A-I of Appendix A. If any of the costs included in the monthly invoice are determined to be unallowable, the invoice will be appropriately reduced. DOE will pay invoices promptly.

B. Final payment will not be made until the Final Report is received and accepted by the Contracting Officer. In no event will the final 5% of the amount of obligated funds be paid to the Participant until DOE has received the Final Report and the Final Cost Report described in Article VII.A. of this Agreement.

ARTICLE V - TERM OF AGREEMENT

The work under the Geothermal Resource Assessment of the Western and Central Cascades, Oregon project is anticipated to take several years. The Participant has submitted a proposal for funding for each of the first four years. The initial term of this Agreement is the first year from May 23, 1979 through July 30, 1980. It is currently anticipated that the subsequent years will be financially supported by DOE and, therefore, the term of this Agreement may be extended as mutually agreed upon by DOE and the Participant.

ARTICLE VI - PROJECT MANAGEMENT

A. In addition to DOE personnel, the Participant agrees to permit non-DOE personnel who are under contract with DOE, and identified from time to time by the Contracting Officer, to assist the DOE representative in performance of his duties and to have necessary access to the Participant's and major subcontractors' records pertaining to the project. DOE correspondence, if any, with subcontractors shall be routed through the Participant.

ARTICLE VI - PROJECT MANAGEMENT (Cont'd)

B. (1) DOE's Program Officer on this project and the person who shall be the Participant's contact for all matters pertaining to this Agreement shall be the following-named person or such other person(s) as may be designated by the Contracting Officer:

Leland L. Mink
Energy and Technology Division
Idaho Operations Office, DOE
550 Second Street
Idaho Falls, Idaho 83401
Telephone 208-526-0638

(2) The Participant's Project Director for the work under this Agreement will be the following person or such other person(s) as may be mutually acceptable to the parties:

Donald A. Hull
Principal Investigator
State of Oregon
Department of Geology and Mineral Industries
1069 State Office Building
Portland, Oregon 97201
Telephone 503-229-5580

C. The term "DOE" means the United States Department of Energy.

D. The term "Contracting Officer" means the person executing this Agreement on behalf of DOE, and includes his successors or any duly authorized representative of such person.

ARTICLE VII - PROJECT INFORMATION

A. All Project Information Reports, as required by DOE Uniform Contractor Reporting System, Volume 1, dated September, and as indicated on the attached DOE Form CR-537, shall be submitted to the DOE Program Officer in accordance with the special instructions.

B. The Final Technical Report shall be due at the end of DOE's support for the project. DOE will advise the Participant one hundred eighty (180) days in advance of termination of support for the project and the Final Technical Report shall be due as noted in the special instructions.

C. Quarterly progress meetings will be held which the Participant is required to attend. DOE will fund travel expenses for one member of the Participant's team.

ARTICLE VIII - CHANGES AND MODIFICATIONS

Any changes or modifications to this Agreement or in the scope of work to be performed shall be made by mutual written agreement of the parties. A change may be initiated by either party to this Agreement. The Contracting Officer shall have the authority to determine what constitutes a change.

ARTICLE IX - TERMINATION

A. It is the express intent of DOE and the Participant to fund their respective cost participation for the project.

B. Notwithstanding the foregoing, it is understood that DOE or the Participant may at any time upon giving sixty (60) days prior written notice to the other party terminate this Agreement for its convenience for any reason.

C. In the event of termination, it is expected that the parties will cooperate with each other to reasonably phase out the Participant's costs and cost commitments, including cost liabilities to third parties; provided, however, that the total amount obligated by the Government under this Agreement shall not be exceeded. Moreover, upon any such termination the Participant agrees to promptly, upon DOE's request, transfer to DOE all information resulting from the work performed to the date of the termination notice.

D. In the event of termination, the Government agrees to pay the Participant all allowable costs incurred prior to receipt of the termination notice, and the Participant after receipt of the termination notice shall:

(1) Place no further orders or subcontracts for materials, services, or facilities intended to be invoiced to the Government for its contribution.

(2) Cancel all orders and subcontracts to the extent that they relate to the performance of work terminated by the Notice of Termination and intended to be invoiced to the Government for its contribution.

(3) Notwithstanding subparagraphs D.(1) and (2) above, the Participant has the right to proceed with such orders and subcontracts should it decide to continue performance of the work at its expense only.

ARTICLE IX - TERMINATION (Cont'd)

E. After a termination, the Participant shall submit to the Contracting Officer its termination claim. Such claim shall be submitted promptly but in no event later than one (1) year from the effective date of termination unless one or more extensions in writing are granted by the Contracting Officer. Upon failure of the Participant to submit its termination claim within the time allowed, the Contracting Officer may determine, on the basis of information available to him, the amount, if any, due to the Participant by reason of the termination and shall thereupon pay to the Participant the amount so determined.

F. Costs claimed, agreed to, or determined pursuant to this article must constitute allowable costs as defined in Article A-1 of the Appendix A of this Agreement.

G. Any termination notice rendered by either DOE or the Participant shall be sent by registered mail with return receipt requested.

ARTICLE X - LIABILITY AND INDEMNIFICATION

The Government will not be liable for payment of damages for injuries to any person, or loss of life or personal property, or loss suffered or sustained and arising from the work performed under this Agreement. The Participant agrees to indemnify and save the Government harmless from any and all claims, demands, damages, actions, costs, or charges against the Government arising as the result of the above-mentioned injuries, damages, or loss, except for any such damages or claims arising out of the negligent act of the Government or its employees in the course of their official duties.

ARTICLE XI - USE OF INFORMATION

All data and information generated, derived or obtained from the activities provided for herein, and this Agreement, will be public information.

ARTICLE XII - DATE OF INCURRENCE OF COSTS

The Participant shall be entitled to reimbursement for costs incurred in an amount not to exceed Two Hundred Thousand Dollars ($200,000.00) on or after May 23, 1979, which, if incurred after this Agreement had been entered into, would have been reimbursable under the provisions of this Agreement.

ARTICLE XIII - ADDITIONAL AGREEMENT PROVISIONS

Appendix A, attached hereto and made a part hereof, sets forth additional general provisions of this Agreement.

DOE Form CR-537
(1-78)

U. S. DEPARTMENT OF ENERGY

REPORTING REQUIREMENTS CHECKLIST

(See Instructions on Reverse)

FORM APPROVED
OMB NO. 38R-0190

1. IDENTIFICATION	2. OBLIGATION INSTRUMENT: DE-FC07-79ID12044

3. REPORTING REQUIREMENTS

A. PROJECT MANAGEMENT	Frequency	B. TECHNICAL INFORMATION REPORTING	Frequency
1. ☐ Management Plan		1. ☒ Notice of Energy RD&D Project (SSIE)	O
2. ☐ Milestone Schedule & Status Report		2. ☒ Technical Progress Report	Q
3. ☐ Cost Plan		3. ☒ Topical Report	Y
4. ☐ Manpower Plan		4. ☒ Final Technical Report	F
5. ☒ Contract Management Summary Report	M	C. PMS/MINI-PMS	
6. ☒ Project Status Report	M	1. Cost Performance Report	
7. ☐ Cost Management Report		☐ Format 1 WBS	
8. ☐ Manpower Management Report		☐ Format 2 Functional	
9. ☒ Conference Record	A	☐ Format 3 Baseline	
10. ☒ Hot Line Report	A	☐ Format 5 Problem Analysis	
		2. ☐ Cost/Schedule Status Report	
		3. ☐ Management Control System Description	
		4. ☐ Summary System Description	
		5. ☐ WBS Dictionary	

FREQUENCY CODES:
A – As Required
C – Contract Change
F – Final (End of Contract)
M – Monthly
O – One Time (Soon After Contract Award)
Q – Quarterly
S – Semi-Annually
X – Mandatory for Delivery with Proposals/Bid
Y – Yearly or Upon Contract Renewal

4. SPECIAL INSTRUCTIONS

Submit all reports to the DOE Program Officer at Idaho Operations Office (ID) as indicated below:

A.5 and 6 - Six copies are due at ID within fifteen days after end of the calendar month.

B.1 - Two copies are due at ID within fifteen days after Cooperative Agreement Award.

B.2 - Six copies are due at ID within fifteen days after end of the calendar quarter.

B.3 - Six copies are due not less than forty-five days prior to completion of the yearly term.

B.4 - Submit in draft forty-five days prior to completion date of Cooperative Agreement. After thirty days for DOE review, submit eleven copies including one camera-ready copy.

5. ATTACHED HEREWITH:

☐ Report Distribution List ☐
☐ WBS/Reporting Category ☐

6. PREPARED BY (Signature and date):	7. REVIEWED BY (Signature and date):

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
A001	1/1/80	07-80ID12044,501	

5. ISSUED BY CODE
U.S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) CODE

7. CONTRACTOR NAME AND ADDRESS CODE FACILITY CODE
(Street, city, county, state, and ZIP Code)
State of Oregon
Department of Geology and
Mineral Industries
1069 State Office Bldg.
Portland, Oregon 97201
Attn: Donald F. Hull

8.
☐ AMENDMENT OF SOLICITATION NO. ______
DATED ______ (See block 9)
☐ MODIFICATION OF CONTRACT/ORDER NO. FC07-79ID12044
DATED 7-24-79 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ______ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ______
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Public Law 95-91 and other applicable laws
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

1. Task 8 to read as follows is hereby added to Article II, Description of Responsibilities.

Task 8 - Supervision of Drilling at Mt. Hood

The Participant shall provide supervision of the scientific testing of deep exploratory drilling at Mt. Hood. Work consists of the following:

a. Assisting in site selection and defining scientific objectives.

b. Assist in the development of project operational plan.

c. Direct and supervise the scientific data acquisition activities.

d. Coordinate with other principle organizations and have primary responsibility for the selection of coring points and determinations for downhole fluids sampling including selection of aquifer testing intervals.

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 3 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR	17. UNITED STATES OF AMERICA
BY Donald A. Hull (Signature of person authorized to sign)	BY J P Anderson (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
Donald A. Hull, State Geologist State of Oregon Dept. of Geology & Mineral Industries	2-6-80	J. P. Anderson, Chief Contract Administration Branch	2/12/80

e. Provide analyses of core, cuttings and fluid samples.

f. Provide interpretation of geophysical logs.

g. Provide and print a final geologic report of scientific data and interpretation from the hole or holes.

2. Notwithstanding the provisions of Paragraph B of Article III, Financial Support of the Project, Paragraphs A and C of Article III are hereby revised to provide as follows:

Paragraph A: The total estimated cost of performing work under the Agreement is increased by $123,842 to a new total of $816,761. The total cost to DOE is increased by $123,842 to a new total of $786,289.

Paragraph C: The amount of funds obligated under this agreement are hereby increased by $123,842 from $662,447 to $786,289.

3. A new sentence is hereby added to Article V, Term of Agreement, to read as follows:

The period of performance for work under Modification No. A001 shall begin January 2, 1980 and be completed December 31, 1980.

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

PAGE 1 OF 1

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
M002			

5. ISSUED BY CODE

U.S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY *(If other than block 5)* CODE

7. CONTRACTOR NAME AND ADDRESS CODE FACILITY CODE
(Street, city, county, state, and ZIP Code)

State of Oregon
Department of Geology & Mineral Industries
1069 State Office Bldg.
Portland, Oregon 97201
Attn: Donald F. Hull

8.
☐ AMENDMENT OF SOLICITATION NO. ______
DATED ______ *(See block 9)*
☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ID12044
DATED 7/24/79 *(See block 11)*

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ______ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA *(If required)*

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ______
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of mutual agreement
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

As requested in your letter dated February 12, 1980, the completion date for performance of tasks under the original contract is extended from July 30, 1980, through January 31, 1981, with no increase in cost to DOE.

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☒ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☐ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN ______ COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR	17. UNITED STATES OF AMERICA
BY ______ (Signature of person authorized to sign)	BY J. P. Anderson (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
		J. P. Anderson, Chief Contract Administration Branch	3-6-8[illegible]

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. AMENDMENT/MODIFICATION NO. A003
2. EFFECTIVE DATE 9-30-80
3. REQUISITION/PURCHASE REQUEST NO. 07-80ID12044.504
4. PROJECT NO. (If applicable)

5. ISSUED BY — CODE
U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) — CODE

7. CONTRACTOR NAME AND ADDRESS (Street, city, county, state, and ZIP Code) — CODE — FACILITY CODE
State of Oregon
Department of Geology and
Mineral Industries
1069 State Office Building
Portland, Oregon 97201
ATTN: Donald A. Hull

8. [ ] AMENDMENT OF SOLICITATION NO. ______ DATED ______ (See block 9)
[X] MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ID12044 DATED 7-24-79 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS
[ ] The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers [ ] is extended, [ ] is not extended.
Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:
(a) By signing and returning ______ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS
(a) [ ] This Change Order is issued pursuant to ______
The Changes set forth in block 12 are made to the above numbered contract/order.
(b) [ ] The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.
(c) [X] This Supplemental Agreement is entered into pursuant to authority of Public Law 95-91 et. al.
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

1. Revise Task 5 - Publications of Article II - DESCRIPTION OF RESPONSIBILITIES to read as follows:

"Publish the final report(s), geophysical, geologic and lineament maps, accompanying texts, and data."

2. Revise Article III - FINANCIAL SUPPORT OF THE PROJECT to read as follows:

"A. The total estimated cost of performing the work under this Agreement is Eight Hundred Forty-Five Thousand Nine Hundred Ninety-Four Dollars ($845,994.00). The Participant shall be reimbursed by DOE for not more than 96.4% of the costs of the project determined to be allowable in accordance with Article A-I of the General Provisions entitled "Allowable Costs." The remaining 3.6% or more of the costs

continued

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. [ ] CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT [X] CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 2 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR
BY Donald A. Hull
(Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY Preston B. Brimhall
(Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print): Donald A. Hull, State Geologist
16. DATE SIGNED: 9-19-80
18. NAME OF CONTRACTING OFFICER (Type or print): Preston B. Brimhall
19. DATE SIGNED: 9-18-80

☆U.S.GPO:1979-0-281-187/5001

of the project so determined shall consitute the Participant's share for which it will not be reimbursed by DOE. The total cost to DOE is hereby established as Eight Hundred Fifteen Thousand Five Hundred Twenty-Two Dollars ($815,522.00), and this amount is also the maximum amount of the project which is subject to reimbursement by DOE unless such maximum cost is changed in writing by the Contracting Officer.

B. The total amount of the funds obligated under this agreement by DOE is Eight Hundred Fifteen Thousand Five Hundred Twenty-Two Dollars ($815,522.00)."

A summary of the estimated cost and share totals is shown below:

	DOE Share	Oregon Share	Estimated Cost
Basic Contract	$662,447	$30,472	$692,919
Mod. A001	123,842	-	123,842
Mod. M002	-	-	-
Mod. A003	29,233	-	29,233
Total	$815,522	$30,472	$845,994
Percentage Share	96.4%	3.6%	

3. The completion date for the performance of Task No. 5 is January 31, 1981.

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
A004		07-81ID12044.501	

5. ISSUED BY — CODE
U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) — CODE

7. CONTRACTOR NAME AND ADDRESS — CODE — FACILITY CODE
(Street, city, county, state, and ZIP Code)
State of Oregon
Department of Geology and Mineral Industries
1069 State Office Building
Portland, Oregon 97201
ATTN: Donald A. Hull

8.
☐ AMENDMENT OF SOLICITATION NO. ______
DATED ______ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ID12044
DATED 7-24-79 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ______ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ______
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Public Law 95-91 et. al.
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

A. Article II - DESCRIPTION OF RESPONSIBILITIES is revised to add the following Tasks 9 and 10:

Task 9 - Reconnaissance of Southern Cascades

A reconnaissance of geothermal resources in the Southern Cascades will be conducted by the Participant. The effort will include testing thermal gradients in existing wells and geochemical sampling of thermal springs. In addition, an in-house compilation of available geologic data will be accomplished to evaluate geologic controls of potential geothermal resources. The end product will be an addition to existing temperature gradient and spring analysis data for the Oregon Cascades available in DOGAMI reports.

Continued...

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 3 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR
BY Donald A. Hull
(Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY Nell W Fraser
(Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
Donald A. Hull State Geologist	1-19-81	Nell W. Fraser	1/29/81

Task 10 - Residual Gravity Maps of the Oregon Cascades

Reduce existing gravity data on the Oregon Cascades to a residual gravity. The product of this study will be a series of residual gravity maps at a 1:250,000 scale and a report describing the study and conclusions. Dr. Richard W. Couch, Associate Professor in Geophysics, Oregon State University, will conduct this study

2. Article III - FINANCIAL REPORT OF THE PROJECT is revised to read as follows:

"A. The total estimated cost of performing the work under this Agreement is Eight Hundred Seventy-Five Thousand Nine Hundred Ninety-Four Dollars ($875,994.00). The Participant shall be reimbursed by DOE for not more than 96.5% of the costs of the project determined to be allowable in accordance with Article A-I of the General Provisions entitled "Allowable Costs." The remaining 3.5% or more of the costs of the project so determined shall constitute the Participant's share for which it will not be reimbursed by DOE. The total cost to DOE is hereby established as Eight Hundred Forty-Five Thousand Five Hundred Twenty-Two Dollars ($845,522.00), and this amount is also the maximum amount of the project which is subject to reimbursement by DOE unless such maximum cost is changed in writing by the Contracting Officer."

B. The total amount of funds obligated under this Agreement by DOE is Eight Hundred Forty-Five Thousand Five Hundred Twenty-Two Dollars ($845,522.00).

A summary of the estimated cost and share totals is shown below:

	DOE Share	Oregon Share	Estimated Cost
Basic Contract	$662,447	$30,472	$692,919
Mod. A001	123,842	---	123,842
Mod. M002	---	---	---
Mod. A003	29,233	---	29,233
Mod. A004	30,000	---	30,000
Total	$845,522	$30,472	$875,994
Percentage Share	96.5%	3.5%	

3. Article V - TERM OF AGREEMENT is revised to extend the term of the Agreement from January 31, 1981 to October 31, 1981.

4. Article VI - PROJECT MANAGEMENT Paragraph B.(2) is revised to name the following as the Participant's Project Director:

George R. Priest

121980
7H-B21

U.S. DEPARTMENT OF ENERGY
IDAHO OPERATIONS OFFICE

COOPERATIVE AGREEMENT

ID FORM-182
(Rev 05-80)
Ref CMD

PURSUANT TO AUTHORITY OF PL 93-410, PL 93-438, PL 93-473, PL 93-577, and PL 95-91

1.a. Agreement No.: DE-FC07-79ID12044

1.b. Modification No.: M005

2. Agreement Period
From: 5-23-79 To: 1-31-82

3. Participant Name and Address
State of Oregon
Department of Geology and Mineral Industries
1069 State Office Building
Portland, Oregon 97201

4. Participant Type
☐ Educational ☐ Nonprofit
☒ State or Local Government ☐ Profit

5. Project Title
Geothermal Resource Assessment of the Western and Central Cascades, Oregon

6. Project Will be Conducted per
See Article II

7. Technical Reports Are Required
See Article VII

8. Principal Investigator(s) or Program Director(s) Name and Address
George R. Priest
(Address same as Block No. 3)

9. DOE Program Officer (Name and Address)
L. L. Mink, Chief, Geothermal Energy Branch
Energy and Technology Division
Idaho Operations Office, 550 Second Street
Telephone No. 208-526-0638 Idaho Falls, Idaho 834

10. Accounting and Appropriation Data
N/A

11. Method of Payment
☐ % At Award, % When Requested, 5% Upon Receipt of Final Report
☐ Letter of Credit
☐ Reimbursement
☒ Other (specify) See Article IV

12. Submit Vouchers to
Director, Contracts Management Division
Idaho Operations Office, 550 Second Str.
~~Idaho Falls, Idaho 83401~~

13. Funding Sources

Source	Amount
DOE:	$ 845,522.00
Participant:	$ 30,472.00
Total Funding:	$ 875,994.00

14. Remarks:
As requested by Participant's letter dated September 1, 1981, the term of the Agreement is hereby extended to January 31, 1981 with no change in the financial support of the project.

should be 1/31/82
CAR.

15. Amount Obligated By This Action: $ -0-

16. DOE Issuing Office (Name and Address)
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

17. DOE Contracting Officer
William C. Drake 10-30-81
Signature of Contracting Officer (Date)

Name (typed) William C. Drake
Telephone No. 208-526-0775

18. Participant Acceptance
By ______ ______
Signature of Authorized Official (Date)

Name (typed) ______
Title ______

(Replaces ID F-182 (11-79))

DOE F 4600.1
(7-81)

U.S. DEPARTMENT OF ENERGY
NOTICE OF FINANCIAL ASSISTANCE AWARD
(See Instructions on Reverse)

OREGON MOD 006 2/5/82
NOTE to 2/28/82

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
FEB 1982
Contracts Division

Under the authority of Public Law 93-410, 93-438, 93-473, 93-577, 95-91
subject to legislation, regulations and policies applicable to *(cite legislative program title)*: Geothermal Resource Assessment Program

1. PROJECT TITLE: Geothermal Resource Assessment of the Western and Central Cascades, Oregon

2. INSTRUMENT TYPE: ☐ GRANT ☒ COOPERATIVE AGREEMENT

3. RECIPIENT *(Name, address, zip code, area code and telephone no.)*
State of Oregon, Dept. of Geology & Mineral Industries, 1069 State Office Building
Portland, Oregon 97201

4. INSTRUMENT NO.: DE-FC07-79ID12044

5. AMENDMENT NO.: M006

6. BUDGET PERIOD: FROM: 5-23-79 THRU: 2-28-82

7. PROJECT PERIOD: FROM: 5-23-79 THRU: 2-28-82

8. RECIPIENT PROJECT DIRECTOR *(Name and telephone No.)*
George R. Priest

9. RECIPIENT BUSINESS OFFICER *(Name and telephone No.)*
John D. Beaulieu

10. TYPE OF AWARD: ☐ NEW ☒ CONTINUATION ☐ RENEWAL ☐ REVISION ☐ SUPPLEMENT

11. DOE PROJECT OFFICER *(Name, address, zip code, telephone No.)*
S.M.Prestwich, Energy & Technology Division
U.S. Department of Energy, 550 Second Street
Idaho Falls, ID 83401 (208) 526-1147

12. ADMINISTERED FOR DOE BY *(Name, address, zip code, telephone No.)*
E. M. Hyster
U. S. Department of Energy
R&D Contracts Branch, Contracts Mgmt. Div.
550 Second St., Idaho Falls, ID 83401
(208) 526-1229

13. RECIPIENT TYPE
☒ STATE GOV'T ☐ INDIAN TRIBAL GOV'T ☐ HOSPITAL ☐ FOR PROFIT ORGANIZATION ☐ C ☐ P ☐ SP ☐ INDIVIDUAL
☐ LOCAL GOV'T ☐ INSTITUTION OF HIGHER EDUCATION ☐ OTHER NONPROFIT ORGANIZATION ☐ OTHER *(Specify)*

14. ACCOUNTING AND APPROPRIATIONS DATA

a. Appropriation Symbol	b. B & R Number	c. FT/AFP/OC	d. CFA Number
N/A			

15. EMPLOYER I.D. NUMBER/SSN

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION

(1) DOE Funds Obligated This Action	$ -0-
(2) DOE Funds Authorized for Carry Over	$ -0-
(3) DOE Funds Previously Obligated in this Budget Period	$ 845,522.00
(4) DOE Share of Total Approved Budget	$ 845,522.00
(5) Recipient Share of Total Approved Budget	$ 30,472.00
(6) Total Approved Budget	$ 875,994.00

b. CUMULATIVE DOE OBLIGATIONS

(1) This Budget Period *[Total of lines a.(1) and a.(3)]*	$ 845,522.00
(2) Prior Budget Periods	$ -0-
(3) Project Period to Date *[Total of lines b. (1) and b. (2)]*	$ 845,522.00

17. TOTAL ESTIMATED COST OF PROJECT $ 875,994.00
(This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD/AGREEMENT TERMS AND CONDITIONS

This award/agreement consists of this form plus the following:

a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreement)

b. Applicable program regulations *(specify)* National Geothermal Resource Assessment Program *(Date)* N/A

c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and ☐ B (Grants), or ☒ C (Cooperative Agreements).

d. Application/proposal dated 1-15-79, 2-5-79, 2-12-80, & 11-5-80 ☐ as submitted ☒ with changes as negotiated

Approved For $

Approved By:

Contracts Management Division

Date:

Work covered by this invoice was performed satisfactorily to the best of my knowledge.

Approved By:
Technical Monitor

Date:

19. REMARKS
This Modification No. M006 provides for an extension from 1-31-82 to 2-28-82 with no change in the financial support of the project.

20. EVIDENCE OF RECIPIENT ACCEPTANCE

John D Beaulieu 2/5/82
(Signature of Authorized Recipient Official) *(Date)*

John D. Beaulieu
(Name)

Deputy State Geologist
(Title)

21. AWARDED BY

William C. Drake 1-29-82
(Signature) *(Date)*

William C. Drake
(Name)

Contracting Officer
(Title)

DOE F 4600.1
(7-81)

M2.16

U.S. DEPARTMENT OF ENERGY

NOTICE OF FINANCIAL ASSISTANCE AWARD

(See Instructions on Reverse)

Under the authority of Public Law 93-410, 93-438, 93-473, 93-577, 95-91 and subject to legislation, regulations and policies applicable to *(cite legislative program title)*: National Geothermal Resource Assessment Program

1. PROJECT TITLE
Geothermal Resource Assessment of the Western and Central Cascades, Oregon

2. INSTRUMENT TYPE
☐ GRANT ☒ COOPERATIVE AGREEMENT

3. RECIPIENT *(Name, address, zip code, area code and telephone no.)*
State of Oregon, Department of Geology & Mineral Industries, 1069 State Office Building, Portland, Oregon 97201

4. INSTRUMENT NO. DE-FC07-79ID12044

5. AMENDMENT NO. A007

6. BUDGET PERIOD FROM: 5-23-79 THRU: 9-30-82

7. PROJECT PERIOD FROM: 5-23-79 THRU: 9-30-82

8. RECIPIENT PROJECT DIRECTOR *(Name and telephone No.)*
G.R. Priest

9. RECIPIENT BUSINESS OFFICER *(Name and telephone No.)*
J.D. Beaulieu

10. TYPE OF AWARD
☐ NEW ☐ CONTINUATION ☒ RENEWAL
☐ REVISION ☐ SUPPLEMENT

11. DOE PROJECT OFFICER *(Name, address, zip code, telephone No.)*
S.M. Prestwich, Energy & Technology Division
DOE-Idaho Operations Office, (208) 526-1147
550 Second St., Idaho Falls, ID 83401

12. ADMINISTERED FOR DOE BY *(Name, address, zip code, telephone No.)*
E.M. Hyster, Contracts Management Division
DOE-Idaho Operations Office
550 Second Street
Idaho Falls, ID 83401, (208) 526-1229

13. RECIPIENT TYPE
☒ STATE GOV'T ☐ INDIAN TRIBAL GOV'T ☐ HOSPITAL ☐ FOR PROFIT ORGANIZATION ☐ INDIVIDUAL
☐ LOCAL GOV'T ☐ INSTITUTION OF HIGHER EDUCATION ☐ OTHER NONPROFIT ORGANIZATION ☐ C ☐ P ☐ SP ☐ OTHER *(Specify)*

14. ACCOUNTING AND APPROPRIATIONS DATA

a. Appropriation Symbol	b. B & R Number	c. FT/AFP/OC	d. CFA Number
89X0224.91	AM1510		

15. EMPLOYER I.D. NUMBER/SSN

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION

(1) DOE Funds Obligated This Action	$ 120,000.00
(2) DOE Funds Authorized for Carry Over	$ -0-
(3) DOE Funds Previously Obligated in this Budget Period	$ 845,522.00
(4) DOE Share of Total Approved Budget	$ 965,522.00
(5) Recipient Share of Total Approved Budget	$ 32,285.00
(6) Total Approved Budget	$ 997,807.00

b. CUMULATIVE DOE OBLIGATIONS

(1) This Budget Period [*Total of lines a.(1) and a.(3)*]	$ 965,522.00
(2) Prior Budget Periods	$ -0-
(3) Project Period to Date [*Total of lines b. (1) and b. (2)*]	$ 965,522.00

17. TOTAL ESTIMATED COST OF PROJECT $ 997,807.00

(This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD/AGREEMENT TERMS AND CONDITIONS

This award/agreement consists of this form plus the following:

a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreement)

b. Applicable program regulations *(specify)* Nat'l Geothermal Resource Assessment Program *(Date)*

c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and ☐ B (Grants) or ☒ C (Cooperative Agreements).

d. Application/proposal dated 12/2/81, ☐ as submitted ☒ with changes as negotiated

19. REMARKS

This Amendment No. A007 provides for an addition to the scope and the financial support of the Agreement.

20. EVIDENCE OF RECIPIENT ACCEPTANCE

Donald A. Hull 3/1/82
(Signature of Authorized Recipient Official) *(Date)*
Donald A. Hull
(Name)
State Geologist
(Title)

21. AWARDED BY

William C. Drake 3/8/82
(Signature) *(Date)*
William C. Drake
(Name)
Contracting Officer
(Title)

Amendment No. A007
DE-FC07-79ID12044

1. Article II - DESCRIPTION OF RESPONSIBILITIES is revised to add Task 11:

   Task 11 - Phase II Assessment of the Ashland, Oregon Area

   The Participant will drill sufficient shallow temperature gradient holes to outline anomalous thermal areas in the Ashland, Oregon area and will conduct geochemical sampling of aquifers encountered and detailed geologic mapping. The Participant will produce temperature gradient and spring analysis data additional to that available on the area and an outcrop map of the Ashland, Oregon area at a scale of 1:24,000.

2. Article III - FINANCIAL SUPPORT OF THE PROJECT is revised to read as follows:

   "A. The total estimated cost of performing the work under this Agreement is Nine Hundred Ninety-Seven Thousand Eight Hundred Seven Dollars ($997,807.00). The Participant shall be reimbursed by DOE for not more than 96.8% fo the costs of the project determined to be allowable in accordance with Article A-I of the General Provisions entitled "Allowable Costs." The remaining of 3.2% or more of the costs of the project so determined shall constitute the Participant's share for which it will not be reimbursed by DOE. The total cost to DOE is hereby established as Nine Hundred Sixty-Five Thousand Five Hundred Twenty-Two Dollars ($965,522.00), and this amount is also the maximum amount of the project which is subject to reimbursement by DOE unless such maximum cost is changed in writing by the Contracting Officer."

   B. The amount of funds obligated under this Agreement by DOE is Nine Hundred Sixty-Five Thousand Five Hundred Twenty-Two Dollars ($965,522.00).

   A summary of the estimated cost and share totals is shown below:

	DOE Share	Oregon Share	Estimated Cost
Basic Contract	$522,447	$30,472	$692,919
Mod. A001	123,842	-	123,842
Mod. A002	-	-	-
Mod. A003	29,233	-	29,233
Mod. A004	30,000	-	30,000
Mod. A005	-	-	-
Mod. A006	-	-	-
Mod. A007	120,000	1,813	121,813
Total	$965,522	$32,285	$997,807
Percentage Share	96.8%	3.2%"	

3. Article V - TERM OF AGREEMENT is revised to extend the term of the Agreement from February 28, 1982 to September 30, 1982.

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

VICTOR ATIYEH
GOVERNOR

December 2, 1981

Dr. Leland L. Mink
Energy and Technical Division
Idaho Operations Office
550 - 2nd Street
Idaho Falls, Idaho 83401

Dear Roy,

Attached is the detailed budget for the drilling project in Ashland, Oregon. A copy of the project description from my letter of October 20, 1981 is also enclosed. This can be Task 11 of Contract DE-FC07ID12044, except as noted below.

Don Hull has suggested that the Low-Temperature (DE-FC07-79ET27220) and the Cascades (DE-FC07-79ID12044) contracts be combined for the following reasons:

1. The Ashland project (Task 11) can only be accomplished by using labor funds from both the 27220 and 12044 budgets.

2. Because of 1. above, both contracts 27220 and 12044 will have to be time-extended through at least October 31, 1982 in order to accomplish the Ashland project.

3. Handling the program under a single contract will considerably simplify accounting and reporting.

4. There is already a considerable overlap in assigned tasks for 27220 and 12044 (e.g., note Task 12 of 27220 and the Willamette Pass and Belknap-Foley study areas of Figure 1 in the low-temperature research proposal dated February 6, 1981).

5. Because we cannot commit to $10,000 of cost share, owing to recent legislative budget cuts, a new contract could be written such that $10,000 of the total funding could cover a reduced Oregon share. This money could mostly come from savings accrued in highly cost-effective drilling programs recently completed in both 27220 and 12044. If a similar savings occurs in the Ashland drilling project, then the $10,000 could easily be covered by monies assigned to drilling.

6. A new contract could incorporate goals of both the Low-Temperature and Cascades programs, thus allowing a more broadly based package for eventual transferral to another agency, when U.S.D.O.E. is disbanded.

If you should look favorably on these suggestions, the new contract would have to become active on or before January 31, 1982. On this date, the Cascades contract (12044) ends and current Cascade publications being funded for editing and printing at that time would have to be shelved pending a new contract.

With completion of the Ashland project, all major population centers having evidence of low-temperature resources in Oregon will have been brought through geothermal exploration Phase II (see attached explanation of exploration phases). This is a considerable accomplishment for the state-coupled program, considering that only one area in the state (Klamath Falls) was at this phase prior to beginning the program. Hopefully, the state-coupled geothermal assessment project can continue with the goal of exploring new areas in the Basin and Range and southern Cascades of Oregon, where possible high-temperature resources may occur.

Sincerely,

George R. Priest

George R. Priest
Geothermal Specialist

GRP:lk
Encl.

Approved by Donald A. Hull

Donald A. Hull
State Geologist

BUDGET SUMMARY

<u>Personnel</u>

Geologist II (1,982.00 $/mo. X 6 mo. X 2)		*
Subtotal		*
+ O.P.E. (Subtotal X 1.45; see attachment for explanation of O.P.E.)		$ *

<u>Services and Supplies</u>

Travel 3.0 mo. X 20 days/mo. X 40.00 $ per diem X 2	2,400	
Analytical expenses (geochemistry, etc.)	2,000	
Direct supplies (maps, reagents, sample sacks)	1,000	
Printing (Open-File reports of raw data)	1,000	
Subtotal		$ 6,400.00

<u>Subcontracts</u>

Drilling	$ 38,000.00

<u>Subtotal</u>	$ 44,400.00
Indirect Costs (0.167 X Subtotal)	$ 7,414.80
TOTAL	$ 51,814.80

* Charged against residual funds of contracts DE-FC07-79 ET 27220 and DE-FC07-79 ID 12044.

VICTOR ATIYEH
GOVERNOR

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

October 20, 1981

Leland L. Mink
Energy and Technology Division
Idaho Operations Office, DOE
550 Second Street
Idaho Falls, Idaho 83401

Dear Mr. Mink:

Pursuent to our phone conversation of October 20, 1981, I would like to request that Co-operative Agreement DE-FC07-79 ID 12044 be time-extended to October 31, 1982 to allow completion of one additional task. The additional task will be a Phase II geothermal assessment of the Ashland, Oregon area. The task will require drilling of several shallow temperature-gradient wells and detailed geologic mapping of the immediate project area. Preliminary work on the task will begin this winter and drilling should be completed during the 1982 field season. Labor cost for the task can be largely covered from residual funds in our existing U.S.D.O.E. contracts, but an additional $50,000 will be needed to cover drilling expenses. There will be no Oregon cost share on this task, owing to recent budget cuts.

A formal description of the task is attached.

Sincerely,

George R. Priest

George R. Priest
Geothermal Specialist

Donald A. Hull

Approved by Don Hull
State Geologist

GRP:ab

Attachment

Task 11 - Phase II Assessment of the Ashland, Oregon Area

Drill sufficient shallow temperature gradient holes to outline anomalous thermal areas in the Ashland, Oregon area. The effort will also include geochemical sampling of aquifers encountered and detailed geologic mapping of local areas at a scale of 1:24,000. The end product will be addition to existing temperature gradient and spring analysis data and an outcrop map of the Ashland, Oregon area at a scale of 1:24,000.

GEOTHERMAL EXPLORATION PHASES

PHASE I - REGIONAL RECONNAISSANCE

1. Literature search
2. Temperature gradient measurement in existing wells -- wide spacing
3. Spring and well sampling of groundwater -- wide spacing
4. Broad reconnaissance geologic mapping and lineament analysis
5. Regional geophysical studies - wide spacing
    a) Heat Flow
    b) Aeromagnetics
    c) Gravity
    d) Other methods as appropriate (e.g. seismic methods)

PHASE II - INITIAL DIRECT EXPLORATION OF IDENTIFIED RESOURCE AREAS

1. Temperature gradient measurement in all available wells
2. Spring and well sampling of water in all available wells and springs
3. Detailed geologic mapping
4. Shallow drilling of 500' temperature gradient wells to define heat flow anomalies - wide spacing
5. Detailed geophysical exploration - close spacing
    a) Heat Flow
    b) Electrical methods (especially resistivity)
    c) Other methods if appropriate (e.g. gravity)
6. Qualitative and quantitive hydrologic analysis
7. Shallow drilling of 500' temperature gradient wells on a close spacing to refine anomalies encountered in initial drilling

PHASE III - DIRECT EXPLORATION OF THERMAL ANOMALIES

1. Intermediate depth drilling of 2000' wells to define shallow thermal anomalies at depth.
2. Geophysical Exploration
    a) Deep-penetration electrical methods calibrated to electrical measurements of rocks and aquifers identified in drilling
    b) Other methods as appropriate
3. Quantitative hydrologic modeling of the geothermal system

PHASE IV - DIRECT TESTING OF GEOTHERMAL RESOURCES AT DEPTH

1. Deep Drilling of 3000' to 6000' wells to test geothermal aquifers for production temperatures and flow rates
2. Reservoir testing - engineering evaluation of magnitude of the reservoir, including pump tests
3. Quantitative reservoir estimation

MEMO ROUTE SLIP
Form ERDA-93 (1-75) ERDAM 0240

☐	See me about this.	☐	For concurrence.	☐	For action.
☐	Note and return.	☐	For signature.	☐	For information.

TO (Name and unit)	INITIALS / DATE	REMARKS
Oregon	INITIALS: DATE:	User Assit Request — 100°C owner of Vale H.S., historically was a resort, nearby complex
Chevron Vale, Republic drilling Wilson + Bully, -	INITIALS: UURI DATE: EGG	using H_2O 8-423 4111 FTS 889-3232 SCS Office Oregon Trail — Paul Rutten PI Loan Guarantee Mushroom drying operation nearby
~~X~~ Gradient? on major faulting	INITIALS: ~~DATE~~	~~1~~ at ~~4~~ 700' 180

FROM (Name and unit)	REMARKS
Vitto Maglioni Joe Cullen Kathy Schlegel	415-273-7151 IDWR logged a well in RR Valley 480' 150°F for a user assist request from ESL
PHONE NO. / DATE	SE SE Sec 3? T11S R27E

USE OTHER SIDE FOR ADDITIONAL REMARKS

643—16—83488-1 GPO

503-229-5580

Dave Brown (Oregon)
[Replacing Joe Riccio]

Modified Summer Program
Low Temp for users
~~Intended~~
instead of Drilling 500' holes

Take Information to locate deeper drilling

in Oak Ridge area 500'
go over old Oak city well
Now is 500' go down to 2000'
Shear zone run under the city.

Ignore the Bellmap Foley area
Industry is doing something there now.
No user in the area
Just using present data – No drilling

Parkdale Area
Moving the holes to new location within the area 2–500'
Dee – has a warm well
1 good hole 500'

Powell Butte area

Want to go into the area with more detail
Indications it is larger than estimated
a number of holes (300') to site a deeper hole

Harney Basin - 4 - 500' holes

1 - near Crane School
1 - Burnes High School
1 - near lumber company
1 - near Shear Zone

Back to Powell Buttes to drill 2000' hole if it is needed to evaluate Resource potential (6" hole)

GEOTHERMAL BIBLIOGRAPHY

Oregon Department of Geology and Mineral Industries

Blackwell, D.D., Black, G.L., and Priest, G.R., 1981, Geothermal gradient data: Oregon Department of Geology and Mineral Industries Open-File Reports 0-81-3A, 63 p; 0-81-3B, 98 p; 0-81-3C, 374 p.

5

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.

5

Bodvarsson, G., 1966, Energy and power of geothermal resources: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 28, no. 7, p. 117-124.

——1974, Telluric current exploration for geothermal anomalies in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 36, no. 4, p. 93-107.

Bowen, R.G., 1971, Geothermal activity in 1970: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 33, no. 1, p. 16-18.

——1972, Geothermal activity in 1971: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 34, no. 1, p. 12-15.

——1972, Geothermal gradient studies in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 34, no. 4, p. 68-71.

——1973, Geothermal activity in 1972: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 35, no. 1, p. 4-5.

——1974, Geothermal activity in 1973: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 36, no. 1, p. 9-11.

——1975, Geothermal activity in 1974: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 1, p. 9-10.

——1975, Geothermal gradient data: Oregon Department of Geology and Mineral Industries Open-File Report 0-75-3, 114 p.

——1975, Geothermal power, _in_ Proceedings of the Citizens' Forum on Potential Future Energy Sources, Portland, Oreg., January 17, 1974: Oregon Department of Geology and Mineral Industries Miscellaneous Paper 18, p. 43-50.

Bowen, R.G., and Blackwell, D.D., 1973, Progress report on geothermal measurements in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 35, no. 1, p. 6-7.

——1975, The Cow Hollow geothermal anomaly: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 7, p. 109-121.

Bowen, R.G., Blackwell, D.D., and Hull, D.A., 1975, Geothermal studies and exploration in Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-75-7, 66 p.

———1977, Geothermal exploration studies in Oregon: Oregon Department of Geology and Mineral Industries Miscellaneous Paper 19, 50 p.

Bowen, R.G., Blackwell, D.D., Hull, D.A., and Peterson, N.V., 1976, Progress report on heat-flow study of the Brothers fault zone, central Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 38, no. 3, p. 39-45.

Bowen, R.G., and Peterson, N.V., 1970, Thermal springs and wells in Oregon: Oregon Department of Geology and Mineral Industries Miscellaneous Paper 14, (listed on back of location map, scale 1:1,000,000).

Bowen, R.G., Peterson, N.V., and Riccio, J.F., 1978, Low- to intermediate temperature thermal springs and wells in Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-10 (listed on back of location map, scale 1:1,000,000).

Brown, D.E., Black, G.L., and McLean, G.D., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Craig Mountain-Cove area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-4, 68 p.

———1980, Preliminary geology and geothermal resource potential of the Powell Buttes area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-8, 117 p.

Brown, D.E., McLean, G.D., and Black, G.L., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the western Snake River Plain, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-5, 114 p.

———1980, Preliminary geology and geothermal resource potential of the northern Harney Basin, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-6, 52 p.

———1980, Preliminary geology and geothermal resource potential of the southern Harney Basin, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-7, 90 p.

Brown, D.E., McLean, G.D., Priest, G.R., Woller, N.M., and Black, G.L., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Belknap-Foley area, Oregon: Oregon Department of Geology nad Mineral Industries Open-File Report 0-80-2, 58 p.

Brown, D.E., McLean, G.D., Woller, N.M., and Black, G.L., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Willamette Pass area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-3, 65 p.

Couch, R.W., French, W., Gemperle, M., and Johnson, A., 1975, Geophysical measurements in the Vale, Oregon, geothermal resource area: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 8, p. 125-129.

Couch, R.W., Gemperle, M., and Connard, G., 1978, Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-9, scale 1:125,000.

C?

Couch, R.W., Gemperle, M., McLain, W.H., and Connard, G.G., 1981, Total field aeromagnetic anomaly map, Cascade Mountain Range, southern Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series, GMS-17, scale 1:250,000.

C?

Couch, R.W., Pitts, G.S., Braman, D.E., and Gemperle, M., 1981, Free-air gravity anomaly map and complete Bouguer gravity anomaly map, Cascade Mountain Range, northern Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series, GMS-15, scale 1:250,000.

Couch, R.W., Pitts, G.S., Veen, C.A., and Gemperle, M., 1981, Free-air gravity anomaly map and complete Bouguer gravity anomaly map, Cascade Mountain Range, southern Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series, GMS-16, scale 1:250,000.

Geoscience Research Consultants, 1980, Geologic linears of the northern part of the Cascade Range, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 12, 25 p.

Godwin, L.H., and Peterson, N.V., 1969, Geothermal energy, in Mineral and water resources of Oregon: Oregon Department of Geology and Mineral Industries Bulletin 64, p. 299-304.

Groh, E.A., 1966, Geothermal energy potential in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 28, no. 7, p. 125-135.

Hull, D.A., 1975, Geothermal gradient data, Vale area, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-75-4, 18 p.

——1975, Geothermal studies in the Vale area, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 6, p. 104-106.

——1976, Electrical resistivity survey and evaluation of the Glass Buttes geothermal anomaly: Oregon Department of Geology and Mineral Industries Open File Report 0-76-1, 11 p.

Hull, D.A., Blackwell, D.D., and Black, G.L., 1978, Geothermal gradient data: Oregon Department of Geology and Mineral Industries Open-File Report 0-78-4, 187 p.

Hull, D.A., Blackwell, D.D., Bowen, R.G., and Peterson, N.V., 1977, Heat-flow study of the Brothers fault zone, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-77-3, 43 p.

Hull, D.A., Blackwell, D.D., Bowen, R.G., Peterson, N.V., and Black, G.L., 1977, Geothermal gradient data: Oregon Department of Geology and Mineral Industries Open-File Report O-77-2, 134 p.

Hull, D.A., Bowen, R.G., Blackwell, D.D., and Peterson, N.V., 1976, Geothermal gradient data, Brothers fault zone, central Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-76-2, 24 p.

———1977, Preliminary heat-flow map and evaluation of Oregon's geothermal energy potential: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 39, no. 7, p. 109-123.

Hull, D.A., and Newton, V.C., 1976, Geothermal activity in 1975: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 38, no. 1, p. 10-17.

———1977, Geothermal activity in 1976: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 39, no. 1, p. 7-15.

Larson, K., and Couch, R.W., 1975, Preliminary gravity maps of the Vale area, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 8, p. 138-142.

MacLeod, T., and Hill, J. (Logging Geologists, R.F. Smith Corporation), 1980, Engineering and air and mud drilling data of DOGAMI geothermal exploratory well Old Maid Flat 7A: Oregon Department of Geology and Mineral Industries Open-File Report O-80-11, 16 p.

Newton, V.C., and Hull, D.A., 1978, Geothermal energy in 1977: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 40, no. 1, p. 8-16.

Oregon Department of Geology and Mineral Industries, 1978, Geophysical logs, Old Maid Flat #1, Clackamas County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-78-6, 2 p., 7 logs.

———1981, Geophysical logs, Old Maid Flat Well 7A, pt. 1: Oregon Department of Geology and Mineral Industries Open-File Report O-81-2A.

———1981, Geophysical logs, Old Maid Flat Well 7A, pt. 2: Oregon Department of Geology and Mineral Industries Open-File Report O-81-2B.

Oregon Department of Geology and Mineral Industries (Hull, D.A., principal investigator), 1980, Progress report on activities of the low-temperature resource assessment program 1979-1980: Oregon Department of Geology and Mineral Industries Open-File Report O-80-14, 79 p.

Peterson, N.V., and Brown, D.E., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Alvord Desert area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-80-10, 57 p.

Peterson, N.V., Brown, D.E., and McLean, G.D., under the direction of Riccio, J.F., 1980, Preliminary geology and geothermal resource potential of the Lakeview area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-80-9, 108 p.

Peterson, N.V., and Groh, E.A., 1967, Geothermal potential of the Klamath Falls area, Oregon, a preliminary study: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 29, no. 11, p. 209-231.

Pitts, G.S., and Couch, R.W., 1978, Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-8, scale 1:125,000.

Priest, G.R., Riccio, J.F., Woller, N.M., Gest, D., and Pitts, G.S., 1980, Heat flow along the High Cascade-Western Cascade transition zone: Proceedings of the Oregon Academy of Science, v. XVI, p. 15.

Riccio, J.F., ed., 1979, Geothermal resource assessment of Mount Hood: Oregon Department of Geology and Mineral Industries Open-File Report O-79-8, 273 p., 5 maps.

Riccio, J.F., 1979, Preliminary geothermal resource map of Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-11, scale 1:500,000.

Riccio, J.F., and Newton, V.C., Jr., 1979, Geothermal exploration in Oregon in 1978: Oregon Department of Geology and Mineral Industries, Oregon Geology, v. 41, no. 3, p. 39-46.

U.S. Geological Survey and Oregon Department of Geology and Mineral Industries, 1979, Chemical analyses of thermal springs and wells in Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-79-3, 170 p.

Walker, G.W., 1974, Some implications of late Cenozoic volcanism to geothermal potential in the High Lava Plains of south-central Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 36, no. 7, p. 109-119.

White, C., 1980, Geology and geochemistry of Mt. Hood volcano: Oregon Department of Geology and Mineral Industries Special Paper 8, 26 p.

———Geology of the Breitenbush Hot Springs quadrangle, Oregon 1980: Oregon Department of Geology and Mineral Industries Special Paper 9, 26 p.

Wimer, R.D., LaMori, P.N., and Grant, A.D., 1977, Potential environment issues related to geothermal power generation in Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 39, no. 5, p. 73-91.

Wollenberg, H.A., Bowen, R.G., Bowman, H.R., and Strisower, B., 1979, Geochemical studies of rocks, water, and gases at Mt. Hood, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-79-2, 57 p.

Youngquist, W.L., 1980, Geothermal gradient drilling, north-central Cascades, of Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-80-12, 47 p.

Posted 11/15
M 2.14

NOTICE OF FINANCIAL ASSISTANCE AWARD
(See Instructions on Reverse)

Under the authority of Public Law 93-410

subject to legislation, regulations and policies applicable to *(cite legislative program title)*:
Geothermal Research, Development, and Demonstration Act of 1974

1. PROJECT TITLE
Geothermal Resource Assessment of the Western and Central Cascades, Oregon

2. INSTRUMENT TYPE
☐ GRANT ☒ COOPERATIVE AGREEMENT

3. RECIPIENT *(Name, address, zip code, area code and telephone no.)*
State of Oregon, Department of Geology and Mineral Industries, 1069 State Office Bldg, Portland, Oregon 97201

4. INSTRUMENT NO. DE-FC07-79ID12044

5. AMENDMENT NO. M008

6. BUDGET PERIOD FROM: 5-23-79 THRU: 9-30-83

7. PROJECT PERIOD FROM: 5-23-79 THRU: 9-30-83

8. RECIPIENT PROJECT DIRECTOR *(Name and telephone No.)*
George R. Priest

9. RECIPIENT BUSINESS OFFICER *(Name and telephone No.)*
J. D. Beaulieu

10. TYPE OF AWARD
☐ NEW ☐ CONTINUATION ☐ RENEWAL
☒ REVISION ☐ SUPPLEMENT

11. DOE PROJECT OFFICER *(Name, address, zip code, telephone No.)*
S. M. Prestwich, E&TD, DOE-ID
208-526-1147

12. ADMINISTERED FOR DOE BY *(Name, address, zip code, telephone No.)*
E. M. Hyster, CMD
DOE-ID
208-526-1229

13. RECIPIENT TYPE
☒ STATE GOV'T ☐ INDIAN TRIBAL GOV'T ☐ HOSPITAL ☐ FOR PROFIT ORGANIZATION ☐ INDIVIDUAL
☐ LOCAL GOV'T ☐ INSTITUTION OF HIGHER EDUCATION ☐ OTHER NONPROFIT ORGANIZATION ☐ C ☐ P ☐ SP ☐ OTHER *(Specify)*

14. ACCOUNTING AND APPROPRIATIONS DATA

a. Appropriation Symbol	b. B & R Number	c. FT/AFP/OC	d. CFA Number
N/A	N/A		

15. EMPLOYER I.D. NUMBER/SSN

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION

(1) DOE Funds Obligated This Action	$ -0-
(2) DOE Funds Authorized for Carry Over	$ -0-
(3) DOE Funds Previously Obligated in this Budget Period	$ 965,522
(4) DOE Share of Total Approved Budget	$ 965,522
(5) Recipient Share of Total Approved Budget	$ 32,285
(6) Total Approved Budget	$ 997,807

b. CUMULATIVE DOE OBLIGATIONS

(1) This Budget Period *[Total of lines a.(1) and a.(3)]*	$ 965,522.00
(2) Prior Budget Periods	$ -0-
(3) Project Period to Date *[Total of lines b. (1) and b. (2)]*	$ 965,522.00

17. TOTAL ESTIMATED COST OF PROJECT $ 997,807
(This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD/AGREEMENT TERMS AND CONDITIONS

This award/agreement consists of this form plus the following:

a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreement)

b. Applicable program regulations *(specify)* Geothermal Resource Assessment Program *(Date)*

c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and ☐ B (Grants) or ☒ C (Cooperative Agreements).

d. Application/proposal dated 9-7-82, ☒ as submitted ☐ with changes as negotiated

19. REMARKS

This modification provides for an extension of the period of performance to 9-30-83 with no change in the total estimated cost and financial support of the project.

20. EVIDENCE OF RECIPIENT ACCEPTANCE

Donald A. Hull 10/4/82
(Signature of Authorized Recipient Official) *(Date)*
Donald A. Hull
(Name)
State Geologist
(Title)

21. AWARDED BY

William C. Drake
William C. Drake
(Signature) *(Date)*
Contracting Officer
(Name)

(Title)