GL00486

Proposal Submitted to

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

by

Earth Science Laboratory
University of Utah Research Institute
391 Chipeta Way, Suite C
Salt Lake City, Utah 84108

TITLE: Research, Technology Development and Technical Support for Geothermal Energy

TYPE OF REQUEST: New Contract -- Five Years

PERIOD OF THIS PROPOSAL: December 1, 1984 Through December 31, 1985

CO-INVESTIGATORS: D. Foley
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Stanley H. Ward, Director
Earth Science Laboratory
University of Utah Research Institute

Phillip M. Wright
Technical Vice President
University of Utah Research Institute

November 15, 1984

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INTRODUCTION

This proposal briefly presents general justifications for geoscientific research and technology development in geothermal development, some of our accomplishments to date and details the research, development and technical support for ID that we propose for FY 1985. We have proposed work on 15 separate projects. The total of the budgets for these 15 is probably more than DOE will have available. We, therefore, ask that DOE choose from among these projects those that best support its program.

This proposal is for a five-year contract. We would like our contract year to run from 1 January through 31 December of each year except this initial one, which we propose to run from 1 December, 1984 to 31 December, 1985. The purpose of this is to obviate problems we have had in running short of funds during the interval October to December, i.e. after the end of the federal fiscal year, to which we have previously been keyed, and before funds become available for disbursal by ID.

JUSTIFICATION FOR RESEARCH IN THE GEOSCIENCES

Geothermal development is an interdisciplinary endeavor. Figure 1 shows some of the components of the team that must work together successfully if a site is to be developed. Because geothermal resources are geological phenomena, earth science information is needed for all phases of the development. This involvement of the earth sciences is similar to that required for development of petroleum and mineral reserves. However, the petroleum and minerals industries are well established whereas the geothermal industry is in its infancy.

The petroleum and minerals industries have developed earth science tools and techniques to solve their particular problems in an optimum way, and this has required the expenditure of literally tens of billions of dollars. By contrast, relatively little has been spent in developing earth science tools and techniques especially to solve problems in the geothermal environment. Because the geothermal industry is so young and is not yet profitable (except at The Geysers, CA), it is unable to fund the research and technology development necessary to do so. Geothermal developers have had to resort to application of existing earth science tools, which are not generally optimum. In some cases, no tools or techniques have existed to solve a particular problem.

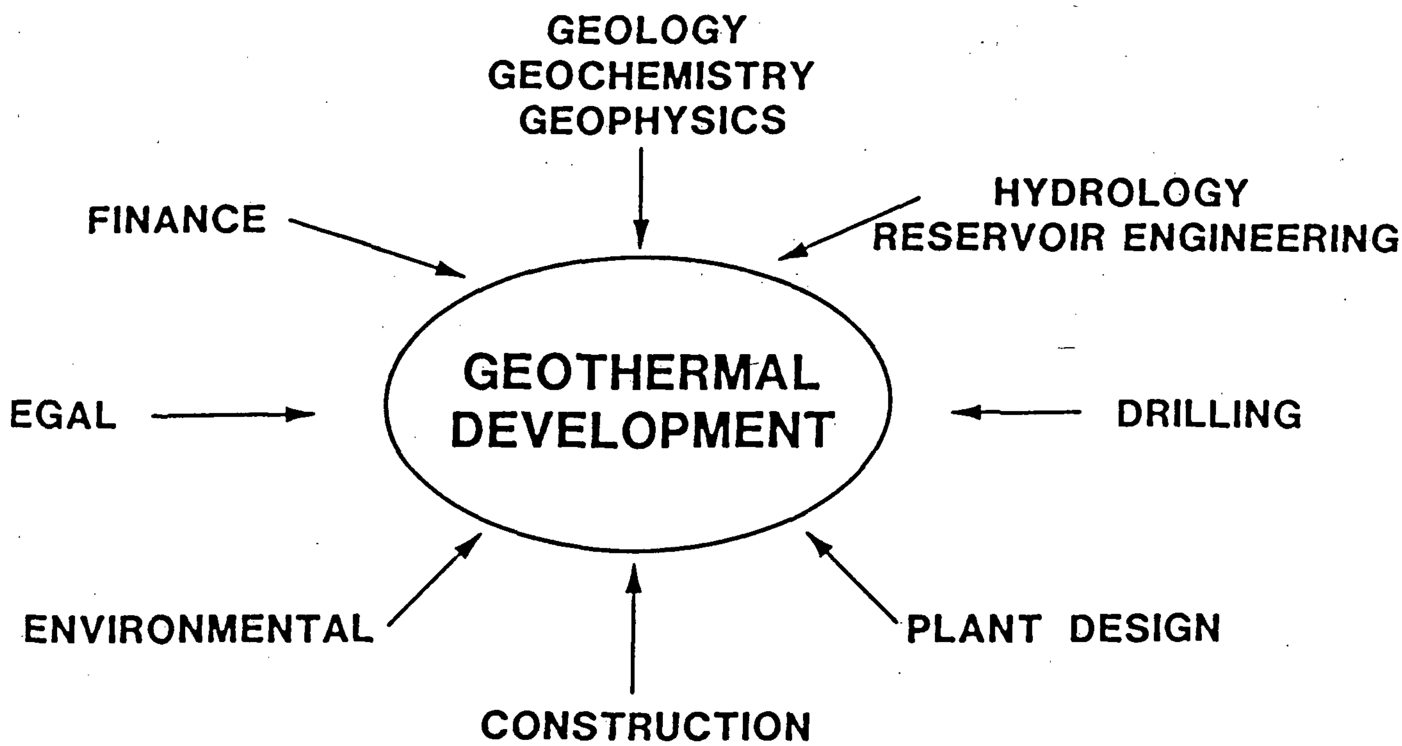
The geosciences have two primary applications in geothermal development:

1. Exploration for geothermal systems, and
2. Exploration within geothermal systems (reservoir definition), with consequent development of a conceptual resource model.

Figure 2 indicates one suggested series of steps for this exploration. The reconnaissance stage is designed to filter available prospect areas and to prioritize them for detailed exploration. These stage refers to (1) above,

GEOTHERMAL DEVELOPMENT

AN INTERDISCIPLINARY ENDEAVOR



BECAUSE GEOTHERMAL OCCURRENCES ARE GEOLOGICAL PHENOMENA, EARTH SCIENCE INFORMATION IS NEEDED FOR ALL PHASES OF DEVELOPMENT

THE DEVELOPMENT TEAM MUST WORK CLOSELY TOGETHER FOR THE PROJECT TO SUCCEED

Figure 1.

SUGGESTED HIGH TEMPERATURE HYDROTHERMAL EXPLORATION STRATEGY

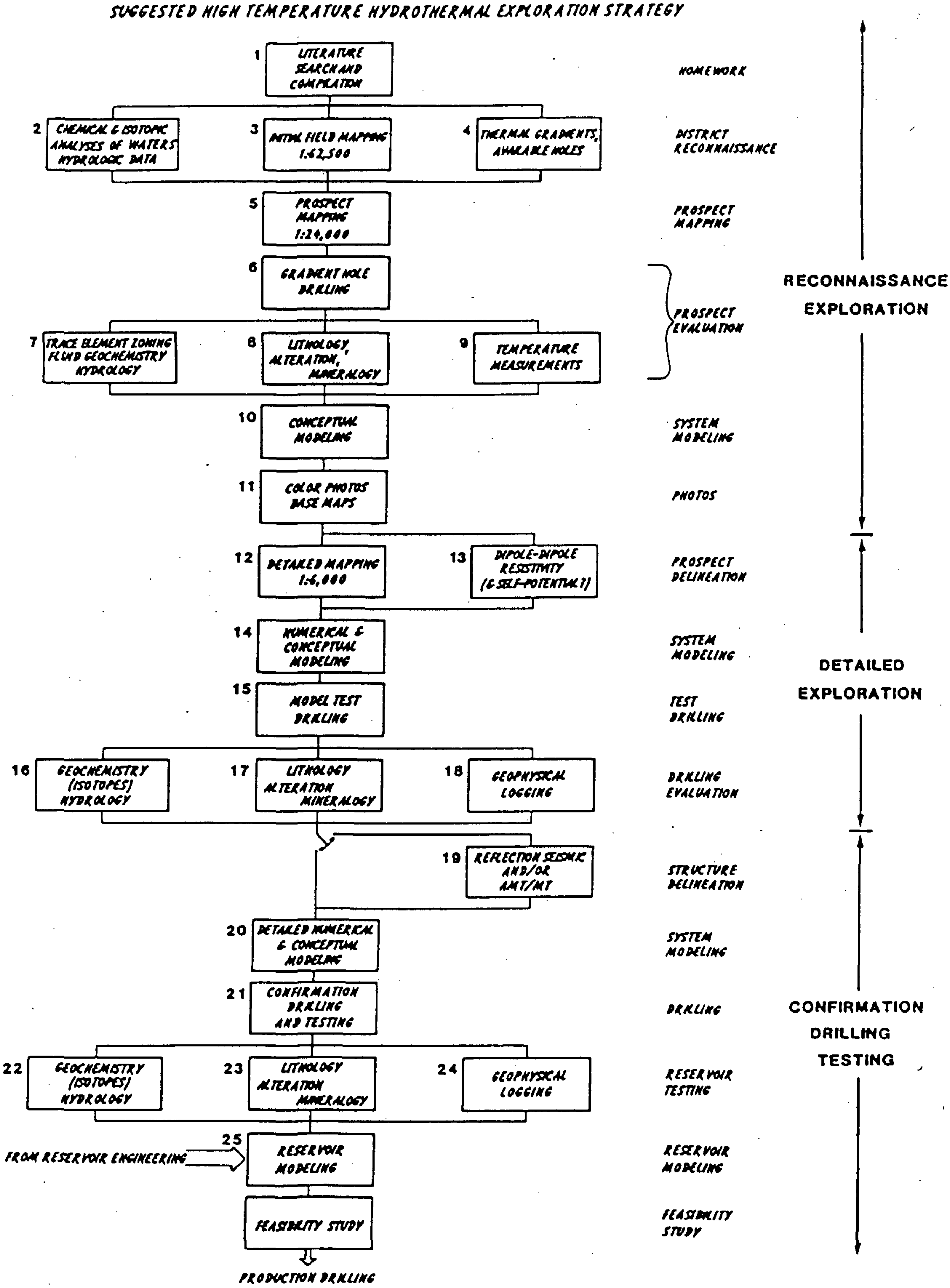


Figure 2.

i.e. exploration for geothermal systems. Once a geothermal system has been located, exploration becomes more detailed within the system. The primary objective of both phases of this exploration is to select drill sites --drill sites to locate a resource area, to confirm the presence of a resource, and then to obtain production of fluids for the utilization plant and to dispose of spent fluids through injection. Because the drilling of geothermal wells is so costly, refinement of exploration techniques has great potential for lowering development costs by avoiding wasted drill holes.

Once a geothermal system has been explored to a certain extent, the scientists and engineers working on the project can begin to form a conceptual resource model. Figure 3 indicates the process. Data for the model come from the fields of geology, geochemistry, geophysics and hydrology. These data are preferably detailed enough to be a function of three 3 space coordinates and of time (x,y,z,t). The conceptual resource model is, in turn, used to make predictions for use in further exploration and in reservoir engineering and management. The conceptual model is continually refined by comparison of predictions to the known situation.

Even though the development and refinement of such a resource model has gone on far more than 20 years at The Geysers, developers there still are unable to predict with certainty the boundaries of the resource, the best places to drill a well, and such important reservoir engineering results as optimum field development strategies or longevity. A great deal more research and development will be required to provide techniques to the industry to increase the reliability of such predictions. A similar situation exists in exploration for new geothermal resources. Statistics (see the annual review of geothermal drilling activities published each year by Geothermal Energy magazine) show that, outside of The Geysers and Imperial Valley geothermal

DEVELOPMENT OF RESOURCE MODEL

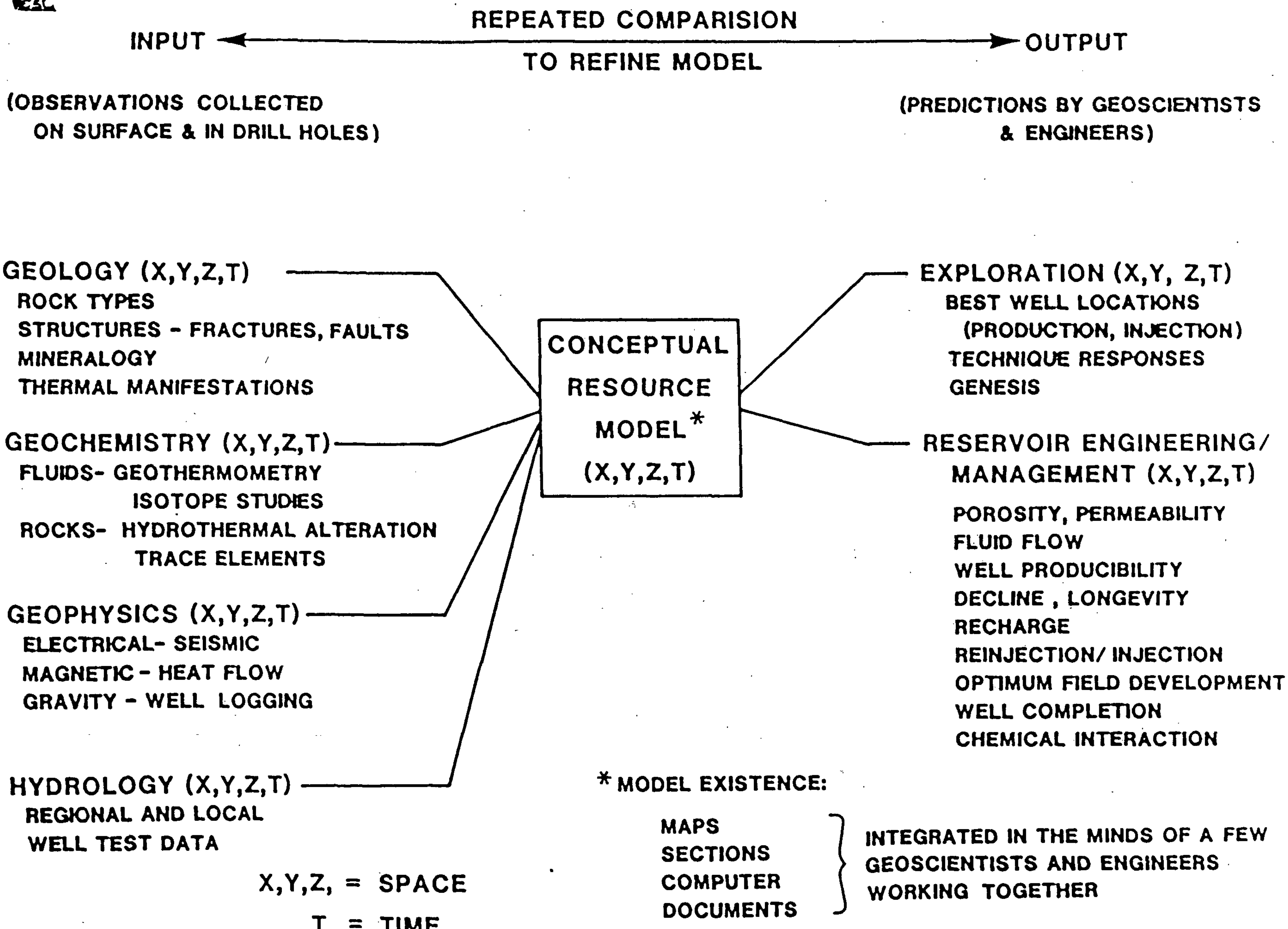


Figure 3.

systems, only about 1 wildcat geothermal well in 10 is successful in the high-temperature hydrothermal environment. Federal assistance in upgrading exploration, reservoir definition and reservoir engineering techniques is clearly indicated.

At the same time, new sources of geothermal energy will be required for future generations. Recently discovered hydrothermal systems on the ocean floor appear to offer great potential for providing truly vast and truly renewable resources. At the present time very little is known about these resources. It is appropriate to DOE's charter to learn more about ocean hydrothermal systems and to assess their potential contribution for providing energy.

ACCOMPLISHMENTS OF ESL/UURI TO DATE ON BEHALF OF DOE

Since FY 1978 the Earth Science Laboratory of the University of Utah Research Institute has played an integral part in the geothermal R&D program of the U.S. Department of Energy. We have built a reputation within industry and the scientific community for high quality work that is of great value to geothermal development, and for timely dissemination of results.

A large percentage of our work has been done in cooperative programs with industry. This cooperative research work began with the Industry Coupled Program, and it continues today with the research we are doing with Union Geothermal at Baca, NM, the Salton Sea and Brawley, CA, with Union, Shell and Aminoil at The Geysers, CA, and with B.C. Hydro at Meager Creek, B.C. In each of these areas, industry has given us proprietary core and/or drill chip samples, as well as exploration and reservoir data that are not in the public domain, and we are working with these samples and data on detailed reservoir definition research projects that the companies helped us design to solve their problems. DOE has provided us with the funding for such work. In addition, our association with the Department of Geology and Geophysics of the University of Utah has provided the opportunity for ESL/UURI to involve students, especially graduate students, in our research work, and to thereby foster development, in young scientists, of skills that the geothermal industry needs.

In the text that follows, we list some of our more significant accomplishments on behalf of DOE.

<u>Reservoir Structural Studies in High-Temperature Geothermal Areas</u>. Under sponsorship of the Industry Coupled and Exploration Technology Development programs, ESL/UURI has performed detailed structural, lithologic, geochemical

and geophysical studies in more than 15 of the best geothermal prospects in the western U.S., including Roosevelt Hot Springs, Cove Fort/Sulphurdale, Beowawe, Dixie Valley, Soda Lake/Stillwater, Colado, McCoy, Baltazor, Tuscarora, The Geysers, Coso Hot Springs, Brawley, East Mesa and Baca. These studies have included interpretation of available data as well as collection and interpretation of new data. Integrated interpretations of all geological, geochemical and geophysical data with development of reservoir conceptual models have resulted. More than 50 reports complete with maps and data have been published on this work. Our geologic mapping has been of such high quality that the U.S. Geological Survey has included it directly in their own map compilations. Our published maps and other results at Roosevelt Hot Springs formed the common data base upon which the unit was formed with Phillips Geothermal as the operator. Our geological and geophysical work at Coso prior to drilling of the unsuccessful DOE well showed that the well was mislocated, but it was decided not to relocate it. Later drilling by California Energy Co. has found substantial geothermal production in the area selected by ESL to be most favorable. This is well documented in our reports.

More recently, work by UURI at Baca in the Valles caldera of New Mexico has begun to bear fruit. We have been able to explain the observed distribution of fracturing in this system in terms of the resurgent doming process. Doming has caused the upper portion of the system to be in extension, keeping fractures open, whereas the bottom portion of the system is in compression, and open fractures are scarce. We believe that hot fluids ascend from great depth along relatively few through-going fractures. Our structured model also predicts depth to magma to be about 4-5 km.

Studies of lithology and hydrothermal alteration have also proven fruitful. An alteration zoning pattern has been developed, and one primary conclusion from the alteration mineralogy is that the upper parts of the system are cooler now than they once were.

We are joining Los Alamos in a joint proposal to OBES to extend the Baca work throughout the Valles caldera. The OBES proposal will include further drilling, and may eventually lead to a series of deeper holes sponsored by the Continental Scientific Drilling Program.

Trace Element Geochemical Techniques Developed and Tested. Prior to initiation of our research work in 1974, the term "geochemistry" was synonymous with "fluid geochemistry" in the geothermal community because the USGS had done the only significant work to that time, and had worked almost exclusively with fluids from geothermal areas in developing their very useful geothermometers. We began by working with rock and soil geochemistry. We used surface and drill chip samples to perform the first studies of trace element chemical zoning in geothermal systems in the U.S. We demonstrated reservoir-wide zoning, i.e. how chemical elements are distributed around and within a convecting hydrothermal system due to motion of the fluids. The results of this work are used to help locate the center of heat in upwelling geothermal fluids and to locate faults and fractures that are carrying geothermal fluids for the purpose of siting wells. We also demonstrated zoning in chemical elements in drill holes around fractures that are carrying geothermal fluids. Such studies can be used to locate potential fluid entries in a newly drilled well and to predict approach of the drill stem to fluid entries. This work has proved to be highly successful and has provided techniques that industry now uses.

More recent work by our geochemistry group on drill chip samples donated to us by Union Geothermal from the Salton Sea geothermal field has developed interesting results. We have shown that there are light hydrocarbons and other organic gases contained in fluid inclusions. Fluid inclusions are microscopic bubbles within mineral grains that are partly occupied by liquids and partly by gases at room temperature. They represent the hydrothermal fluid that formed the particular mineral. In addition to methane, ethane and propane, the Salton Sea fluid inclusions were found to contain both COS and CS_2, which have not been reported before in geothermal systems. We have preliminary evidence of zoning of gases in the two wells studied, and we plan to pursue zoning and other studies that may eventually lead to a better understanding of the chemical evolution of active geothermal systems.

Unique Geophysical Modeling Techniques Developed. Prior to about 1980, interpretation of electrical geophysical surveys in the geothermal environment relied on the use of very simple, usually one-dimensional, models. Whereas such models are satisfactory for some simple geological applications, in the geothermal environment they are usually not satisfactory. The geothermal environment is generally very complex geologically, and proper geophysical interpretation requires two- or three-dimensional models, whose mathematical expressions and computer implementations are vastly more complex.

We have played an integral role, along with the geophysical group at LBL, in developing two-dimensional and three-dimensional interpretation methods for galvanic resistivity, the magnetotelluric (MT) and audiomagnetotelluric (AMT) techniques, the electromagnetic (EM) technique, and for the self-potential (SP) technique. We have written more than a dozen different computer interpretation programs and have advertised and distributed more than 300 copies of these programs to the geothermal community worldwide. All of these programs are also available through The National Energy Software Center (NESC).

Over the past several months, work has resulted in development of computer algorithms for modeling the expected electrical anomalies due to fractures in the wall rock beyond a borehole. Appropriate algorithms to do this have not been available before, so our developments have pushed the state of the art ahead measurably. We have modeled the following problems:

(1) Single borehole and cross-borehole resistivity,

(2) Borehole-to-surface resistivity,

(3) Borehole-to-surface and borehole-to-borehole mise-a-la-masse (the fracture itself is energized), and

(4) Surface-to-borehole time domain electromagnetics.

These modeling programs are currently being used to select an optimum system for detecting fractures that could be implemented in the field. Their use has led to a potentially patentable field system that would deply electrodes partly down a borehole and partly on the surface to measure a set of electrical data that would give redundant indications of fractures in the wall of a wellbore, and thereby increase confidence in interpretation.

User Coupled Confirmation Drilling Program. ESL/UURI played the key role in conceiving this program, in presenting it to DOE-HQ and DOE-ID, and in designing and implementing the program. Once the program was underway, we performed geological, geochemical and geophysical work at Alamosa and at the Geoproducts site at the Wendel-Amadee KGRA, and our geologists were heavily involved in selection of the successful drill site for Geoproducts--the drill site was moved about one-half mile to its successful site upon our recommendation.

Injection Research at Raft River and East Mesa in Cooperation with EG&G. ESL/UURI conceived some of the original research ideas that have been the topics of injection research at Raft River and at East Mesa, including the use of huff-puff, injection-production testing along with chemical tracers and geophysical surveys for mapping fluid flow around a well. This research work shows great promise as a new technique for industry.

Part of our work has been directed toward tracer development. The objectives of our work conducted specifically on tracers are: 1) Identify tracers suitable for use in high temperature geothermal systems; 2) Test and develop analytical methods for determining tracer concentrations; and 3) Develop recovery (mixing) curves.

There have been several significant results so far from these investigations. We have established the injection-backflow technique as a method for testing tracers. Despite the importance of tracers in the evaluation of reservoir characteristics there has been virtually no systematic testing of organic dyes and salts under actual geothermal conditions. We have studied the following candidate tracers at Raft River, ID and East Mesa, CA: Cl, I, Br, SCN, Mg, B, disodium fluorescein and rhodamine-B. Of these, Cl, I, Br, disodium fluorescein appear to be conservative, the others undergoing various degrees of loss in the formation. The organic dyes, fluorescein and rhodamine, which have a reputation for being thermally degraded, appear to be stable up to 185°C.

We have also developed a new, precise analytical method for the determination of thiocyanate (SCN) as a tracer in geothermal waters. Thiocyanate can be analyzed colorimetrically when completed with ferric iron. The method appears to be specific and interference free and has a detection limit of .5 mg/l.

Geothermal Sample Library. From the beginning of the Industry Coupled Program, ESL/UURI has operated the Geothermal Sample Library, where drill chips and core as well as surface samples are curated. Our collection contains over 6,300 feet of core, chips from more than 240,000 feet of drilling and 200 surface samples, collected from 22 geothermal areas in the western U.S. It is by far the largest single collection of samples from geothermal areas available anywhere. Some of these samples are proprietary, having been donated to us for research purposes by industry, but the majority is in the public domain. This library is open to anyone to study the samples, and, with permission from DOE-ID, we make splits of the samples available to others for research purposes.

Major Contributions to Geothermal Geoscience. ESL/UURI has published 75 reports and 58 journal publications, has presented 68 papers at professional meetings and has presented 5 workshops, all on behalf of the DOE geoermal program, since our inception.

Management and Technical Assistance for $45M in DOE-Funded Programs. ESL/UURI has provided technical assistance to DOE for management of the Industry Coupled, State Coupled and User Coupled Programs, which have provided funding of more than $46 million to companies and state agencies.

Planning Contributions. ESL/UURI has contributed to planning and implementation of plans for the following programs:

Exploration and Assessment Technology Development Program Plan

User Coupled Confirmation Drilling Program Plan

MX/RES Geothermal Program Plan

Market Shares Estimates Studies of DOE

National Direct Heat Program Plan

USFS RARE II Geothermal Assessment

BLM Wilderness Geothermal Assessment

National Geothermal Progress Monitor

We believe that we provide a unique mix of talent and experience, unavailable at the national laboratories, that is a vital component to DOE's geothermal program. From the above, it is clear that one of our biggest contributions has been of ideas. We are proud that we have contributed innovative research ideas to DOE's program, and that the results of our work are well recognized by industry as being useful to them.

1.0 CASCADES THERMAL GRADIENT DRILLING PROGRAM

Background

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

UURI proposes to provide technical assistance to DOE-ID in the Cascades Thermal Gradient Drilling Program, and to perform research studies to enhance the scientific value of the program. In the sections that follow, we outline proposed tasks as follows:

1.1 Technical Assistance
1.2 Geophysical Studies
1.3 Cascade Magma Chambers Studies

1.1 TECHNICAL ASSISTANCE

The specific nature of the assistance that DOE-ID will require on this program depends, to a significant extent, on the nature and number of the proposals yet to be received by DOE, and on the quantity and quality of data the proposers are able to provide. Thus, the tasks proposed below attempt to allow some flexibility while outlining the major items as we presently see them. We will work closely with DOE-ID in modifying our work as required to ensure the best use of available funds.

Scope of Work

Task 1.1.1 Technical Assistance for Drilling. ESL/UURI will provide technical assistance and advice to DOE for the drilling operations on this program as required. We will review drilling plans, track drilling progress, provide advice as requested during drilling and document drilling experience for the benefit of subsequent exploration in the Cascades. We will provide on-site assistance as requested by DOE--we do not propose to have UURI personnel on the drill sites continuously except in the case of trouble or for other reasons as specified by DOE. We do propose to visit each drill project at least once, probably during the later stages of drilling, to assemble drillers logs and talk with the drill crew about any problems encountered.

Task 1.1.2 Data Collection and Dissemination. ESL/UURI will establish sampling procedures for lithologic samples acquired in the drilling operation. We anticipate that the drill chips and core samples will be acquired by the participating company. We will archive splits of the drill chips and fluid samples in the Geothermal Sample Library. We will archive all data in our library and will release data to the public by open-filing as instructed by DOE. We will provide expert advice for various phases of the project at DOE's request.

Task 1.1.3 Lithologic Logging. We propose to produce lithologic logs of the cuttings and core, to interpret the logs in relation to the local surface geology, and to produce geologic cross sections.

Task 1.1.4 Aquifer Characterization. One of the key objectives of DOE's program is the evaluation of the effects of stacked aquifers, and on cold water flow that has been postulated in these aquifers, on the surface geothermal manifestations of the Cascades province. We propose to evaluate the extent of cold water overflow in each of the drill holes. This will be done by thorough analyses of all available data. We will do a comprehensive analysis of the geophysical well logs to help determine zones of porosity and permeability. We will obtain several temperature profiles in each hole until an equilibrium profile is obtained. These temperature logs will be especially scrutinized since these logs are often able to detect fluid movement in aquifers.

Another component of our proposed aquifer studies will be to add tracers to the drilling fluids. These tracers will allow the determination of the amount of drill fluid contamination of water samples collected for chemical analyses and the calculation of chemical geothermometers. This will facilitate the collection of uncontaminated samples. We anticipate that the participating company will collect water samples, and we propose to collect additional samples using UURI's down hole fluid sampler. We will attempt to obtain water samples from each aquifer for chemical analysis.

We propose to investigate the hydrothermal alteration in drill chip and core samples to determine the maximum temperatures experienced by the rocks and compare those with the present temperatures measured in the holes. The alteration mineralogy will also aid in evaluating the permeability of the aquifers and the change of permeability through time. X-ray diffraction, stable isotopic and fluid inclusion data will be utilized where applicable.

Task 1.1.5 Supplemental Data Collection. ESL/UURI proposes to collect supplemental data that may be deemed necessary to the evaluation of the drilling project as a case study, or to evaluation of specific exploration techniques. For example, in some areas it may be judged important to have electrical resistivity geophysical data, which the proposer does not already have, to either site the drill hole, to evaluate the effectiveness of the resistivity technique for a specific project or to round out a specific case study. We will work closely with DOE-ID to determine what data need collection under this task. Then, to the limits imposed by budget, we will provide such data, either using our staff or by subcontract.

Task 1.1.6 Case Studies. To be of maximum use to geothermal developers in the Cascades, the data acquired through this program will be compiled into a case study of the entire program. This case study will include a review of existing literature, a discussion of the siting criteria used for the thermal gradient holes, and the results of topical reports, open-file data, and other geoscientific work done on each hole, both by us and by others.

Task 1.1.7 Cascades Exploration Strategies. Using all of the information developed from the program, we will formulate optimum exploration strategies for the Cascades region. We will examine the contribution of each of the commonly used exploration and reservoir assessment techniques to siting discovery and step-out wells, and will evaluate cost effectiveness of each method. The results will be one or more suggested strategies, i.e. combinations of existing exploration techniques that appear to be the most effective in discovery and assessment of geothermal resources in the Cascades region.

SCHEDULE AND DELIVERABLES

FY 1985

	TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1.1.1	Technical Assistance for Drilling				|——	——	——	——	LOE	——	——	——	Δ1
1.1.2	Data Collection				|——	——	——	——	LOE	——	——	——	Δ2
1.1.3	Lithologic Logging						|——	——	——	——	——	Δ3	
1.1.4	Aquifer Characterization						|——	——	——	——	——	Δ4	
1.1.5	Supplemental Data Collection						|——	——	——	——	——	Δ5	
1.1.6	Case Studies												Δ6
1.1.7	Cascades Exploration Strategies												Δ7

Deliverables

1. Drilling History Report
2. Progress Report
3. Technical Report(s)
4. Technical Report
5. Technical Report(s)
6. Case Study Report
7. Exploration Strategies Report

1.1 TECHNICAL ASSISTANCE

BUDGET

A. Salaries and Wages:

	Days		Amount
1. Salaries- Professional			$ 50,216
M. C. Adams	30		
J. N. Moore	90		
D. L. Nielson	25		
H. P. Ross	20		
B. S. Sibbett	90		
P. E. Wannamaker	30		
P. M. Wright	30		
2. Salaries-Support			5,003
Staff Analyst	10		
Draftsperson	20		
Secretary	20		
Technician	20		
3. Wages-Professional			2,870
Research Assistants	60		
Total Salaries and Wages			$ 58,089

B. Employee Benefits:

1. .39 of A.1 & A.2		21,535	
2. .095 of A.3		273	
Total			21,808

C. Travel:

1. Vehicle Rental-(4x4) for 5,660 miles @ $.30/mile		1,698	
2. Per Diem - 40 days @ $21/day		840	
3. Lodging - 40 days @ $45/day		1,800	
4. Trips to DOE/ID (6)		3,240	
5. Airfare to Portland, Oregon (20)		8,400	
6. Technical Meetings (4)		3,000	
Total			18,978

D. Supplies:

1. Laboratory Supplies		1,200	
2. Drafting Supplies		600	
3. Office Supplies		400	

	Total		2,200
E.	Computer:		
	1. PRIME 400		2,000
F.	Reproductions:		
	1. Printing, Binding and Distribution Costs		2,000
G.	Other Costs:		
	1. X-ray Analyses	7,000	
	2. Geochemical Analyses (Fluid)	4,500	
	3. Geochemical Analyses (Rock)	6,000	
	4. FLuid Inclusion Analyses	2,000	
	5. Stable Isotope Analyses	4,000	
	Total		23,500
H.	Total A thru G:		$128,575
I.	Indirect Costs:		
	1. .45 of "H"		57,859
J.	G & A Costs:		
	1. .145 of "H"		18,643
K.	Total H thru J:		$205,077
L.	Fee:		
	1. .065 of "K"		13,328
M.	Total Project Costs:		$218,405

1.2 GEOPHYSICAL STUDIES

Background

Two geophysical methods have been examined as aids to remote detection of intrusions or hydrothermal systems in the Cascades, but to date there is no consensus on the applicability of these methods. These are the magnetic method and the various methods that yield electrical resistivity information. Of all of the geophysical methods, these two are among the most useful in remote detection of geothermal systems. We propose to examine these two methods in some detail, including the work that has been done to date by others, to help determine their potential effectiveness in geothermal exploration in the Cascades.

Aeromagnetic Data. The U. S. Geological Survey has acquired aeromagnetic data for geothermally interesting parts of the Cascades. Additional aeromagnetic data have been acquired by universities and others in the area. Several methods of interpretation have been applied to these data, and these interpretations merit scrutiny.

Aeromagnetic data in the Cascades can be expected to yield information on subsurface structure, among other things. Our work at Meager Creek, B. C. has indicated that at least one component of fluid flow is along the margins of hypabyssal dikes in the quartz diorite intrusions. If the same is true of the rest of the Cascades, the aeromagnetic data should be looked at with a view to interpreting linear patterns as possible dike swarms. This may help lead to drilling targets.

The Cascades aeromagnetic data have also been interpreted in terms of depth to the Curie point isotherm. Rocks above temperatures of 450°C to 550°C cease to be magnetic in the usual sense. In areas of intrusion, the 450°C to 550°C isotherm is higher in the earth's crust than its normal depth. Under such conditions, aeromagnetic data can be interpreted in terms of the depth at which rocks cease to be magnetic, i.e. in terms of depth to the Curie point isotherm. Such interpretations are fraught with assumptions, however. An assessment of the Curie point isotherm interpretation using geologic models for Cascade magma chambers and the quality of data available for the Cascades is needed. We may be able to conclude that the method has real merit in locating magma chambers at depth. Alternatively, we may conclude that data of higher quality are needed, or that the method is not suitably sensitive for the geologic models of the Cascades. The work that we propose would be primarily a study of available data--we propose no new data collection.

Resistivity Techniques. A second geophysical technique that has perhaps the best potential for remote detection of hydrothermal systems at depth in the Cascades is resistivity in its broad sense. This includes conventional galvanic resistivity as well as MT, AMT and EM methods. Some resistivity data are already available for Cascades environments. The U.S. Geological Survey has collected several kinds of such data at Newberry Caldera, Lassen Peak and elsewhere. Other data are available through LBL for Mt. Hood. We propose to acquire and interpret such data where possible and to work with USGS and LBL people who have already done resistivity surveys in areas of interest. Our modeling capabilities for MT and AMT are superior to those available at either the USGS or LBL, and will be of considerable use in data interpretation.

We also propose to acquire dipole-dipole resistivity and MT data over one selected site in the Cascades where a geothermal resource is known or strongly suspected to exist at depth. The most likely candidate site is at Lassen Peak, but other sites will also be considered. We anticipate that dipole-dipole lines and 15 MT stations will be sufficient for an appraisal of these methods.

We will attempt to demonstrate detectability or lack thereof of the hydrothermal system at the site selected using resistivity data. If we can demonstrate that the method works and can define the necessary survey parameters, this would be valuable knowledge to industry.

Scope of Work

Task 1.2.1 Curie-Point Magnetic Data Interpretation. We will acquire available aeromagnetic data in the Cascades and will review existing interpretations of these data. We will form geologic models of Cascades-type magma chambers (see 1.3), and will construct magnetic models from these geologic models. The postulated effect of an intrusion on the magnetic data will thus be estimated. We will then determine under what conditions such an effect would be detectable using Curie-point isotherm interpretation techniques. We will determine whether or not valid Curie-point interpretations can be made from the existing data.

Task 1.2.2 Structural Interpretation of Magnetic Data. We will use the Meager Creek geologic model to form a magnetic model of a Cascades-type hydrothermal/intrusive complex. Then we will determine the detectability of such a system under the thick subareal volcanic sequences that cover the intrusions underlying the Cascades. We will interpret the magnetic data in terms of structure for selected portions of the data around known areas of recent volcanism. We will specifically search the data for dike complexes.

Task 1.2.3 Resistivity Studies. We will acquire available galvanic resistivity, MT and AMT data for Cascades area, and will interpret these data. We will work closely with the USGS and LBL in this task. Through work with DOE-ID, we will select one area for resistivity testing. We will perform dipole-dipole resistivity surveying in this area as well as MT surveying. We will interpret these data using 2-dimensional and 3-dimensional computer programs to form a subsurface resistivity model. We will then compare the model to geologic models of Cascades systems, and attempt to evaluate whether or not these methods are useful in the Cascades for geothermal exploration and reservoir assessment.

1.2 GEOPHYSICAL STUDIES

SCHEDULE AND DELIVERABLES

FY 1985

	TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
1.2.1	Curie-Point Magnetic Data Interpretation		|------	------	______	______	______|		Δ1					
1.2.2	Structural Interpretation of Magnetic Data		|------	------	______	______	______|		Δ2					
1.2.3	Resistivity Studies				|------	------	------	------	------	______	______	______	______|	Δ3

Deliverables

1. Technical Report
2. Technical Report
3. Technical Report

1.2 GEOPHYSICAL STUDIES

BUDGET

A. Salaries and Wages:

	Days		Amount
1. Salaries- Professional			$ 15,579
H. P. Ross	23		
P. E. Wannamaker	62		
P. M. Wright	10		
2. Salaries-Support			2,446
Staff Analyst	5		
Draftsperson	15		
Secretary	15		
3. Wages-Professional			8,850
Research Assistants	185		
Total Salaries and Wages			$ 26,875

B. Employee Benefits:

1. .39 of A.1 & A.2	$7,030	
2. .095 of A.3	841	
Total		7,871

C. Travel:

1. Vehicle Rental-(4x4) for 5,400 miles @ $.30/mile	$1,620	
2. Per Diem - 54 days @ $21/day	1,134	
3. Lodging - 45 days @ $35/day	1,575	
4. Trips to Menlo Park, California (2)	1,420	
5. Technical Meetings (2)	1,500	
Total		7,249

D. Supplies:

1. Field Supplies	$1,500	
2. Drafting Supplies	500	
3. Office Supplies	75	
Total		2,075

E. Computer:

1. PRIME 400	3,000

F.	Reproductions:	
	1. Printing, Binding and Distribution Costs	900
G.	Other Costs:	
	1. Resistivity Equipment Rental	2,000
H.	Total A thru G:	$49,970
I.	Indirect Costs:	
	1. .45 of "H"	22,487
J.	G & A Costs:	
	1. .145 of "H"	7,246
K.	Total H thru J:	$79,703
L.	Fee:	
	1. .065 of "K"	5,182
M.	Total Project Costs:	$84,885

1.3 CASCADE MAGMA CHAMBERS STUDIES

Background

The magma chambers beneath andesitic Cascade-type volcanoes are thought to form at intermediate levels (8-14 km) in the crust. These depths plus the geometry of the storage chambers themselves and short residence time of magma in the chambers may determine heat-source characteristics of the magmas with respect to geothermal systems that are accessible within reasonable drilling depths. However, it is probable that silicic by-products of andesitic volcanism form high-level chambers and erupt at the surface as pyroclastic flows (Mt. St. Helens), calderas (Crater Lake and Newberry) and dome fields (Medicine Lake). These silicic eruption centers are common throughout the Cascades and are obvious targets for geothermal exploration. Modern petrologic techniques can be used to evaluate magma chamber temperatures and oxygen fugacity using co-existing iron-titanium oxides. Once temperatures are known, the plagioclase geothermometer can be used to estimate water pressure. We can then estimate total pressure and water content of the liquid and thus allow a determination of magma chamber depth. This has been done by Ritchey at Crater Lake. He has determined that the eruption which led to the formation of Crater Lake resulted from 850-960°C magma from a 6-10 km deep chamber.

The work proposed herein is needed in order to form geologic models of Cascades intrusive/hydrothermal systems. Such models are useful in evaluating various exploration techniques and strategies. The work prepared here will support that described under 1.2, GEOPHYSICAL STUDIES.

Scope of Work

Task 1.3.1 Sample Collection. We will sample the major felsic eruptive centers of the Cascades to determine the variation of magma chamber depths and temperatures using the above described petrologic techniques. Many of these complexes will have been dated by radiometric techniques, but those which have not will be sampled and dated using K-Ar techniques.

Task 1.3.2 Data Analysis. The data will be compiled into a summary report on Quaternary silicic volcanism in the Cascades province. This report will discuss the chemistry, age relationships, and probable magma chamber characteristics of these centers. We will evaluate the data collected in terms of the utility of these techniques to geothermal exploration. This will develop a regional picture of the geothermal potential of these silicic centers in the Cascades.

Task 1.3.3 Reporting. The results of this project will be presented in a technical report or published in a professional journal.

1.3 CASCADE MAGMA CHAMBERS

SCHEDULE AND DELIVERABLES

FY 1985

TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1.3.1 Sample Collection												
1.3.2 Data Analysis												
1.3.3 Reporting												Δ1

<u>Deliverables</u>

1. Technical Report

1.3 CASCADE MAGMA CHAMBERS

BUDGET

A. Salaries and Wages:

	Days		Amount
1. Salaries- Professional			$10,591
D. L. Nielson	60		
2. Salaries-Support			1,201
Staff Analyst	5		
Draftsperson	5		
Secretary	5		
Total Salaries and Wages			$11,792
B. Employee Benefits:			
1. .39 of A.1 & A.2			4,599
C. Travel:			
1. Vehicle Rental-(4x4) for 3,700 miles @ $.30/mile		$1,110	
2. Per Diem - 20 days @ $21/day		420	
3. Lodging - 18 days @ $45/day		810	
4. Airfare to Portland, Oregon (2)		840	
5. Trips to Los Alamos (2)		1,540	
6. Technical Meetings (1)		750	
Total			5,470
D. Supplies:			
1. Field Supplies		$250	
2. Drafting Supplies		175	
3. Office Supplies		50	
Total			475
E. Computer:			
1. PRIME 400			200
F. Reproductions:			
1. Printing, Binding and Distribution Costs			1,000
G. Other Costs:			
1. Chemical Analyses		$2,000	
2. K-Ar Age Dating		1,750	

	3. Electron Microprobe	500	
	4. Thin Sections	300	
	Total		4,550
H.	Total A thru G:		$28,086
I.	Indirect Costs:		
	1. .45 of "H"		12,639
J.	G & A Costs:		
	1. .145 of "H"		4,072
K.	Total H thru J:		$44,797
L.	Fee:		
	1. .065 of "K"		2,913
M.	Total Project Costs:		$47,710

2.0 BRINE INJECTION RESEARCH PROGRAM

We are proposing work in three areas in injection research for FY 85:

1. Tracer Development
2. Support for Injection-Backflow Field Experiments,
3. Geophysical Technique Development

For tracer development, we propose to examine the geothermal applications of a new type of chemical tracer--the fluorinated hydrocarbons. These compounds appear to be conservative and are detectable in concentrations of parts per trillion, representing a factor of 10,000 or more greater detectability than other tracers. This is very important in tracing fluids between wells where dilution effects have been shown at Wairakei, for example, to be 10^8. We propose a laboratory study of these tracers before possible field application.

We also propose to support any new huff-puff field experiments. We request, however, that if a field experiment is planned, that we be funded for our field support in order to preserve the two research budgets in tracer development and geophysical technique development. Past years have seen the vast majority of our budget spent on field work and analytical chemistry, with relatively little remaining for research.

We propose to look at the geophysical techniques we have used in the past field experiments to determine under what conditions they may be expected to work in the field.

2.1 TRACER DEVELOPMENT

Background

Tracers provide essential information during the development of a geothermal field on the rates and directions of fluid movement. Yet, despite the importance of the data, there have been few systematic attempts to test and develop tracers suitable for use in high temperature geothermal systems. An effective tracer should be (1) environmentally safe, (2) detectable at low concentrations, and its concentration can be quantified, (3) present in negligible or at least well known and constant concentrations in reservoir fluids, (4) unreactive with the reservoir rock and fluid, (5) stable, (6) inexpensive, and readily available. Although effective tracers have been developed for normal ground water applications, the behavior of most tracers in geothermal reservoirs is poorly known. The geothermal environment poses much more severe conditions due to the high temperature and reactive nature of most geothermal brines.

Most of the tracers currently used fall into one of three general categories: 1) isotopes, 2) organic dyes, or 3) salts of sodium iodide, bromide or chloride. Each has several important drawbacks. Although isotopic tracers (such as tritium) are relatively inert and can be used in minute quantities, they are difficult to handle, expensive to analyze and may be environmentally hazardous. Many of the organic dyes are thought to be both heat and light sensitive and may be adsorbed onto clays or zeolites in the reservoir rocks. The salts, while relatively stable and inexpensive, may also be adsorbed, and chloride is already present in geothermal brines and consequently must be used in relatively large quantities. Tests at East Mesa and Raft River suggest that Cl, Br, and I are stable at least up to moderate temperatures of 150°C. However, their disappearance in other high temperature tests (Roland Horne, pers. comm.) suggests that other factors, such as water-rock interactions may inhibit their movement.

The purpose of the work proposed here is to initiate investigations on a new class of tracers, fluorinated hydrocarbons, which appear from chemical and thermodynamic considerations to be ideal tracers. They are expected to be thermally stable, non-adsorptive and chemically diverse. These compounds are produced by substituting fluorine for hydrogen in organic molecules. Fluorinated hydrocarbons have the property that they can be produced in homologous series, i.e., series whose components vary regularly in their chemical and physical properties. Each component in the series can be analyzed simultaneously by the same technique (chromatography) and can be detected in very small quantities. By adding different fluorinated hydrocarbons to fluids being injected each of in several wells in a geothermal field, it may be possible to label each of the injection wells, so that movement of fluid from each can be independently monitored. Furthermore, fluorocarbons can be designed to partition into either the gas or the liquid phase of a geothermal fluid, allowing the possibility of investigating separately both components of two phase systems.

We propose to initiate laboratory tests on fluorinated hydrocarbons to assess their stability and adsorptive characteristics at temperature and pressure conditions typical of high-temperature geothermal reservoirs. We will also examine methods of analysis that appear to be quantitative as well as inexpensive. During FY 84, we initiated similar tests of the organic dye, fluorescein. These tests indicate that at a temperature of 185°C and a run duration of 78 hours, fluorescein does not thermally decompose or adsorb onto granitic rocks. We believe that such laboratory tests on the fluorinated hydrocarbons are necessary before we decide whether or not to recommend field trials of these new tracers in injection-backflow tests.

If we could establish the fluorinated hydrocarbons as effective tracers in the geothermal environment, it would be an important contribution.

Scope of Work

Task 2.1.1 Experimental Test Design. Prior to conducting bench tests, a comprehensive experimental program will be designed. We will identify appropriate hydrocarbons for the initial testing, establish the conditions for the experimental runs, and define appropriate handling and analytical techniques.

Task 2.1.2 Laboratory Testing. Laboratory bench testing of selected fluorinated hydrocarbons will be conducted using high-temperature experimental apparatus that simulates the conditions within a geothermal reservoir. We will examine the effects of four variables: 1) temperature, 2) time, 3) rock type and 4) brine composition. Rock chip samples from geothermal reservoirs, stored at UURI's geothermal sample library, and mineral separates will be used in the experiments. The fluids will be artificially made to closely match geothermal reservoir brines.

Task 2.1.3 Analysis. The composition of the fluids used in the experiments will be determined before and after each experiment to evaluate the extent of the reactions which have occurred. The concentrations of the major and minor elements, pH, bicarbonate, total dissolved solids, sulfate, chloride and fluoride will be determined in addition to the concentrations of tracer being tested. These data will be coupled with mineralogic data obtained from petrographic and X-ray analyses of the rock chip samples both before and after the test to describe the water-rock reactions that occurred during the tests. This will enable us to evaluate tracer behavior under these simulated field conditions.

2.1 TRACER DEVELOPMENT

SCHEDULE AND DELIVERABLES

FY 1985

TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
2.1.1 Experimental Test Design		|———	———	———	|							
2.1.2 Laboratory Testing				|———	———	———	———	———|				
2.1.3. Analysis					|———	———	———	———	———	———	—Δ1	

<u>Deliverables</u>

1. Technical Report on Fluorinated Hydrocarbons as Geothermal Tracers

2.1 TRACER DEVELOPMENT

BUDGET

A. <u>Salaries and Wages:</u>

	Days		Amount
1. Salaries- Professional			$ 44,537
M. C. Adams	130		
R. L. Kroneman	15		
J. N. Moore	44		
P. M. Wright	90		
2. Salaries-Support			2,667
Staff Analyst	10		
Draftsperson	10		
Secretary	15		
3. Wages-Professional			5,741
Research Assistants	120		
Total Salaries and Wages			$ 52,945

B. <u>Employee Benefits:</u>

1. .39 of A.1 & A.2		$18,410	
2. .095 of A.3		545	
Total			18,955

C. <u>Travel:</u>

1. Trips to Tucson, Arizona (6)		$4,620	
2. Trips to DOE/ID (3)		1,320	
3. Technical Meetings (4)		3,000	
Total			8,940

D. <u>Supplies:</u>

1. Laboratory Supplies		$6,375	
2. Drafting Supplies		125	
3. Office Supplies		50	
Total			6,550

E. <u>Computer:</u>

1. PRIME 400			1,500

F.	Reproductions:		
	1. Printing, Binding and Distribution Costs		475
G.	Other Costs:		
	1. X-ray Analyses	$ 3,000	
	2. Chemical Analyses	15,000	
	Total		18,000
H.	Total A thru G:		$107,365
I.	Indirect Costs:		
	1. .45 of "H"		48,314
J.	G & A Costs:		
	1. .145 of "H"		15,568
K.	Total H thru J:		$171,247
L.	Fee:		
	1. .065 of "K"		11,133
M.	Total Project Costs:		$182,380

2.2 SUPPORT FOR INJECTION-BACKFLOW FIELD EXPERIMENTS

Background

Injection-backflow (huff-puff) tests have been an integral part of the overall injection program during the last two years. During this time, ESL/UURI has actively participated in the design of field experiments at Raft River and East Mesa, provided field and laboratory support and collected and interpreted geologic, geochemical and geophysical data.

One purpose of these investigations has been to develop new methods of mapping the direction and rate of fluid movement in the subsurface using a single well. Essentially, these tests consist of injecting fluids spiked with tracer into the reservoir for varying lengths of time before backflowing them and collecting samples of the recovered fluid for determination of tracer concentration and other chemical analyses. During the tests, geoscientific and engineering measurements can be made. Because only a single well is used, data can be obtained on the fluid movement without relying on the interconnection between multiple wells.

As a result of these tests, a significant amount of new data on tracers, scale inhibitors, and fluid movement in geothermal systems has been obtained. Because these data are collected under actual operating conditions, they can be utilized directly by the geothermal industry. Consequently, these tests have been supported by the geothermal industry.

Under this task, UURI will provide geoscientific support, analyses and data interpretation to the field program, in accordance with management agreements among DOE/ID, UURI and EG&G.

Because it is unclear at this time what huff-puff tests will be conducted during FY 85, if any, the tasks and especially the schedule and budget given below are chosen to be representative. We have assumed that about one month of field testing will be undertaken and that ESL will be required to provide field support as well as fluid sampling, field geochemistry, laboratory analytical chemistry, data integration with resulting recovery curves, and data analysis. If these assumptions are modified, the schedule and budget proposed below will also require modification.

Scope of Work

Task 2.2.1 Sampling and On Site Geochemistry. All necessary on site geochemical analyses and sample collection will be performed.

Task 2.2.2 Laboratory Chemical Analyses. Complete chemical analyses of the samples collected during the field program will be performed at UURI's laboratory facilities in Salt Lake City.

Task 2.2.3. Geologic Support. Geologic data will be collected, where possible, and integrated with hydrologic data (collected and interpreted by EG&G) to establish a realistic hydrologic model of the geothermal reservoir.

Task 2.2.4. Geochemical Interpretation. The geochemical data will be used to construct recovery curves for the tracers and cations contained in the injected fluids. These curves will be used to assess the extent of water-rock interaction occurring in the reservoir.

Task 2.2.5 Geophysical Surveys. Provided that field tests are conducted in an area that appears to be a good candidate for geophysical surveys designed to detect movement of the injected fluid, such surveys will be carried out.

2.2 SUPPORT FOR INJECTION-BACKFLOW FIELD EXPERIMENTS

SCHEDULE AND DELIVERABLES*

FY 1985

	TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
2.2.1	Sampling and On-Site Geochemistry				---	---	---						
2.2.2	Laboratory Chemical Analyses					---	---	---	---	Δ1			
2.2.3	Geologic Support			---	---	---	---	Δ2					
2.2.4	Geochemical Interpretation							---	---	---	---	Δ3	
2.2.5	Geophysical Surveys				---	---	---	Δ4					

Deliverables

1. Report of Chemical Data
2. Technical Report
3. Technical Report
4. Technical Report

* No definite schedule for field tests established yet.

2.2 SUPPORT FOR INJECTION-BACKFLOW FIELD EXPERIMENTS

BUDGET

A. Salaries and Wages:

	Days		Amount
1. Salaries- Professional			$ 31,837
M. C. Adams	85		
R. L. Kroneman	60		
J. N. Moore	40		
B. S. Sibbett	30		
P. M. Wright	15		
2. Salaries-Support			2,446
Staff Analyst	5		
Draftsperson	15		
Secretary	15		
Total Salaries and Wages			$ 34,283

B. Employee Benefits:

1. .39 of A.1 & A.2			13,370

C. Travel:

1. Vehicle Rental-(4x4) for 6,300 miles @ $.30/mile		$1,890	
2. Per Diem - 81 days @ $21/day		1,701	
3. Lodging - 72 days @ $45/day		3,240	
4. Trips to DOE/ID (4)		1,760	
5. Technical Meetings (3)		2,250	
Total			10,841

D. Supplies:

1. Field Supplies		$500	
2. Drafting Supplies		100	
3. Office Supplies		50	
Total			650

E. Computer:

1. PRIME 400			4,000

F.	Reproductions:		
	1. Printing, Binding and Distribution Costs		1,000
G.	Other Costs:		
	1. X-ray Analyses	$ 2,000	
	2. Chemical Analyses	40,000	
	Total		42,000
H.	Total A thru G:		$106,144
I.	Indirect Costs:		
	1. .45 of "H"		47,765
J.	G & A Costs:		
	1. .145 of "H"		15,391
K.	Total H thru J:		$169,300
L.	Fee:		
	1. .065 of "K"		11,005
M.	Total Project Costs:		$180,305

2.3 GEOPHYSICAL TECHNIQUE DEVELOPMENT

Background

During the injection-backflow tests at both Raft River and East Mesa, geophysical surveys were conducted in an attempt to map the direction of subsurface fluid movement. At Raft River, both the galvanic resistivity and the spontaneous potential (SP) techniques were used, whereas at East Mesa only SP was attempted. Neither of these test areas was entirely appropriate for the application of such geophysical methods due to depth to the injection zone. None of our geophysical results so far have been useful in determining subsurface fluid movement, although success has been claimed by Sandia National Laboratory in detecting a resistivity anomaly during stimulation tests at Beowawe, NV.

Over the past year, we have been developing computer algorithms to model the geophysical response of conductive fluids in thin fractures using various electrode arrays. Such computer techniques have not been available anywhere before. This work is still in progress under support from the Reservoir Definition Program, out of the San Francisco Operations Office. Certain results of this work look promising, but the specific application to mapping subsurface fluid movement has not been investigated yet because the thrust of the project for SAN is directed toward fracture mapping.

We propose to use our new computer algorithms and others that we already have to model injection-backflow applications. Our purpose is to attempt to define a geophysical technique that will work in huff-puff testing to map direction of fluid flow away from an injection well.

Scope of Work

Task 2.3.1 Resistivity Techniques. We will use newly developed algorithms to investigate various arrays of down-hole and/or surface electrodes to determine an optimum technique and to define the conditions under which it will work.

Task 2.3.2 SP Technique. We will use our SP modeling techniques to attempt to define the conditions under which this technique will work to determine direction of fluid movement during injection.

Task 2.3.3 Magnetic Techniques. The Gas Research Institute is sponsoring an experiment to determine if injected fluid laced with magnetic iron filings can be traced with surface and borehole magnetometers. We will obtain the results of this experiment and evaluate their applicability to our injection-backflow work.

2.3 GEOPHYSICAL TECHNIQUE DEVELOPMENT

SCHEDULE AND DELIVERABLES

FY 1985

TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
2.3.1 Resistivity Techniques			|———	———	——---	---Δ1						
2.3.2 SP Technique			|———	———	——---	------	---Δ2					
2.3.3 Magnetic Techniques		|———	———	——---	------	---Δ3						

Deliverables

1. Technical Report
2. Technical Report
3. Technical Report

2.3 GEOPHYSICAL TECHNIQUE DEVELOPMENT

BUDGET

A. Salaries and Wages:

	Days		Amount
1. Salaries- Professional			$ 7,623
P. E. Wannamaker	20		
P. M. Wright	20		
2. Salaries-Support			1,558
Staff Analyst	5		
Draftsperson	10		
Secretary	5		
3. Wages-Professional			9,153
S. H. Ward	10		
Research Assistants	120		
Total Salaries and Wages			$ 18,334

B. Employee Benefits:

1. .39 of A.1 & A.2	$3,581	
2. .095 of A.3	870	
Total		4,451

C. Travel:

1. Trip to Gas Research Institute	$970	
2. Trips to DOE/ID (1)	440	
3. Technical Meeting (1)	750	
Total		2,160

D. Supplies:

1. Drafting Supplies	200	
2. Office Supplies	50	
Total		250

E. Computer:

1. PRIME 400	4,000

F. <u>Reproductions</u>:

1. Printing, Binding and Distribution Costs	400
G. Total A thru F:	$29,595
H. Indirect Costs:	
1. .45 of "G"	13,318
I. G & A Costs:	
1. .145 of "G"	4,291
J. Total G thru I:	$47,204
K. Fee:	
1. .065 of "J"	3,066
L. Total Project Costs:	$50,270

3.0 STATE COUPLED RESOURCE ASSESSMENT PROGRAM

Background

The Earth Science Laboratory/University of Utah Research Institute proposes a two-part program of technical support to the U. S. Department of Energy's State Coupled Geothermal Resource Assessment Program. The first part of the program will be to continue to act as a technical liaison between DOE and state teams. This role includes monitoring technical progress on deliverables, advising teams and DOE on exploration techniques, and, where appropriate, providing interpretation of results. The second role of UURI on the State Coupled Program will be to provide technical support to DOE and state teams, which will supplement ongoing assessment efforts. UURI will also provide DOE with progress, summary, and technical reports.

During FY 1984, a new component has been added to the existing efforts of the State Coupled Program. New funding to selected states, in the form of grants, has been established to focus state efforts on higher temperature resources, or resource definition tasks that are beyond the capability of the private sector. Previously existing efforts of the states are being completed, with some work extending into FY 1985.

The newly funded FY 1984 work will continue into FYs 1985 and 1986. Teams involved in the new work include the states of Alaska (2 teams), Idaho, Montana, New Mexico, Oregon, Utah, and Washington, which are funded through DOE Idaho Falls, and California, Nevada and Hawaii, which are funded through DOE San Francisco. The establishment of the new programs means that DOE has a continuing need for technical support.

UURI proposes to provide such technical support to DOE/ID and DOE/HQ. UURI efforts will include acting as a technical liasion between DOE and state teams, monitoring the progress of state teams on deliverables, providing DOE with current data on teams, and performing selected research to support team efforts.

Discussion

The State Coupled Program was established by DOE in the mid-1970s, to assess low- and moderate-temperature geothermal resources in the U.S. When the program started, fewer than 250 thermal wells and springs had been identified in the U.S. At the closure of input to the USGS computer file GEOTHERM, more than 6,000 sites were inventoried, and more have been discovered since.

The early efforts of the State Coupled Program were national in scope. Geoscientific investigations were made in all states, with the most intensive activity focusing in states with either existing geothermal resources or a large user potential. These studies demonstrated that most moderate- and high-temperature geothermal resources are found in the western portion of the country, with low-temperature resources also found in the great plains and Atlantic coast regions.

Tasks of the early program included resource assessment, map production, cooperation with USGS assessment efforts, and dissemination of information to interested technical and non-technical people. These efforts greatly increased knowledge about geothermal resources, and led to development projects in many states.

UURI support to DOE and state teams during the early phase of the State Coupled Program included technical program monitoring, coordination of program-wide efforts, and technical support to state teams. Program monitoring included multiple visits to team to review ongoing progress, reviews of manuscripts of team reports, and numerous contacts with teams. Program-wide coordination included supervision of the production of geothermal resource maps, compilation of data required by the USGS in national resource assessment efforts, and convening of technical interchange meetings for all state teams, which included education sessions with UURI exploration professionals. Results of the monitoring and coordination efforts were regularly communicated to DOE. UURI also provided technical support to state teams, in the form of chemical analyses, geophysical modeling, age dating, and other services. These results are contained in many state team reports. UURI efforts on the earlier phase of the program will continue in FY 1985.

The new portion of the State Coupled Program, established in FY 1984, includes multiple efforts in resource assessment. This program is based on grants, rather than cooperative agreements, but many of the participating states are cost-sharing their efforts. Assessment tasks managed by DOE/ID are active in seven states, and include geologic mapping, geochemical investigations, geophysical studies, thermal gradient drilling, and hydrologic studies, all focused on reservoir definition.

UURI has been active in supporting DOE/ID and DOE/HQ during the establishment of these new grants, by providing evaluations of past efforts of individual teams, coordinating with teams on technical tasks to be undertaken, and supporting DOE needs for data during the awarding of the grants. UURI has also been active in tracking the early progress of the teams. The tasks proposed for FY 1985 will continue these efforts, and provide DOE with needed program monitoring and technical activities.

Proposed Scope of Work

The proposed scope of work reflects DOE needs for data on teams that are active in both the earlier and new portions of the program. The unique position of UURI in being the only DOE support contractor active on the State Coupled Program continuously since 1977 enables optimal utilization of personnel and facilities to provide DOE and state teams with needed technical support. The proposed tasks and budget are based on the needs of DOE/ID and DOE/HQ, and the states contracted through DOE/ID, for support. Slight modifications will be required if UURI efforts expand beyond these agencies.

UURI also proposes a modest effort to provide technical support to state teams. This support might include geologic mapping in areas of interest to state teams, geochemical analytic services, geophysical evaluations, or other appropriate studies for which states are not funded or do not have the capability. Studies undertaken will be coordinated with and compliment state team efforts.

Task 3.1 Progress Monitoring

Monitor the technical progress of state teams on all tasks funded through the State Coupled Program. Accomplish such monitoring through phone conversations, written communications, and at least one on-site visit to each team during the year. Provide DOE/ID and DOE/HQ with regular updates on and evaluations of state team progress.

Task 3.2 Technical Support

Provide technical support to state teams, through conducting studies that support state efforts.

Task 3.3 Reporting

Prepare appropriate reports and deliverables based on the above tasks, including monthly progress reports, a year-end progress report, and technical reports as appropriate.

3.0 STATE COUPLED RESOURCE ASSESSMENT PROGRAM

SCHEDULE AND DELIVERABLES

FY 1985

TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
3.1 Progress Monitoring	|———	———	———	———	———	LOE	———	———	———	———	———	———|
3.2 Technical Support	|———	———	———	———	———	LOE	———	———	———	———	———	———|
3.3 Reporting												Δ1 Δ2

Deliverables

1. Annual Progress Report
2. Topical Report on Technical Support Effort

3.0 STATE COUPLED RESOURCE ASSESSMENT PROGRAM

BUDGET

A. SALARIES AND WAGES:	Days		Amount
1. Salaries - Professional			$ 32,630
D. Foley	185		
J. N. Moore	5		
D. L. Nielson	5		
P. M. Wright	10		
2. Salaries - Support			4,053
Staff Analyst	12		
Draftsperson	15		
Secretary	30		
Total Salaries and Wages			$ 36,683
B. EMPLOYEE BENEFITS:			
1. .39 of A.1 & A.2			14,306
C. TRAVEL:			
1. Trips to State Teams (4)		$3,350	
2. Trips to DOE/ID (3)		1,310	
3. Trips to DOE/HQ (2)		2,000	
4. Technical Meeting		1,225	
Total			7,885
D. SUPPLIES:			
1. Drafting Supplies		$375	
2. Office Supplies		150	
Total			525
E. COMPUTER:			
1. Prime 400			170
F. REPRODUCTIONS:			
1. Printing, Binding and Distribution Costs			750

G. OTHER COSTS:	
1. Geochemical Analyses	2,000
H. TOTAL A THRU G:	$ 62,319
I. INDIRECT COSTS:	
1. .45 of "H"	28,044
J. G & A COSTS:	
1. .145 of "H"	9,036
K. TOTAL H THRU J:	$ 99,399
L. FEE:	
1. .065 of "K"	6,461
M. TOTAL PROJECT COSTS:	$105,860

4.0 TECHNOLOGY TRANSFER

Transfer to the private sector of technology developed under federal funding is necessary in order that the fruits of federal research efforts are realized. Federal agencies and contractors are often criticized because of failure to publish research results, and in certain cases this criticism is valid. Technical reports, including journal publications, are probably the most important technology transfer mechanism. Close behind are technical presentations at national or regional meetings of professional societies. Often, however, technical reports, especially journal publications, are too short or are directed along specific lines such that items of interesting and valuable scientific insight go unreported. In addition, on many scientific projects reporting is usually left until last. Often the work is completed when the remaining budget is too small to do a thorough job of reporting or else a large amount of data are collected and there are not enough funds to analyze and report it completely. We therefore believe that allocation of funds for more thorough reporting of work for current and perhaps past projects would be well spent.

One current problem in the geothermal industry is that the smaller companies seem to be more aggresive in exploration and development in the U.S. than the major oil companies, and usually the staff members of these smaller companies have limited experience and education. If these staffs could be helped along it would give the industry a boost. With these things in mind, we would like to propose the following items of technology transfer.

4.1 ANNUAL WORKSHOP IN EXPLORATION TECHNOLOGY

Background

It is clear that problems in exploration and resource assessment continue to contribute heavily to the cost of geothermal development. Nowhere is this more evident than in the Cascades, where industry has only vague and untested ideas about how to locate and assess resources. In spite of a significant industry effort in exploration and a multi-year, multi-disciplinary study by the USGS, the geothermal community is not even able to say whether or not geothermal systems are plentiful in the Cascades. Exploration problems also exist outside of the Cascades. Numerous problems, such as remote detection of fractures and siting drill holes to intersect permeable horizons, are generic, and not restricted to a geographic location.

We suggest that there is a need in the geothermal community for an annual workshop dealing specifically with technology transfer among scientists working in geothermal exploration technology. The workshop would be patterned after the very successful Reservoir Engineering Workshop which is sponsored by Stanford University. Presentations would be solicited from industry, universities, and research laboratories who are working on problems in geothermal exploration and reservoir assessment. The atmosphere would be informal, and hand-written or rough-typed note would be accepted. The proceedings would be available as a compilation of informal papers at the time of the meeting. We would work to develop international participation. The sessions would be held in or near Salt Lake City, probably in the spring. Numerous conference facilities are available in town, at the University, or at one of the nearby popular resorts.

We have been in contact with the organizers of the Stanford workshop, and plan to contact Dave Anderson of the Geothermal Resources Council. We do not feel that our proposed conference would dilute or detract significantly from meetings that they sponsor. Regarding the Stanford workshop, a reasonably clear interface exists between exploration and resource assessment topics on the one hand and reservoir engineering topics on the other hand. Stanford has restricted its interests to the latter. Regarding GRC meetings, no conflict is anticipated with their educational workshops, which are tutorial in nature. Possible overlap would occur with the annual GRC convention. However, this annual meeting attempts to cover the entire range of topics pertinent to geothermal developers, and thus there are compromises on coverage given to each topic area that would not occur in our meeting.

If desirable, the workshop could have other objectives in addition to the objectives of communication among scientists and technology transfer to industry. A special session could be specifically convened to obtain input from industry representatives into problems that they face and priorities. We understand that there are special regulations to be considered to make this process legal, and we would work with DOE to ensure that the conduct of the special session was proper in this regard.

We would like to have lead responsibility for the proposed workshop. This would obviously help enhance our position in the geothermal community and would help foster the federal-university ties the current administration is encouraging. At the same time, however, we would want to work cooperatively with other federally funded groups involved in developing exploration and assessment technology. We would seek cooperation with the relevant national laboratories and with the USGS. In particular, we would propose to work closely with LBL, who has been given the "cognizant laboratory" position with respect to reservoir definition and has been assigned the task of seeking industry input to the hydrothermal research program.

Scope of Work

During the last fiscal year, DOE-HQ has identified fracture detection and mapping as a primary topic for multi-disciplinary research. Detection and mapping of fractures, both within boreholes and from the surface, are difficult using today's technology. We believe that a workshop on this topic would be timely. Another topic also of prime concern today is hydrothermal alteration. The GRC has sponsored organization of a working group in this discipline, and this group is contemplating a meeting separate from the annual GRC meeting. They could easily be incorporated into our proposed meeting.

For the first workshop, we propose a two and one-half day meeting as follows:

First Day: Fracture Detection and Mapping
Second Day: Hydrothermal Alteration
Cascades Environment Exploration
Third Day: General Exploration Topics

We anticipate that once the annual workshop becomes established, it would bring in enough funds to be self supporting. For the first two years we propose to make a modest registration charge which would be increased somewhat after two years. We request financial support from DOE for the first two years.

Task 4.1.1 Conduct Annual Exploration Workshop. Organize and sponsor an annual workshop in geothermal exploration techniques, as discussed above.

Task 4.1.2 Report. Publish a volume of the papers given at the workshop.

4.1 ANNUAL WORKSHOP IN EXPLORATION TECHNOLOGY

SCHEDULE AND DELIVERABLES

FY 1985

	TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
4.1.1	Conduct Annual Exploration Workshop				|-------	--------	--------	--------	-------	-----| Δ1			
4.1.2	Report									Δ2			

Deliverables

4.1 EXPLORATION TECHNOLOGY ANNUAL WORKSHOP

BUDGET

A. Salaries and Wages:

	Days		Amount
1. Salaries- Professional			$ 5,064
D. L. Nielson	12		
P. M. Wright	12		
2. Salaries-Support			4,356
Staff Analyst	30		
Draftsperson	5		
Secretary	10		
Total Salaries & Wages			$ 9,420
B. Employee Benefits:			
1. .39 of A.1 & A.2			3,674
C. Travel:			
1. Vehicle Rental-(4x4) for 750 miles @ $.30/mile for trips to conference site			225
D. Supplies:			
1. Drafting Supplies		$150	
2. Office Supplies		400	
Total			550
E. Reproductions:			
1. Printing, Binding and Distribution Costs			500
F. Total A thru E:			$14,369
G. Indirect Costs:			
1. .45 of "F"			6,466
H. G & A Costs:			
1. .145 of "F"			2,084
I. Total F thru H:			$22,919

J. Fee:

1. .065 of "I" — 1,491

K. Total Project Costs: — $24,410

4.2 SYMPOSIUM ON GEOTHERMAL SYSTEMS IN RECENT VOLCANIC TERRAINS

Background

D. L. Nielson of UURI has been asked by David Anderson of the Geothermal Resources Council and Bob Fournier of the USGS to organize a symposium on geothermal systems in active volcanic terrains for the 1985 meeting of GRC in Kona, Hawaii. The symposium will be international in scope with experts invited from a number of countries. Anderson has agreed to publish full-length peer reviewed papers documenting the results of this symposium. The results of this symposium will be particulary useful for DOE's new program in the Cascades Province by bringing together papers which can emphasize the relationships between geothermal systems and associated volcanic centers elsewhere in the world. The organization of such a symposium will require the following effort.

a. Identification and invitations to authors
b. Review of papers (March 25-28, 1985, San Francisco, CA)
c. Attendance of GRC meeting (August 26-30, 1985, Kona, HI)
d. Peer review of papers
e. Editing of Special Report of GRC containing full-length papers

Scope of Work

Task 4.2.1 Organize Symposium. We will organize a symposium on geothermal systems in recent volcanic terrains for the 1985 GRC meeting. We will also edit a special report of GRC containing full-length papers dealing with geothermal systems in recent volcanic environments.

4.2 SYMPOSIUM ON GEOTHERMAL SYSTEMS IN RECENT VOLCANIC TERRAINS

SCHEDULE AND DELIVERABLES

FY 1985

TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
4.2.1 Organize Symposium			|-----	------	------	------	------	------	------	------	------| Δ1	

<u>Deliverables</u>

1. Special Report of GRC - December, 1985

4.2 SYMPOSIUM ON GEOTHERMAL SYSTEMS IN RECENT VOLCANIC TERRAINS

BUDGET

		Days		Amount
A.	Salaries and Wages:			
	1. Salaries- Professional			$ 4,413
	D. L. Nielson	25		
	2. Salaries-Support			275
	Staff Analyst	1		
	Secretary	3		
	Total Salaries and Wages			$ 4,688
B.	Employee Benefits:			
	1. .39 of A.1 & A.2			1,828
C.	Travel:			
	1. Trip to San Francisco, California		$ 810	
	2. Trip to Kona, Hawaii		1,260	
	3. Trip to Davis, California		600	
	Total			2,670
D.	Supplies:			
	1. Drafting Supplies		$ 150	
	2. Office Supplies		75	
	Total			225
E.	Total A thru D:			$9,411
F.	Indirect Costs:			
	1. .45 of "E"			4,235
G.	G & A Costs:			
	1. .145 of "E"			1,365
H.	Total E thru G:			$15,011
I.	Fee:			
	1. .065 of "H"			974
J.	Total Project Costs:			$15,985

4.3 SPECIAL TOPIC GEOTHERMAL CONFERENCES

Background

Workshops and conferences provide an important forum for the exchange of ideas. For many people in the geothermal industry, these conferences provide the only opportunity for them to present their work for external scrutiny. Most conferences follow a similar format based on the presentation of selected papers, and most have a large number of participants. These characteristics generate several drawbacks. 1) meaningful scientific exchange by the attendees during open discussions is often limited, 2) preliminary ideas and unpublished data are often not discussed, and 3) there is only limited interchange among scientists in different disciplines who are working on related problems.

To develop better interaction among scientists working on geothermal problems, we propose to initiate annual geothermal meetings patterned after the Penrose Conference. Under this format each conference would deal with a topic of particular importance to the geothermal community. We propose to limit the conference attendance to a relatively small number of participants, say, 50-60. Each of the participants would agree to actively contribute. Approximately half of the participants would be from industry.

There are numerous topical areas of interest to the geothermal community which could be appropriate for intensive workshops of this type. One area of immediate and continued concern to DOE and the industry is the movement of fluids in fractured systems.

ESL believes that we have the expertise to take a lead role in the organization of such a workshop. Clearly, however, the skills of many people would be required. We would propose then to establish an organizing committee composed of experts from various industrial, academic and governmental organizations to help screen potential participants.

Scope of Work

Task 4.3.1 Conduct Conference. We will organize a special "Penrose" style conference on one of the following topics, at the discretion of DOE:

1. Geothermal Exploration in Cascades Environments
2. Fluid Movement in Fractured Rocks
3. Geothermal Tracer Technology
4. Fracture Detection and Mapping

4.3 SPECIAL TOPIC GEOTHERMAL CONFERENCES

SCHEDULE AND DELIVERABLES

FY 1985

TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
4.3.1 Conduct Conference			|-------	----------	----------	----------	----------	――――――	――――――|	Δ1		

Deliverables

1. Comprehensive Report of Conference

4.3 SPECIAL TOPIC GEOTHERMAL CONFERENCES

BUDGET

A. Salaries and Wages:

	Days		Amount
1. Salaries- Professional			$ 3,391
J. N. Moore	20		
2. Salaries-Support			3,557
Staff Analyst	20		
Draftsperson	10		
Secretary	10		
Total Salaries and Wages			$ 6,948
B. Employee Benefits:			
1. .39 of A.1 & A.2			2,710
C. Travel:			
1. Trips to Conference Site (2)			1,400
D. Supplies:			
1. Drafting Supplies		$150	
2. Office Supplies		100	
Total			250
E. Reproductions:			
1. Printing, Binding and Distribution Costs			1,500
F. Total A thru E:			$12,808
G. Indirect Costs:			
1. .45 of "F"			5,764
H. G & A Costs:			
1. .145 of "F"			1,857
I. Total F thru H:			$20,429

J. <u>Fee</u>:

1. .065 of "I"	1,326
K. Total Project Costs:	$21,755

4.4 HANDS-ON WORKSHOP IN ELECTRICAL GEOPHYSICS

Background

In general, there are two types of workshops and conferences directed toward the geothermal community. Conferences of broad topical interest include, among others, the annual meeting of the Geothermal Resources Council and the Stanford Reservoir Engineering Conference. Seminars and lecture series on topics of a more restricted interest are frequently held by the Geothermal Resources Council. The format of these meetings is generally similar and consists of the presentation of papers and reports or longer lectures. Unfortunately, this format is not appropriate for the teaching of complex subjects, especially those involving mathematical manipulations.

"Hands-on" workshops offer the student an opportunity to participate in the learning process in a logical manner. Based on our work with the geothermal community, we believe there is a critical need for "hands-on" workshops in several topic areas. Two of these areas are: 1) interpretation of routinely obtained geophysical measurements, such as gravity, aeromagnetic, electrical and thermal data, and 2) the evaluation of basic reservoir engineering data and of downhole logs.

ESL/UURI scientists are recognized as experts in the interpretation of geophysical data and are experienced in the organization and teaching of "hands-on" workshops. During FY 85, we propose to design and conduct a hands-on workshop in interpretation of electrical geophysical data.

There continues to be a great deal of misapplication of electrical geophysical methods in geothermal exploration and reservoir assessment. The main problems are that (1) these methods are usually quite complex to understand, (2) there are numerous electrical methods which differ among themselves significantly (galvanic resistivity, spontaneous potential, induced polarization, electromagnetic, magnetotelluric, audiomagnetotelluric, etc.), and (3) interpretation of electrical data is not straightforward. We have seen a great deal of very poor interpretation published. There is a tendency to apply the simplest interpretation techniques, which are usually based on one-dimensional (layered-earth) formulations. But we know that the geothermal environment is geologically complex, and that two- or three-dimensional interpretation schemes must be applied. Mathematical formulations for 2-D and 3-D interpretations are not easy, however, and some formulations do not even exist yet.

UURI has perhaps the most complete set of computer-based interpretation aids for electrical geophysical data in existence. We have a great deal of experience in applying these aids to geothermal problems. In addition, we have already taught a workshop like the one proposed in application in electrical geophysics in petroleum exploration. Thus, we have a significant portion of the course prepared already.

We would open attendance to anyone interested, would require a nominal registration fee to help cover costs, and would start at a beginning level. The course would be a full 4-1/2 days, and would be quite intensive. Students would take with them a manual from the course. We would provide data from geothermal areas and computer facilities for the student to use in interpretation.

Scope of Work

Task 4.4.1 Conduct a Hands-on Workshop. The topic would be application of electrical geophysical methods to geothermal exploration and development.

4.4 HANDS-ON WORKSHOP IN ELECTRICAL GEOPHYSICS

SCHEDULE AND DELIVERABLES

FY 1985

TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
4.4.1 Workshop		|------	------	------	------|Δ1							

Deliverables

1. Workshop Report and Technical Manual

4.4 HANDS-ON WORKSHOP

BUDGET

A. Salaries and Wages:

	Days		Amount
1. Salaries- Professional			$ 7,493
H. P. Ross	22		
P. E. Wannamaker	22		
2. Salaries-Support			3,822
Staff Analyst	20		
Draftsperson	10		
Secretary	15		
3. Wages-Professional			5,117
S. H. Ward	15		
Total Salaries and Wages			$16,432
B. Employee Benefits:			
1. .39 of A.1 & A.2		$4,413	
2. .095 of A.3		486	
Total			4,899
C. Supplies:			
1. Drafting Supplies		$225	
2. Office Supplies		150	
Total			375
D. Computer:			
1. PRIME 400			2,500
E. Reproductions:			
1. Printing, Binding and Distribution Costs			1,500
F. Total A thru E:			$25,706
G. Indirect Costs:			
1. .45 of "F"			11,568

H.	G & A Costs:	
	1. .145 of "F"	3,727
I.	Total F thru H:	$41,001
J.	Fee:	
	1. .065 of "I"	2,664
K.	Total Project Costs:	$43,665

4.5 SYMPOSIUM AND SPECIAL EDITION OF JOURNAL OF GEOPHYSICAL RESEARCH ON THE VALLES CALDERA

For several years, D. L. Nielson and J. B. Hulen have been working on cuttings from Union Oil Company's Baca project with funding from DOE's Reservoir Definition Program. At the same time, efforts have been underway to establish a scientific drilling program at the Valles caldera under funding to LANL and LBL from DOE/Office of Basic Energy Sciences. As a continuation of this effort to unravel the complex geology of this geothermal system, a conference has been planned at Los Alamos for October 15-17, 1984. This conference will bring together all researchers into the Valles caldera system to discuss the results of their studies. The product of the conference will be a special edition of the Journal of Geophysical Research on the Valles caldera. D. L. Nielson has been asked to chair the sessions on geology at this conference. J. B. Hulen will be present to explain the results of work on stratigraphy, structure, and hydrothermal alteration. This request is for salary and travel funds necessary to get us to this conference. A proposed budget is attached.

Scope of Work

Task 4.5.1 Presentation of Papers. Nielson and Hulen would present papers and these papers will be published in the transactions of the meeting.

4.5 SYMPOSIUM AND SPECIAL EDITION OF JOURNAL OF GEOPHYSICAL RESEARCH ON THE VALLES CALDERA

SCHEDULE AND DELIVERABLES

FY 1985

TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
4.5.1 Presentations	--——	Δ1										

Deliverables

1. Report of Conference (published by LANL) and Special Edition of JGR

4.5 SYMPOSIUM AND SPECIAL EDITION OF JOURNAL OF GEOPHYSICAL RESEARCH ON THE VALLES CALDERA

BUDGET

		Days		Amount
A.	Salaries and Wages:			
	1. Salaries- Professional			$ 1,268
	J. B. Hulen	4		
	D. L. Nielson	4		
	2. Salaries-Support			275
	Staff Analyst	1		
	Secretary	3		
	Total Salaries and Wages			$ 1,543
B.	Employee Benefits:			
	1. .39 of A.1 & A.2			602
C.	Travel:			
	1. Trips to Los Alamos (2)			1,540
D.	Supplies:			
	1. Drafting Supplies		$250	
	2. Office Supplies		150	
	Total			400
E.	Total A thru D:			$4,085
F.	Indirect Costs:			
	1. .45 of "E"			1,838
G.	G & A Costs:			
	1. .145 of "E"			592
H.	Total E thru G:			$6,515
I.	Fee:			
	1. .065 of "H"			425
J.	Total Project Costs:			$6,940

4.6 PUBLICATION OF RESULTS OF ASCENSION ISLAND GEOTHERMAL EXPLORATION

Background

UURI has been conducting a geothermal exploration project on Ascension Island for the U.S. Air Force through DOE/ID since 1982. This project work has resulted in four technical and two final reports which summarize the exploration philosophy, data collected, and results of the project. The data include geologic mapping, radiometric dating, an aeromagnetic survey, electrical resistivity surveys and drilling and thermal gradient information. Funding from the USAF has not allowed compilation of the results into publishable form. In fact, due to negotiations with the British, the USAF has requested that we do not yet release our results. The negotiations should soon be completed, and we anticipate we will have permission to publish the results of the project. The data base for this project is one of the most extensive known for a young volcanic environment, and its release will be valuable for exploration projects in similar environments, including the Cascades.

Scope of Work

Task 4.6.1 Publication. Publish the results of the geothermal exploration of Ascension Island in professional journals. It is now envisioned that papers will discuss geology, aeromagnetic survey results, electrical resistivity survey results, drilling and thermal gradient measurements, and exploration strategy. These papers will constitute a complete case study of the project to that point in time.

4.6 PUBLICATION OF RESULTS OF ASCENSION ISLAND GEOTHERMAL EXPLORATION

SCHEDULE AND DELIVERABLES

FY 1985

TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
4.6.1 Publication	|———	———	———	———	———	———	———	———	———	———	———	———| Δ (1) (2) (3) (4) (5) (6)

<u>Deliverables</u>

1. Geology of Ascension Island
2. Aeromagnetic Survey of Ascension Island
3. Electrical Resistivity Surveys of Ascension Island
4. Thermal Gradient Drilling on Ascension Island
5. Geothermal Exploration of Ascension Island
6. 2 Papers at Professional Meetings

4.6 PUBLICATION OF RESULTS OF ASCENSION ISLAND GEOTHERMAL EXPLORATION

BUDGET

A. Salaries and Wages:

	Days		Amount
1. Salaries- Professional			$13,842
D. L. Nielson	40		
H. P. Ross	20		
B. S. Sibbett	20		
2. Salaries-Support			2,712
Staff Analyst	5		
Draftsperson	15		
Secretary	20		
Total Salaries and Wages			$16,554
B. Employee Benefits:			
1. .39 of A.1 & A.2			6,456
C. Travel:			
1. Technical Meetings (2)			1,500
D. Supplies:			
1. Drafting Supplies		$175	
2. Office Supplies		75	
Total			250
E. Reproductions:			
1. Printing, Binding and Distribution Costs			3,000
F. Total A thru E:			$27,760
G. Indirect Costs:			
1. .45 of "F"			12,492
H. G & A Costs:			
1. .145 of "F"			4,025
I. Total F thru H:			$44,277

J. Fee:

1. .065 of "I" | 2,878

K. Total Project Costs: | $47,155

5.0 OCEAN HYDROTHERMAL RESEARCH PROGRAM

Background

Beginning in the 1960s, there arose a revival of an older idea, initially promoted by Alfred Wegener, that the crust of the earth is made up of rigid plates that are able to move relative to one another. Acceptance of this idea was slow because initially there was no mechanism known to (1) provide the large amount of energy needed to move huge crustal plates, nor (2) to move the plates without crushing them. The discoveries that new crust was being created at the mid-ocean ridges and destroyed at subduction zones, and that rigid crustal plates float on viscous material below changed our basic ideas of the earth's surface. Convincing confirmation of crustal generation at spreading centers essentially resulted from interpretation of the magnetic anomaly pattern in those areas. Within a few years afterward, the basic mechanisms of generation of new crust through intrusion of basalt at mid-coean ridges and the consumption of crust through subduction at convergent plate margins had been outlined. These ideas were found to explain a great deal of diverse geologic fact, some of which had been known for years. The close fit of the shapes of the continents of Africa with South America and Europe with North America across the Atlantic Ocean was seen to be not coincidence but an expresssion of the fact that these land masses had once been joined. Geologic formations had long been known to match on either side of the Atlantic. Also explained were paleomagnetic measurements, i.e. determinations of the direction of the ancient magnetic fields frozen into rocks. Before plate tectonic theories, the magnetic poles had been assumed to wander to account for the diverse magnetic directions shown by rocks of various ages, but now we believe that the plates have wandered, changing the apparent ancient magnetic field direction.

Spreading centers are characterized by active intrusion and volcanism of basaltic magma. Only during the past half dozen years have the extent and implications of this magmatism begun to be fully comprehended. Deep dives made by submersibles, such as the Alvin, have discovered hydrothermal activity in a number of locations on the spreading centers. Large volumes of 350°C fluids vent from the sea floor at some sites, precipitating metallic sulfide, sulfate and oxide minerals. It is too soon yet for accurate assessment of the energy and metal resource potentials, but these hydrothermal processes are now known to have occurred throughout geologic time, at least for the past 2 billion years, because some of the metallic deposits they have formed are being mined from ancient rocks today.

Very preliminary estimates of the hydrothermal energy potential have been made, and they indicate that perhaps 3.3 million megawatts may be continually dissipated into the ocean water from active hydrothermal convection at spreading centers. An even larger amount may be available if capped convective systems, postulated but not known to exist, can be tapped. Hydrothermal vents appear to occur in groups of 6 to 12, that together form a system. Individual systems are often separated by several kilometers, and 3 to 5 systems make up a field. The hydrothermal field that has been discovered on the East Pacific Rise spreading center at 21°N in the Pacific Ocean is estimated to be producing 11,500 MWt.

In a recent assessment of ocean resources within the proposed 200-mile Exclusive Economic Zone (EEZ), the U.S. Geological Survey (Circular 929) did not mention the energy resource possibilities of ocean hydrothermal systems. This is clearly an oversight, if not a blunder. The amount of energy potentially available through exploration of ocean systems is an appreciable fraction (1/3 to 1/2) of the total, continual human energy use. It is obvious that exploitation of this resource has truly great potential for helping with humanity's energy shortage.

Problems and Approach

The ocean hydrothermal resource is poorly understood, as are methods for exploiting it. High-temperature hydrothermal vents occur at five known sites, but only perhaps 150 km of the mid-ocean ridge crests have been explored out of a total length of 53,200 km. From geologic evidence and current models, ocean hydrothermal convection systems should be plentiful. There are no good samples of the vented fluid, and the rates of fluid flow from individual vents have only been crudely estimated. Obviously, before exploitation techniques can be devised, we need to know much more about temperature, flow rate, chemistry and how to tap the fluids.

Methods to use the enormous quantities of heat are likewise poorly understood. There is very little data on chemical processes at 350°C and 2000 bars pressure. Obviously, a great deal needs to be done to develop economic ways to use this truly renewable resource.

A great deal of scientific and engineering research and development work is needed. EG&G Idaho, Inc. is beginning work on development of techniques for utilization of the resource. UURI's role will be to assess the resource, specifically to (1) provide estimates of the physical and chemical characteristics of ocean hydrothermal systems, (2) develop conceptual models of the mechanism of operation of ocean hydrothermal convection for use in estimating system lifetimes, exploration techniques, etc., and (3) develop conceptual models of equipment and surveys for exploration for such systems.

Our fundamental approach will be:

1. FY 85. Gather and analyze available data on the resource, and perform an assessment of the state of the art in exploration of the

resource. The primary vehicle will be a workshop of leading ocean experts to be convened about June 1985. This workshop will focus on assembling the latest reservoir information. A second primary task will be selection of a known ocean site for more detailed investigation in FY 86-87.

2. FY 86-87. Detailed investigations of one or two specific ocean hydrothermal sites will be undertaken. The primary purposes will be to make accurate measurements of fluid temperature and flow rates in the vents, and to map the vent fields. All of these data will be used to determine accurately the heat dissipation from each vent and vent field. Fluid samples will be taken for determination of chemical properties.

Scope of Work - FY 85

Task 5.1 Assemble Available Data. There is some data available on the resource, mainly from oceanographic institutions. Because high-temperature ocean hydrothermal systems are such a recent discovery and are a topic of current work, new data comes in almost daily. We will maintain contact with the scientists working on these systems to assemble the latest data.

Task 5.2 Analyze Data. Current data on ocean hydrothermal resources will be analyzed to help determine the physical and chemical properties of fluids.

Task 5.3 State of the Art. We will evaluate the current state of the art in ocean hydrothermal exploration, including (1) techniques available and their problems, (2) equipment available, and (3) costs. We will compile recommendations for future research.

Task 5.4 Site Selection. We will analyze all available data for the purpose of selecting one site for work in FY 1986.

5.0 OCEAN HYDROTHERMAL RESEARCH PROGRAM

SCHEDULE AND DELIVERABLES

FY 1985

TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
5.1 Assemble Available Data	|—	—	—	—	LOE	—	—	—	—	—	—	—|
5.2 Analyze Data			|—	—	—	—	- - -	- - -	- - -	- - -	- - -	- - -|
5.3 State of the Art												Δ1
5.4 Site Selection												Δ2

<u>Deliverables</u>

1. Report on State of the Art
2. Report on Site Selection

5.0 OCEAN HYDROTHERMAL RESEARCH PROGRAM

BUDGET

A. Salaries and Wages:

	Days		Amount
1. Salaries- Professional			$15,094
J. N. Moore	20		
D. L. Nielson	20		
P. E. Wannamaker	15		
P. M. Wright	25		
2. Salaries-Support			1,824
Staff Analyst	5		
Draftsperson	10		
Secretary	10		
3. Wages-Professional			2,870
Research Assistants	60		
Total Salaries and Wages			$19,788
B. Employee Benefits:			
1. .39 of A.1 & A.2		$6,598	
2. .095 of A.3		273	
Total			6,871
C. Travel:			
1. Trips to Oceanographic Institutions (8)		$7,660	
2. Trips to DOE/ID (2)		880	
3. Trips to Washington, D.C. (2)		2,260	
4. Technical Meetings (2)		1,500	
Total			12,300
D. Supplies:			
1. Drafting Supplies		$175	
2. Office Supplies		125	
Total			300
E. Computer:			
1. PRIME 400			4,000

F.	Reproductions:	
	1. Printing, Binding and Distribution Costs	600
G.	Total A thru F:	$43,859
H.	Indirect Costs:	
	1. .45 of "G"	19,737
I.	G & A Costs:	
	1. .145 of "G"	6,360
J.	Total G thru I:	$69,956
K.	Fee:	
	1. .065 of "J"	4,549
L.	Total Project Costs:	$74,505

6.0 LITHOLOGIC AND STRUCTURAL CONTROLS OF FLUID FLOW IN WELLS WEN-1 AND WEN-2, WENDEL HOT SPRINGS, CALIFORNIA

Background

On-going research on fluid flow paths at the Baca geothermal system in New Mexico has demonstrated that geothermal fluids flow along both fault- and fracture-controlled conduits and along originally permeable stratigraphic horizons. However, volcanic horizons are much more susceptible to sealing by hydrothermal alteration than are the structurally-controlled paths. In the hotter (> 250°C) portions of the Baca field, stratigraphic control appears to predominate, perhaps reflecting fracturing of the stratigraphic units; however, this point requires further investigation. The documentation of this control is important from several standpoints. 1) It suggests targeting models for volcanic-hosted hydrothermal systems. 2) It suggests that although altered volcanics may be poor producers due to rapid sealing, they may be excellent candidates for artificial stimulation. 3) Depending upon the hydrothermal mineral zonation and resulting permeability relationships with distance from the principal fracture-controlled fluid conduit, stratigraphic horizons may serve as key intervals for the re-injection of thermal brines, and thus the proper management of the geothermal resource under production conditions. All of the above will be particularly important considerations in the geothermal development of the Cascades, Ascension Island, and other volcanic-hosted hydrothermal systems.

The Wendel Hot Springs geothermal system has several unique features that may help us get a better handle on stratigraphic vs. structural fluid controls. This system has been explored as part of DOE's User Coupled Confirmation Drilling Program (UCCDP) through two deep production wells, WEN-1 and WEN-2. Fluids produce at a temperature of about 120°C from fractures cutting the granitic basement of the Sierra Nevada batholith. These basement rocks are overlain by a large variety of volcanic rocks which have no fluid production. However, binocular microscope logging of these holes demonstrates rich assemblages of clays + zeolites + pyrite suggesting that they formally contained geothermal fluids. The siting model, prepared by GeothermEx for the wells, was based upon production from a reservoir hosted by the volcanics overlying the granite. At the present state of our knowledge, this is an entirely reasonable model, and one that we will probably see proposed many times in the Cascades program. The question is: Why doesn't it work?

Scope of Work

The objectives of the proposed project are to document present and past fluid flow paths at Wendel Hot Springs using studies of lithology, hydrothermal alteration and geophysical well logs from WEN-1 and WEN-2. We will then evaluate the evolution of these flow paths with time, particularly the sealing of the volcanic vents. This will involve the following tasks.

Task 6.1 Lithologic Logging of Drill Cuttings from WEN-2. Cuttings from WEN-1 were logged previously under DOE's UCCDP.

Task 6.2 Compilation of Down-Hole Geophysical Logs for WEN-2. Geophysical logs for WEN-1, compiled under DOE's UCCDP, are very useful in defining lithologic units, fractures, and thermal fluid entries.

Task 6.3 Documentation of Hydrothermal Alteration. We will study alteration in both WEN-1 and WEN-2 using petrographic microscope, X-ray diffraction, and Scanning Electron Microscope techniques.

Task 6.4 Data Synthesis. We will compare results to other volcanic-hosted systems to develop a better understanding of the genesis of fluid flow paths at Wendel.

6.0 LITHOLOGIC AND STRUCTURAL CONTROLS OF FLUID FLOW IN WELLS WEN-1 AND WEN-2, WENDEL HOT SPRINGS, CALIFORNIA

SCHEDULE AND DELIVERABLES

FY 1985

TASKS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
6.1 Lithologic Logging of Drill Cuttings from WEN-2		|———	———|									
6.2 Compilation of Down-Hole Geophysical Logs for WEN-2		|———	———|									
6.3 Documentation of Hydrothermal Alteration		|———	———	———	———	———|						
6.4 Data Synthesis		|———	———	———	———	———	———	———	———	———	———	———| Δ1

Deliverables

1. Technical Report

6.0 LITHOLOGIC AND STRUCTURAL CONTROLS OF FLUID FLOW IN WELLS WEN-1 AND WEN-2, WENDEL HOT SPRINGS, CALIFORNIA

BUDGET

		Days		Amount
A.	Salaries and Wages:			
	1. Salaries- Professional			$ 7,009
	J. B. Hulen	20		
	D. L. Nielson	20		
	B. S. Sibbett	5		
	2. Salaries-Support			1,640
	Draftsperson	5		
	Secretary	5		
	Technician	15		
	Total Salaries and Wages			$ 8,649
B.	Employee Benefits:			
	1. .39 of A.1 & A.2			3,373
C.	Supplies:			
	1. Drafting Supplies		$100	
	2. Office Supplies		50	
	Total			150
D.	Computer:			
	1. PRIME 400			500
E.	Reproductions:			
	1. Printing, Binding and Distribution Costs			100
F.	Other Costs:			
	1. X-ray Analyses		$2,000	
	2. SEM Analyses		2,000	
	Total			4,000
G.	Total A thru F:			$16,772

H.	Indirect Costs:	
	1. .45 of "G"	7,547
I.	G & A Costs:	
	1. .145 of "G"	2,432
J.	Total G thru I:	$26,751
K.	Fee:	
	1. .065 of "J"	1,739
L.	Total Project Costs:	$28,490

QUALIFICATIONS AND FACILITIES

CAPABILITIES

EARTH SCIENCE LABORATORY

UNIVERSITY OF UTAH RESEARCH INSTITUTE

General Statement

The University of Utah Research Institute (UURI) is a self-supporting corporation organized in December 1972 under the Utah Non-Profit Corporation Association Act. Under its charter, the Institute is separate in its operations and receives no support from either the University of Utah or the State of Utah. The charter includes provisions for UURI to conduct both public and proprietary scientific work for governmental agencies, academic institutions, private industry, and individuals.

The Earth Science Laboratory (ESL) of the University of Utah Research Institute (UURI) provides consulting and contracting services for research and applications of research in a broad range of geoscience topic areas. ESL emphasizes the integration of scientific disciplines and techniques in solving problems in the earth sciences. An optimum, cost-effective combination of techniques from the fields of geology, geochemistry, geophysics, and hydrology can be applied by in-house experts to solve specific problems.

The ESL professional staff is broad and diversified in education and experience (see Table 1). Even though the main portion of a given project may be done by a few scientists, the expertise of this entire staff can be made available as required, and personnel assigned to a project are free to draw upon the talents of other personnel at ESL.

The ESL staff has experience mainly along three different lines: 1) applied scientific work, 2) research, and 3) program management. The

Table 1
EARTH SCIENCE LABORATORY
PROFESSIONAL STAFF*

Geologists			4
	Ph.D.	2	
	M.S.	1	
	B.S.	1	
Geochemists			4
	Ph.D.	1	
	M.S.	2	
	B.S.	1	
Geophysicists			4
	Ph.D.	4	
Electronics Engineers			1
	B.S.	1	
		Total	13
Consulting reservoir engineers	Ph.D.	2	
Consulting geophysicist	Ph.D.	1	
Consulting geochemists	Ph.D.	4	
Consulting isotope geochemist	Ph.D.	1	

* This professional staff is supported by 2 business administrators, 3 technicians, 2 secretaries, 1 draftsperson, and 3-6 University students.

following paragraphs describe some of our more significant project work.

Geothermal Energy

ESL scientists have acquired extensive field experience in more than 15 high-temperature geothermal systems in the western U.S. and have helped the U.S. Department of Energy (DOE) to manage several major geothermal programs on which DOE has spent over $50 million in the past five years (see Table 2). As part of this work, we have performed geological, geochemical, geophysical and hydrological studies of a regional and site-specific nature for high-, intermediate-, and low-temperature geothermal resources.

ESL has also provided geothermal exploration and evaluation services to industry clients with geothermal properties in Utah, Nevada and California, to the Department of Defense (DOD) at several U.S. military installations and to the United Nations at several foreign sites. This work has included detailed geologic mapping, geophysical surveys and interpretation and geochemical analyses and their interpretation.

Subsurface Fluid Flow/Fluid-Rock Interaction

The Earth Science Laboratory professional staff, in conjunction with consultants Dr. David Cole, Dr. Donald Langmuir and Dr. Denis Norton, has extensive experience in identifying and modeling subsurface fluid flow paths, fluid mixing, and calculation of fluid-mineral equilibrium relationships. These techniques are used successfully in predicting the possibility of pollution resulting from solid waste disposal, acid mine-water drainage, solution mining and other industrial related contamination and in predicting fluid-reservoir rock interaction in geothermal systems.

Table 2
REPRESENTATIVE GEOTHERMAL PROGRAM MANAGEMENT
(for U. S. Department of Energy)

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1. Industry Coupled Program. Assist DOE in management of national program of cooperation in geothermal exploration between DOE and industry. Management assistance role consisted of helping to write procurement solicitations, helping to evaluate proposals from industry to DOE and helping to monitor contracts between industry and DOE. Also responsible for the acquisition of new geological, geochemical and geophysical data from 14 geothermal areas in the western U.S. to supplement industry data. Published interpretations of new data along with data originally collected by the geothermal industry in reports and case studies. Total DOE expenditures on program have been $16 million.

2. State Coupled Program. Coordinate DOE programs in western U.S. wherein teams of geologists under separate contract to DOE worked in each state to assess low- and moderate-temperature (<150°C) geothermal resources. Management role includes formulating policy and procedures for program, communicating program goals to state teams, conducting workshops for bringing state teams together, evaluating proposals from state teams to DOE, and monitoring project progress. This program will ultimately result in publication of detailed geothermal resource maps for about 25 states in the western U.S. where most of the geothermal resources occur. Total DOE expenditures on program have been $26 million during the past 7 years.

3. Exploration Technology Development Program. Manage national program for the development of new technology for exploration and evaluation of geothermal resources. ESL's management role consists of assisting DOE in issuing solicitations and evaluating proposals and evaluating quality of work performed by other contractors. In addition, ESL plays a major role in this program by performing in-house research and technology development. Total DOE expenditures on program have been $6 million during the past 5 years. Program will continue after FY 1982.

4. Technology Transfer Program. Provide geological, geochemical and geophysical consulting services to potential new users of geothermal energy in the western U.S. Coordinate engineering and economic aspects of projects with other DOE contractors. Provide speakers for professional and general audience seminars. Total DOE expenditures on program were $1 million. Program phased out at the end of 1982.

5. User Coupled Confirmation Drilling Program. Designed and implemented new DOE program for cost sharing by DOE of drilling for low- and intermediate-temperature geothermal resources (<150°C). Currently manage the geoscience aspects of program nationally for DOE. Total program expenditures by DOE were $4 million over the past 3 years. Program will phase out in 1984.

6. Department of Defense Geothermal Exploration. Manage two large projects for geothermal exploration at Lackland Air Force Base and Ascension Island, South Atlantic Ocean. Each project includes detailed geological, geochemical and geophysical studies to site drill tests, supervision of drilling and evaluation of results.

7. Geothermal Sample Library. Manage national library where drill chip and core samples from geothermal wells drilled with DOE and other funding are studied and curated. Library currently contains nearly 80,000 m of drill chip samples and 2100 m of core from 171 geothermal wells.

In-Situ Leaching and Solution Mining Research

ESL has conducted an in-depth evaluation of the state of the art in in-situ leaching and solution mining on behalf of 6 large mining companies, the National Science Foundation and the U.S. Bureau of Mines. This study was aimed specifically at identifying the research problems of highest priority in developing new technologies for in-situ leaching and solution mining.

Drilling

Members of the geologic staff have extensive experience in well-site geology and in planning and supervising drilling operations. This includes deep, large diameter rotary holes in addition to shallow rotary holes and diamond core drilling.

Proper logging of drill cuttings in all types of rocks and unconsolidated materials, involving hundreds of thousands of feet of drill hole, have been handled by the staff. Accurate, clean, and orderly acquisition, curation, and labeling of drill-derived materials should be a normal part of a drilling operation. In addition, ESL has made systematic studies of geochemical contaminants introduced into samples by the drilling process. This is an important prerequisite to studies of subsurface geochemistry.

Soil Geochemistry

ESL has conducted extensive research work and numerous surveys to determine gas and trace element concentrations in soils resulting from the activity of hot subsurface water in geothermal systems and for mineral exploration. We have successfully developed exploration techniques for a number of resource types.

Minerals

Our minerals exploration, evaluation and development experience is broad in topic and is both regional and site-specific in area. ESL geoscientists have worked in sedimentary, intrusive, skarn, and metamorphic environments on disseminated and massive sulfide deposits of base metals, and on precious metals, uranium, iron, coal, diamonds and petroleum. Our professionals have worked in most of the major mineral provinces of the United States and in Australia, Botswana, Brazil, Canada, Cyprus, Haiti, Mexico, South Africa, and Zambia.

Environmental and Waste Hazards Studies

The Earth Science Laboratory/UURI has participated in a Phase II study to determine the magnitude and extent of environmental contamination at Hill Air Force Base as part of the Department of Defense Installation Restoration Program. This program included an extended records search, geophysical surveys, soil coring, drilling of hydrologic test holes, chemical analysis of soil and fluid samples and the recommendation of remedial actions.

Nuclear Waste Disposal

Dr. Howard Ross, ESL/UURI, has been active as a member of peer review panels for all of the nation's high level radioactive waste disposal geologic exploration programs. These include:

Geology Review Group - ONWI - Battelle - Salt Program, 1979 - present

Geology Peer Review Group - DOE - Nevada Test Site - 1979, 1981

Geology Overview Committee - Rockwell Hanford, Basalt Waste Isolation, 1979-present

Through this participation Dr. Ross has worked with various teams of national and local experts in hydrology, geochemistry, geology and geophysics in addressing geologic and environmental problems resulting from hazardous waste isolation. His duties have been expanded in the National Program to provide expert geophysical consultation to Battelle for specific work in the salt programs in Utah, Texas, Mississippi, Louisiana and for early stage planning and review of the granitic rocks program in the North Central, Northeastern and Southeastern United States.

ESL/UURI has completed detailed model interpretations of induced polarization and electrical resistivity data for the USGS in support of the nuclear waste disposal program at the Nevada Test Site. This work has been instrumental in delineating faults and potential resource conflicts.

Research

ESL's research experience includes development and implementation of new geological, geochemical and geophysical techniques for geothermal and mineral resources (Table 3). Specialities are: structural and stratigraphic controls of fluid flow, trace element geochemistry, fluid geochemistry, mineralogy, fluid/mineral equilibrium models, advanced interpretation techniques for electrical, gravity and magnetic data, physical properties studies, and development and implementation of computer algorithms.

Workshops and Conferences

ESL has had a great deal of experience in presenting technical workshops, shortcourses and conferences. These are tailored specifically to the needs of the client. Recent examples of such presentations include:

Geology of Geothermal Systems. Yellowstone Park shortcourse programs.

Application of geothermal, geology, geochemistry and geophysics in gold exploration.

Geophysical Exploration Workshops

Table 3
MAJOR GEOTHERMAL RESEARCH AND INSTRUMENTATION DEVELOPMENT

Research Accomplishments	Where Applied
1. Trace Element Geochemistry. Developed new techniques for geothermal exploration and resource evaluation, for siting of drill holes and for gathering data during drilling of holes using trace element geochemistry of surface samples and of drill chips and cores. Conducted major research studies at The Geysers, CA and Roosevelt Hot Springs, Utah. Applied techiques at several other areas. These techniques are currently in use by major geothermal companies in the U.S. Published 7 reports.	The Geysers, CA Roosevelt Hot Springs, UT Cove Fort/Sulphurdale, UT Colado, NV Beowawe, NV McCoy, NV
2. Mercury Geochemistry. Documented relationships between temperature distribution underground and occurrence of mercury in drill chip samples. Showed that mercury geochemistry can be used to site drill holes, guide drilling and locate fluid entries in drill holes. Published 2 reports.	The Geysers, CA Roosevelt Hot Springs, UT Beowawe, NV Colado, NV McCoy, NV
3. Resistivity Data Interpretation. Developed new highly sophisticated programs using two-dimensional and three-dimensional models for interpretation of resistivity and induced polarization geophysical data. Complete mathematical formulation had never been done before. Published 6 reports.	Roosevelt Hot Springs, UT Cove Fort/Sulphurdale, UT Beowawe, NV Colado, NV Tuscarora, NV McCoy, NV Lakes District, Ethiopia Olkaria District, Kenya
4. Magnetotelluric Data Interpretation. Developed new and unique computer programs using two-dimensional and three-dimensional models for interpretation of magnetotelluric geophysical data. Mathematical formulation had never been done before. Published 3 reports.	Roosevelt Hot Springs, UT Tuscarora, NV
5. Self Potential Data Interpretation. Developed new and unique methods for interpretation of self potential data. Reports in press.	Roosevelt Hot Springs, UT

6. Resistivity and Induced Polarization Instrumentation. Developed a new, state-of-the-art, four-channel field receiver for resistivity and induced polarization data collection. Features are light weight, field programmable computer control, phase and amplitude measurement.

   Field tested in Colorado.

7. Magnetotelluric Instrumentation. Developed a new and unique field system for acquisition of magnetotelluric geophysical data. Features are computer control with digital magnetic recording of data. Uses SQUID magnetometers. For research purposes -- this field system will not be marketed in its present configuration.

   Roosevelt Hot Springs, UT

The Self Potential Method as applied to geothermal exploration

Application of Geophysical Methods to Minerals Exploration

Electrical Methods in Oil and Gas Exploration

DOE Geothermal Direct Heat Program. State Coupled Geothermal Resource Assessment Technical Conferences.

Military Bases

ESL has performed geoscience studies on the following military bases:

China Lake Naval Air Station, California

Hill Air Force Base, Utah

Williams Air Force Base, Arizona

Ascension Auxilliary Airfield, Ascension Island, South Atlantic

Adak Naval Air Station, Alaska

Lackland Air Force Base, Texas

Clients from Private Industry

Table 4 contains a list of domestic industrial clients we have served from 4/1/80 to the present and Table 5 contains a similar list of foreign clients.

Summary of Staff Expertise and Facilities

Geology

Geologic investigations provide essential data for successful completion of a wide variety of earth science projects. The ESL staff has a broad background in design and management of geologic work as well as in application of individual geologic techniques such as field mapping, structural and stratigraphic studies, mineralogy, petrology, and lithologic logging of drill chips and core. ESL's project management experience includes a full spectrum of

Table 4
PRIVATE INDUSTRY CONTRACTS
4/80-7/84
DOMESTIC

- GEOPHYSICS
  - Anaconda Copper Company
  - CH_2M Hill, Inc.
  - Energy Fuels Nuclear, Inc.
  - Florida Exploration Company
  - Hunt Energy Corporation
  - JCW, Inc.
  - Rocky Mountain Energy
  - Umont Mining Co.

- SOLUTION MINING
  - Amax, Inc.
  - Amoco Minerals Company
  - Anaconda Copper Company
  - Duval Corporation
  - Kennecott Copper Corporation
  - Phelps Dodge Corporation

- GEOCHEMISTRY
  - American Microsystems, Inc.
  - Aminoil, USA
  - Amoco Minerals Company
  - Anderson & Kelly, Inc.
  - Berkeley Group, Inc.
  - Chevron Oil Fields Research Co.
  - Chevron Resources
  - Coleman National Fish Hatchery
  - EarthFax Engineering, Inc.
  - Ecology & Environment, Inc.
  - EG&G Idaho, Inc.
  - Gertsch, Juncal & Associates
  - Getty Oil Company
  - Grace Geothermal Corporation
  - GRI Corporation
  - Hunt Energy Corp.
  - Indian Valley Hospital District
  - Kennecott Minerals Company
  - MAPCO
  - Morrison-Knudsen Co., Inc.
  - Native Plants
  - Nevin Sadlier-Brown Goodbrand, Ltd.
  - Nu-Energy Resources, Inc.
  - Occidental Geothermal, Inc.
  - Occidental Minerals Corporation
  - Occidental Resources Corporation
  - Phillips Petroleum Co.
  - Rocky Mtn. Center for Occupational and Environmental Health
  - Silver King Mines
  - Sohio Alaska Petroleum Co.
  - Sohio Petroleum Co.
  - Supron Energy Corporation
  - Technical Research Associates
  - Terra Tek Core Services
  - Terra Tek Research
  - Trans-Pacific Geothermal
  - Union Oil Company of California
  - United States Steel Corporation
  - Utah Biomedical Test Laboratories

- GEOLOGY
  - California Energy
  - CH_2M Hill
  - Evans & Sutherland
  - Grace Geothermal
  - GRI Operator
  - Homestake Mining Company
  - Hunt Energy Corporation
  - Hunt Geothermal
  - Kennecott Minerals Company
  - Marek Tokarz
  - Montgomery Engineering
  - Morrison-Knudsen
  - Nielson Geoconsultants
  - Occidental Geothermal, Inc.
  - Philippine Geothermal
  - Phillips Geothermal
  - Radian Corp.
  - Rocky Mountain Corrosion Control
  - Terra Tek
  - Trans-Pacific Geothermal
  - Union Geothermal
  - Utah Biomedical Test Laboratories

Table 5
PRIVATE INDUSTRY CONTRACTS
4/80-7/84
FOREIGN

GEOPHYSICS
- C.R.A. Exploration Pty. Limited, Australia
- Premier Geophysics, Inc., Canada

GEOCHEMISTRY
- Nevin/Sadlier-Brown/Goodbrand Ltd., Canada

COMPUTER
- C.R.A. Exploration Pty. Limited, Australia
- British Petroleum of Canada, Canada

services from project design and execution to supervision of drilling and evaluation of results. ESL is experienced in formulation of exploration models, regional geologic interpretation, detailed stratigraphic and structural analysis, and development and testing of techniques for specific applications. Dr. Dennis L. Nielson is manager of the geologic group. His resume is included with this document.

Geochemistry

Geochemistry has, during the last decade, become an increasingly essential component of earth science investigations. ESL's broad practical experience and proven exploration and research capabilities allow us to offer services ranging from routine analysis of geologic materials to design, execution and management of fully integrated geochemical exploration programs and from application of existing geochemical techniques to development of new techniques. ESL has made significant contributions to development and application of new geochemical techniques for a wide variety of applications.

A geochemical laboratory designed especially for geothermal and mineral studies has been operational since 1977. The laboratory is equipped with an ARL Inductively Coupled Plasma Spectrometer (ICP), capable of analyzing 37 elements simultaneously, an IL Atomic Absorption Spectrophotometer, a Jerome Gold Film Mercury Detector, an Orion Specific Ion Meter and electrodes, an X-ray diffraction instrument and complete sample preparation facilities. In addition, an electron microprobe, a scanning electron microscope, and K-Ar and fission track age dating are also available. Interactive computer programs available on ESL's PRIME 400 computer allow statistical treatment and provide geochemical plots of the analytical data. Dr. J. N. Moore is manager of the geochemistry group and Ms. Ruth Kroneman is manager of ESL's analytical facilities. Their resumes are included.

Geophysics

Application of geophysical techniques greatly enhances ESL's ability to investigate the subsurface. The staff has broad competence and experience in survey design and management and in integrated geological interpretation of geophysical data for a wide variety of resources. ESL has a suite of user-interactive computer programs that operate on the PRIME 400 computer to facilitate quantitative modeling and interpretation. ESL's research scientists have pioneered in the development of new interpretation techniques for geophysical data and the implementation of these techniques on the computer in a highly cost-effective way. ESL can help the client to develop their in-house computer-based interpretation capabilities and can provide training of personnel in operation of available programs. Dr. Howard P. Ross is manager of the geophysics group. His resume is included.

Electronics Engineering

High-quality field data are vital for today's earth scientists. ESL's electronics engineers provide broad competence and experience in instruments for electrical geophysical surveys. The latest hardware and software are available for custom application. The Electronics Laboratory is well equipped for development of microprocessor-integrated geophysical instrumentation. Test, design, and prototype construction facilities are state-of-the-art. Mr. Dale Green manages the electronics engineering group. His resume is included.

Computer Operations

ESL's computer center offers a broad range of computer services. The group specializes in development and implementation of user-interactive software for display, analysis and interpretation of geological, geochemical and geophysical data. The software can be used either at a client's facility or on a time-sharing basis on ESL's computer via the telephone.

Computer facilities consist of a PRIME 400 minicomputer system with a link to the University of Utah's UNIVAC 1100/60 computer. The system includes a PRIME 400 CPU with time-sharing capability and virtual memory, 1256 K bytes of main memory, 460 M bytes of disk storage, a 9-track magnetic type drive, a 36-inch Zeta pen plotter, a Statos electrostatic plotter, two line printers, 2 Tektronix 4014 graphics terminals with digitizing tablets, a DECwriter terminal, 7 CRT terminals, and two Texas Instruments Silent 700 terminals. Three dial-in phone lines are available to users, one at 300 baud and two at 1200 baud data transmission rates. The system is specifically oriented to scientific and engineering computation and to handling and interpreting geoscience data.

Sample Library

The Sample Library provides open-file accessibility and archival storage for field and drill samples as well as reference to analyses done on the samples. We provide proprietary storage for confidential samples as well as storage of samples that are accessible by the public. At present, the Library contains over 80,000 meters of drill chip samples and 2,100 meters of core from 171 shallow thermal gradient holes and deep holes, mainly in geothermal areas. Samples may be studied at our facility by clients in order to compare their own drill results with samples from other geothermal areas. Complete sample preparation facilities are available and are used to prepare samples for storage and for routine or special chemical or physical analyses. Density and magnetic susceptibility measurements can be done at our facility.

Document Library

ESL has an extensive document library that is available for use by clients. We have issues of all the important geothermal journals and many other earth science journals as well. Xerox and microfiche copies of many published articles are available. At present the library contains about 12,000 titles.

In addition, ESL has exchange privileges with the complete library facilities on the University of Utah campus where 2,000,000 titles are available.

Office Facilities

The main offices of the Earth Science Laboratory are located in Research Park, on the east side of the Salt Lake Valley, adjacent to the University of Utah. There are over 11,000 square feet of laboratory and office space in two buildings. Located here are the geochemical laboratory, the electronics laboratory, the computer center and our extensive document library as well as offices. The Sample Library occupies 4000 square feet in a small building in suburban Salt Lake City and is accessible to the main offices in a 10-minute drive. The campus of the University of Utah, where the Department of Geology and Geophysics is located, is but a 5-minute drive from ESL's main facilities.

Management

The Earth Science Laboratory operates under a matrix management system where a principal investigator is able to draw on members of the geology, geochemistry, geophysics, computer or electrical engineering groups to form a scientific team most qualified to handle a specific project. The principal investigator is then responsible for management and technical guidance of the working group. The principal investigator is responsible to the Associate

Director/Technology and the Associate Director/Administration for the technical and financial portions of the contract, respectively. The organization structure of ESL is shown in Figure 1. Dr. Stanley H. Ward is the Director and Dr. Phillip M. Wright is Associate Director/Technology for ESL. Their resumes are included.

Figure 4

ESL ADMINISTRATIVE MANAGEMENT

DIRECTOR
S.H. WARD

ASSOC. DIRECTOR
P.M. WRIGHT

- GEOCHEMISTRY
- GEOLOGY
- GEOPHYSICS
- COMPUTER OPERATIONS
- ELECTRONICS

ASSOC. DIRECTOR
W.L. FORSBERG

- CONTRACT NEGOTIATIONS & COMPLIANCE
- FACILITIES
- FISCAL MANAGEMENT
- MARKETING
- PERSONNEL & PURCHASING

SW/I-010

RESUMES OF KEY PERSONNEL

RESUME

Duncan Foley

POSITION: Geologist, Project Manager, Earth Science Laboratory, University of Utah Research Institute, Salt Lake City, Utah

EDUCATION: B.A., Geology, 1971, Antioch College, Yellow Springs, Ohio
M.Sc., Geology, 1973, Ohio State University; emphasis on environmental geology
Ph.D., Geology, 1978, Ohio State University; emphasis on volcanic geology

PROFESSIONAL AFFILIATIONS: 1982, American Association of Petroleum Geologists
1980, Utah Geological Association (Secretary, 1981-1982)
1979, American Geophysical Union
1978, Geothermal Resources Council (President, Basin and Range Section, 1980-1982)
1976, Society of Sigma-Xi
1972, Geological Society of America

PROFESSIONAL EXPERIENCE:

1/84-present Division of Continuing Education, University of Utah. Teaching "Geology and the Environment".

6/79-present Geologist, Project Manager, Earth Science Laboratory, University of Utah Research Institute, Salt Lake City, Utah. Management and technical duties on Federal and private sector projects. Program Manager for U.S. Department of Energy funded low- and moderate-temperature geothermal resource assessment programs in 16 western states, including coordination with U.S. Geological Survey resource assessment programs. Served as technical advisor to DOE, and directed production of geothermal resource maps. Technical tasks include geologic mapping, studies of geothermal systems in Utah, Idaho and Texas (including drilling a deep well); evaluation of exploration techniques in different geologic environments, and assessment of geothermal resource potential at federal facilities and wilderness areas.

1979-present Instructor, Yellowstone Institute, for "Calderas and Hydrothermal Systems," a week long lecture and field course that emphasizes interpretation of ash-flow tuff stratigraphy, caldera evolution, and the geological nature of hydrothermal systems in calderas; taught in Yellowstone National Park.

1/78-6/79 Associate Geologist, Earth Science Laboratory. Assisted in management of U. S. Department of Energy funded program of low-temperature geothermal resource assessment in western U. S. Environmental geologist for overview of southern Utah Known Geothermal Resource Areas.

9/73-1/78 Research and Teaching Associate, Department of Geology and

Mineralogy, Ohio State University. Teaching and research in volcanology, environmental studies, K-Ar geochronology, field geology, stratigraphy, and strip mine reclamation.

6/71-9/71 and 9/72	Field Assistant, U.S. Geological Survey, Western Mineral Resources Branch, Menlo Park, California. Geologic mapping near Goldfield, Nevada, with emphasis on volcanic stratigraphy.
4/69-8/69	Physical Science Aide, U.S. Geological Survey, Pacific Mineral Resources Branch, Menlo Park, California. Mineral separations lab; geochemical sampling of alteration assemblages and detailed geologic mine mapping in Goldfield and Silver Peak, Nevada.
9/66-12/66	Assistant, Geology Department, Field Museum of Natural History, Chicago, Illinois. Fossil Invertebrates; curating trilobite collection.

PROFESSIONAL ACTIVITIES:

Presented talks on geologic parameters of geothermal energy to American Association for the Advancement of Science (1980), Industrial Development Research Council (1980), National Rural Electric Cooperative Association (1980), National Water Well Association (1979), U.S. Department of Energy Contractors (1978, 1979, 1980), Intermountain Institute of Food Technologists (1982), and Snake River Section of American Institute of Mining Engineers (twice in 1982).

Coleader of Geothermal Systems of the Yellowstone Caldera fieldtrip, Geothermal Resources Council (1980); leader of Wyoming Geological Association field trip to hydrothermal systems of northern Yellowstone National Park (1982).

Courses and workshops attended: Geothermal energy in the Cascades (1981); Geochemical fundamentals for geothermal exploration and reservoir evaluation (1980); Fission-track age dating (1979), "Direct Utilization of Geothermal Energy: Development of Four Educational Reports" (1979), Geothermal Geology of Yellowstone (1978); Volcanic rocks and their vent areas (1978); Direct utilization of geothermal energy (1978).

PUBLICATIONS:

"Environmental geology and land-use planning on the Big Darby Creek, Ohio, watershed," Foley, D., unpub. M.Sc. thesis, Ohio State University (1973).

"Geology and Land-Use Planning on the Big Darby Creek, Ohio, Watershed," Foley,D. and McKenzie, G. D., Geol. Soc. of Am., Abstracts with Programs, 6, No. 6, 508 (1974).

"The geology of the Stonewall Mountain Volcanic Center, Nye County, Nevada," unpub. Ph.D. dissertation, Ohio State Univ., 139 p. (1978).

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"Exploration Strategies for Regional Assessment of Hydrothermal Resources," Ward, S. H., Foley, D., Moore, J. N., Nielson, D. L., Ross, H. P., Wright, P. J., in Witherspoon, P., Bresee, J., eds., in preparation.

"Low-temperature Geothermal Resources in the Central and Eastern United States," Sorey, M. L., Reed, M. J., Foley, D., Renner, J. L., in Reed, M. J., ed., Assessment of low-temperature geothermal resources of the United States-1981: U. S. Geological Survey Circular 892, p. 51-65 (1983).

"Hydrothermal Systems of Central Utah - A Regional Perspective," (abs.), Foley, D., in, Britt, T. L., ed., Program and abstracts for the Utah Geological Association 1982 symposium on the overthrust belt of Utah; Utah Geological Assoc. Pub. 11, p. 18.

"Road logs: West Yellowstone to Canyon Junction, Canyon Junction to Mud Volcano - Sulphur Cauldron Area, Canyon Junction to Tower Junction to Mammoth Hot springs, Mammoth Hot Springs to Norris Junction, Madison Junction to Old Faithful", Foley, D., Nielson, D. L., Nichols, C. R., in Reid, S. G., Foote, D. J., Geology of Yellowstone Park Area: Wyoming Geological Association 33rd Annual Field Conference Guidebook, pgs. 343-352, 356-363 (1982).

"Road Log, Field Trip #3 Emphasizing Geothermal Phenomena," Foley, D., in Goolsby, J. E., ed., Field Trip Road Logs: Wyoming Geological Association 33rd Annual Field Conference, p. 22-24, (1982).

"Tables of Co-located Geothermal Sites and BLM Wilderness Study Areas," Foley, D., Dorscher, M., Earth Science Lab Open File Report 107, DOE/ID/12079-88, 166 p., (1982).

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"Geothermal resources of the Balcones-Ouachita Trend, Central Texas", Foley, D., Zeisloft, J., Woodruff, C. M., Am. Assoc. Petrol. Geol., Bull., v. 68, p. 477 (1984).

RESUME

Joseph N. Moore

DATE OF BIRTH: January 21, 1948

POSITION: Geologist/Project Manager and Section Manager of Geochemical Group, Earth Science Laboratory, University of Utah Research Institute, Salt Lake City, Utah

EDUCATION: B.S., Geology, 1969, City College of New York
M.S., Geology, 1972, Pennsylvania State University
Ph.D., Geology, 1975, Pennsylvania State University

SOCIETY AFFILIATIONS: Geological Society of America
Geothermal Resources Council

HONORS AND AWARDS: 1971, Sigma Xi Grant
1971, Paul D. Krynine Fund Award
1972, Sir William Logan Medallion
1973, Phi Kappa Phi Honor Society
1978, American Men and Women in Science

PROFESSIONAL EXPERIENCE:

1979-present Section Manager, the Geochemistry group, Earth Science Laboratory. Responsibilities include management of ESL geochemical programs and analytical facilities as well as the development of new geochemical techniques for use in geothermal exploration.

1977-1979 Geologist, Earth Science Laboratory. Conduct and supervise geologic programs in known geothermal resource areas of the Basin and Range.

1975-1977 Staff geologist, Uranium Division/The Anaconda Co. Primary responsibilities included developing an exploration program in volcanic terrains for hydrothermal uranium deposits and detailed and reconnaissance mapping in the Basin and Range.

1972-1975 Graduate Teaching Assistant, Pennsylvania State University. Duties included preparation of laboratories and laboratory lectures for basic physical geology and mineralogy courses.

1970-1972 Graduate Research Assistant, Pennsylvania State University. Research involved a comparison of igneous and impact breccias.

1971 summer Geologist, Johns-Manville Ltd. Detailed mapping in the Stillwater Complex, Montana.

1968-1969 summers Geologic Field Assistant, U.S.G.S., Dr. Nicholas Ratcliffe, party chief. Assist in detailed bedrock mapping of Taconic geology in southwestern Massachusetts.

1968 Part-Time Laboratory Assistant, Lamont Geological Observatory, Paleomagnetism Section, Dr. Neil Opdyke, supervisor. Duties included cutting, preparation, and magnetic analysis of deep sea drill cores.

PUBLICATIONS:

"Northeast Breccia Pipes and Dikes," Moore, J. N. and Gold, D. P., International Geologic Congress (24th Session) Guidebook, Monteregian Hills: Diatremes, Kimberlites, Lamprophyres, and Intrusive Breccias West of Montreal (1972).

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"Trace Element Geochemical Zoning in the Roosevelt Hot Springs Thermal Area, Utah," Christensen, O. C., Moore, J. N. and Capuano, R. M., Geothermal Resources Council Trans., 4, 149-152 (1980).

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"Hg and As soil geochemistry as a technique for mapping permeable structure over a hot-water geothermal system", Capuano, R. M., and Moore, J. N., [abs.] Geol. Society America, Rocky Mt. Section 12, no. 5, 269 (1980).

"K/Ar Ages of the Pyramid Sequence in the Vicinity of the San Emidio Geothermal Area, Washoe County, Nevada," Evans, S. H., Moore, J., Adams, M., Isochron/West, No. 31, 19-21 (1981).

"The Roosevelt Hot Springs, Utah Geothermal Resource - An Integrated Case Study," Ross, H. P., Nielson, D. L., Glenn, W. E, Moore, J. N., Smith, Christian and Christensen, O. D., 66th Annual AAPG Meeting, San Francisco, June (1981).

"Geochemical Indicators of a High-Temperature Geothermal System" [abs.], Moore, J. N., Capuano, R. M., and Christensen, O. D., 9th International Geochemical Exploration Symposium, Saskatoon, Canada, May 12-14 (1982).

"An Exploration Case Study of the Roosevelt Hot Springs Geothermal System, Utah, Ross, H. P., Nielson, D. L., and Moore, J. N., Amer. Assoc. of Petrol. Geologists Bulletin, v. 66, p. 879-902 (1982).

"The Cove Fort-Sulphurdale KGRA - A Geological and Geophysical Case Study" Ross, H. P., Moore, J. N. and Christensen, O. D., ESL Report 90, 29 p. (1982).

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"Geologic map of the McCoy geothermal prospect, Adams, M. C., Moore, J. N., and Struhsacker, E., ESL Report 111 (DOE/ID/12019-92), (1982).

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"Nevada Geothermal Areas; Steamboat Springs, Brady Hot Springs, Humbolt House Colado, Beowawe," Moore, J. N. and Cerling, B. W., eds., Guidebook for Field Trip #2, GRC, 1980 Annual Meeting, 95 p. (1983).

"Preliminary geothermal assessment of the Tuttapani thermal area, Madhya Prodesh, India: Geothermal Resources Council Transactions, in press.

"Geochemistry of the Meager Creek geothermal field, Moore, J. N., Adams, M. C., and Stauder, J. J., British Columbia Geothermal Resources Council, in press.

RESUME

Dennis L. Nielson

POSITION: Section Manager - Geology, Earth Science Laboratory, University of Utah Research Institute, Salt Lake City, Utah

EDUCATION: B.A., Geology, 1970, Beloit College, Beloit, Wisconsin
M.A., Geology, 1972, Dartmouth College, Hanover, New Hampshire
Ph.D., Geology, 1974, Dartmouth College, Hanover, New Hampshire

SHORT COURSES: Volcanic Rocks and Their Vent Areas, University of Nevada, Reno, 1977
Engineering Management by Objectives for Improving Productivity, University of Utah, 1978
Geothermal and Hydrothermal Systems, Yellowstone Institute, 1978
Economics of Minerals and Energy Projects, AIME, 1981

SOCIETY AFFILIATIONS: American Geophysical Union
Geological Society of America
Geothermal Resources Council
Society of Economic Geologists
Utah Geological Association

HONORS AND AWARDS: Haven Science Prize, Beloit College (1970)
NDEA Title IV Fellowship - Dartmouth College (1971-1974)
American Men and Women of Science
President, Basin and Range Section, Geothermal Resources Council (1979)

PROFESSIONAL EXPERIENCE:

7/80-present — Section Manager - Geology. Earth Science Laboratory, University of Utah Research Institute. Responsible for overall technical quality of geologic work and management of the geologic staff.

7/79-present — Geologist/Project Manager, Earth Science Laboratory, University of Utah Research Institute. Project manager for the following programs under Department of Energy contracts: Geothermal Exploration and Assessment Technology Program, Industry Coupled Program, M-X/Renewable Energy Systems Program. Responsible for coordinating technical work at Roosevelt Hot Springs KGRA, Utah; and Beowawe; Tuscarora; Colado; McCoy; Soda Lake-Stillwater KGRAs, NV. Formulation and technical review of procurements, contract monitoring , and program design. Principal investigator for the geothermal exploration of Ascension Island, South Atlantic Ocean, under contract to U.S. Department of Energy and U.S. Air Force. Participated in a program to assess the state-of-the-art and recommend needed research in an industry sponsored program in solution mining and hydrometallurgy. Have participated in numerous DOE advisory committees including those concerned with the Baca Geothermal Demonstration Power Plant, Deep Continental Scientific Drilling Program, and the Hot Dry Rock Project.

1979-present	Instructor, Yellowstone Institute, for a course on Calderas and Hydrothermal Systems which concentrates on the formation of calderas, ash-flow tuff stratigraphy, and the geology of hydrothermal systems in the caldera environment.
4/78-7/79	Geologist, Earth Science Laboratory, University of Utah Research Institute. Develop case studies for geothermal resource areas in western U.S. Responsibilities include supervision of geologic programs, geologic mapping, synthesis and publication of exploration data, and formation of exploration criteria.
6/74-4/78	Staff Geologist, The Anaconda, Co., Salt Lake City, Utah. Uranium exploration in frontier project areas in the United States. Responsible for generating and supervising projects through the initial drilling stages. Experience in Precambrian plutonic and metasedimentary environments and Tertiary volcanic and sedimentary environments. Activities included detailed mapping, quadrangle mapping, regional reconnaissance, interpreting geophysical and geochemical data, supervising rotary and diamond drilling, and land acquisition through leasing and claim staking.
1971 summer	Field Geologist, Great Lakes Exploration Co. (subsidiary of Bear Creek Mining Co.). Reconnaissance mapping in the Precambrian Shield of the Upper Peninsula of Michigan and northern Wisconsin. The mapping was designed to locate areas having potential for massive sulfide deposits.
1970 summer	Field Geologist, Great Lakes Exploration Co. (subsidiary of Bear Creek Mining Co.). Quadrangle mapping and geochemical surveys of water wells and soils in conjunction with a massive sulfide exploration program in northern Wisconsin.
1968 fall	Field Assistant, Bear Creek Mining Co. Base metal exploration in the Upper Peninsula of Michigan and northern Wisconsin. Duties included drafting, supervising diamond drilling, and assisting with field mapping.

PUBLICATIONS:

PAPERS AND TECHNICAL REPORTS

Nielson, D. L., 1973, Silica diffusion at Ascutney Mountain, Vermont: Contributions to Mineralogy and Petrology, v. 40, p. 141-148.

Nielson, D. L., Clark, R. G., Lyons, J. B., Englund, E. J., and Borns, D. J., 1976, Gravity models and mode of emplacement of the New Hampshire Plutonic Series, in Lyons, P. C., and Brownlow, A. H. (eds.) Studies in New England Geology: Geological Society of America Memoir 146, 301-318.

Nielson, D. L., Sibbett, B. S., McKinney, D. B., Hulen, J. B., Moore, J. N., and Samberg, S. M., 1978, Geology of Roosevelt Hot Springs KGRA, Beaver County, Utah: University of Utah Research Institute, Earth Science Laboratory, Rept. No. 12, 121 p.

Nielson, D. L., 1978, Radon in geothermal exploration, theory and an example from Roosevelt Hot Springs KGRA, Utah: University of Utah Research Institute, Earth Science Laboratory, Rept. No. 14, 31 p.

Nielson, D. L., and Moore, J. N., 1979, The exploration significance of low-angle faults in the Roosevelt Hot Springs and Cove Fort-Sulphurdale Geothermal Systems, Utah: Geothermal Resources Council Transactions, v. 3, p.503-506.

Nielson, D. L. (ed.) 1979, Program Review: Geothermal Exploration and Assessment Technology Program including a report of the Reservoir Engineering Technical Advisory Group: University of Utah Research Institute, Earth Science Laboratory, Rept. No. 29, 128 p.

Foley, D., Nielson, D. L., and Nichols, C. R., 1980, Geothermal systems of the Yellowstone Caldera: Geothermal Resources Council Field Trip No. 1, 69 p.

Glenn, W. E., Hulen, J. B., and Nielson, D. L., 1980, A comprehensive study of LASL Well C/T-2 Roosevelt Hot Springs KGRA, Utah and application to geothermal well logging: Los Alamos Scientific Laboratory, Rept. LA-8686-MS, 175 p.

Nielson, D. L. (ed.) 1980, Geothermal Systems in Central Utah: Geothermal Resources Council Guidebook to Field Trip No. 7, 54 p.

Nielson, D. L., 1980, Summary of the geology of the Roosevelt Hot Springs Geothermal System, Utah: in Nielson, D. L. (ed.), Geothermal Systems in Central Utah, Geothermal Resources Council Guidebook to Field Trip No. 7, p.25-29.

Nielson, D. L., Moore, J. N., and Forrest, R. J., 1980, Road log to geothermal systems in central Utah: in Nielson, D. L. (ed.), Geothermal Systems in Central Utah, Geothermal Resources Guidebook to Field Trip No. 7, p.44-54.

Sibbett, B. S., and Nielson, D. L., 1980, Geology of the central Mineral Mountains, Beaver County, Utah: University of Utah Research Institute, Earth Science Laboratory, Rept. No. 33, 42 p.

Ward, S. H., Ross, H. P., and Nielson, D. L., 1981, Exploration strategy for high-temperature hydrothermal systems in the Basin and Range Province: Am. Assoc. Petroleum Geologists Bull., 65/1 p.86-102. Reprinted in Energy Minerals, AAPG reprint Series No. 25, p. 232-248.

Nielson, D. L., 1981, The bedrock geology of the Hillsboro quadrangle, New Hampshire: N. H. Dept. of Resources and Economic Development Bull. No. 8, 76 p.

Ross, H. P., Nielson, D. L., and Moore, J. N., 1982, Roosevelt Hot Springs geothermal system, Utah-Case Study: Am. Assoc. Petroleum Geologists Bull., v. 66, no. 7, p. 879-902.

Nielson, D. L., (ed.), 1982, Overthrust belt of Utah: Utah Geological Association Publication 10, 335 p.

Hulen, J. B. and Nielson, D. L., 1982, Stratigraphic permeability in the Baca geothermal system, Redondo Creek area, Valles Caldera, New Mexico: Geothermal Resources Council Transactions, v. 6, p. 27-30.

Evans, S. H. and Nielson, D. L., 1982, Thermal and tectonic history of the Mineral Mountains intrusive complex: Geothermal Resources Council Transactions, v. 6, p. 15-18.

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ABSTRACTS

Nielson, D. L., 1973, Contact metamorphism and molecular diffusion at Ascutney Mountain, Vermont: Geological Society of America, Abstracts with Programs, Northeastern Section, p.203.

Nielson, D. L., Lyons, J. B., and Clark, R. G., 1973, Gravity and structural interpretations of the mode of emplacement of the New Hampshire Plutonic Series: Geological Society of America, Abstracts with Programs 1973 Annual Meetings, p.750.

Nielson, D. L., Sibbett, B. S., and McKinney, D. B., 1979, Geology and structural control of the geothermal system at Roosevelt Hot Springs KGRA, Beaver County, Utah (abs.): American Association of Petroleum Geologists Bull., v. 63/5, p.836.

Ward, S. H., Chapman, D. S., Evans, S. H., Nielson, D. L., Wannamaker, P. E., and Wilson, W. R., 1979, Roosevelt Hot Springs Geothermal System: Geologic and geophysical models: IAVCEI Abstracts and timetables, IUGG XVII General Assembly, Canberra, Australia.

Nielson, D. L, 1980, Geology of low- and intermediate-temperature hydrothermal systems: National Conference on Renewable Energy Technologies, Proceedings, Honolulu, p.8-3 to 8-4.

Sibbett, B. S., and Nielson, D. L.,1980, The Mineral Mountains intrusive complex, Utah: Geological Society of America, Abstracts with Programs, Rocky Mountain Section, v. 12, No. 6, p.305.

Ward, S. H., Ross, H. P., and Nielson, D. L., 1980, Strategy of exploration for high temperature hydrothermal systems in the Basin and Range Province (abs.): Am. Assoc. Petroleum Geologists Bull., v. 64/5, p.799.

Ross, H. P., Nielson, D. L., and Glenn, W. E., et al., 1981, Roosevelt Hot Springs, Utah geothermal resource-integrated case study (abs.): Am. Assoc. Petroleum Geolgists Bull., v. 65/5, p. 982.

RESUME

Howard P. Ross

BIRTHPLACE AND DATE: Stockbridge, Massachusetts, October 26, 1935

POSITION: Senior Geophysicist/Project Manager, and Manager of Geophysical Group, Earth Science Laboratory, University of Utah Research Institute, Salt Lake City, Utah

EDUCATION: B.A., Geology, 1957, University of New Hampshire
M.Sc., Geophysics, 1963, Pennsylvania State University
Ph.D., Geophysics, 1965, Pennsylvania State University

Short Course, Modern Methods of Seismic Data Processing, GeoQuest International, Inc., October, 1979

PROFESSIONAL AFFILIATIONS: Society of Exploration Geophysicists
American Geophysical Union
European Assn. Exploration Geophysicists
American Assn. Petroleum Geologists
Utah Geological Association

PROFESSIONAL EXPERIENCE:

1/80-present Consultant in Exploration Geophysics. Clients include:
Thermal Power Co., San Francisco, CA
Exxon Minerals Co., Tucson, AZ
Dept. of Energy/Nevada Operations, Las Vegas, NV
Kennecott Exploration, Inc., Casper, WY

8/77-present Section Head, Geophysics; Senior Geophysicist and Project Manager, Earth Science Laboratory, University of Utah Research Institute, Salt Lake City, Utah. Principal investigator for geophysical survey planning, supervision, and interpretation contracts. Coordinate, interpret, and evaluate geophysical surveys and geologic data to form technical case histories of geothermal exploration/reservoir assessment studies. Provide management assistance and technical evaluation as necessary to Department of Energy. Supervise and conduct geophysical interpretations for industry clients, U.S.G.S., and UN contracts.

9/79-present Consultant, Office of Nuclear Waste Isolation (ONWI), Battelle Memorial Institute, Columbus, Ohio. Member of the Geologic Review Group for site characterization studies of the national nuclear waste storage program.

9/79-1983 Consultant, DOE/Richland, Washington and Rockwell Hanford Operations. Member Geologic Overview Committee for Basalt Waste Isolation Project.

1969-1977 Senior Geophysicist, Bear Creek Mining Company/Kennecott Exploration, Inc., Geophysics Division, Salt Lake City, Utah.

Designed, supervised, conducted and interpreted geophysical field surveys in search of porphyry copper and other mineralization-induced polarization, magnetic, and gravity methods. Developed interpretation programs for magnetic data, and magnetic properties studies. Supervised contract aeromagnetic surveys and the geologic interpretation of these data. Presented seminars on the use and interpretation of geophysical data. In-company consultant on remote sensing (SLR and other imagery programs). Group Leader, Interdisciplinary Research Program for skarn research, September 1971 - March 1972. Field experience and interpretative work in New Mexico, Arizona, Nevada, Wisconsin, Minnesota, Montana, Utah and Tennessee.

1967-1969 Senior Research Geophysicist, Kennecott Exploration, Inc., Geophysics Division R&D, Salt Lake City, Utah. Conducted research in aeromagnetic interpretation, field rock magnetization studies. Developed first generation computer programs for magnetic interpretation schemes. Programmed electromagnetic coupling problem for IP studies. In-company consultant for remote sensing programs. Detailed and reconnaissance aeromagnetic interpretation. Supervised interpretation of deep-sea magnetic data (manganese nodule research).

1965-1967 Research General Physical Scientist, Air Force Cambridge Research Laboratories, Lunar-Planetary Research Branch, Bedford, Massachusetts. Organized and conducted laboratory reflection spectroscopy experiments and telescopic observations of the moon in the 0.2 to 3.0 micron (UV-VIS-IR) region of the spectrum. Pursued theoretical studies of the moon and planets. Developed instrumentation and monitored contracts for their fabrication. Programmed in Fortran IV for the reduction of spectroscopic data, signal-to-noise studies, mathematical models of geologic processes. NASA co-investigator Apollo Application Program (pre ERTS).

1961-1965 Graduate Research Assistant, The Pennsylvania State University, Mineral Conservation Section, University Park, Pennsylvania. Planned, executed and interpreted geophysical field surveys conducted each summer to determine if diabase or massive magnetite gives rise to various magnetic anomalies.

1958-1961 Computer and Acting Chief Computer, United Geophysical Corporation, Pasadena, California. Computer for reflection seismic crew engaged in oil and gas exploration; interpreted and processed seismic records; also organized office work, drafting, accounting.

PUBLICATIONS:

"In Situ Determination of the Remanent Magnetic Vector of Two-Dimensional Tabular Bodies," Ross, H. P. and Lavin, P. M., Geophysics, 31, No. 5, 949-962 (1966).

"A Bidirectional Reflectance Accessory for Spectroscopic Measurements," Hunt, G. R. and Ross, H. P., Applied Optics, 6, No. 10, 1687-1690 (1967).

"A Simplified Mathematical Model for Lunar Crater Erosion," Jour. Geophysical Research, 73, No. 4, 1343-1354 (1968).

"A Statistical Analysis of the Reflectance of Igneous Rocks from 0.2 to 2.65 Microns," Ross, H. P., Adler, J. E. M. and Hunt, G. R., Icarus, 11, 46-54 (1969).

"Recognition of the Geologic Framework of Porphyry Copper Deposits on ERTS-1 Imagery," Allan, J. W., Andrews, R. K., Ross, H. P. and Wilson, J. C., Kennecott Expl. Inc., Final Report to NASA, September (1975).

"Interpretation of Resistivity and Induced Polarization Profiles, Calico Hills and Yucca Mountain Areas, Nevada Test Site," Ross, H. P. and Lundbeck, J., University of Utah Research Institute, Earth Science Laboratory, Rept. No. 8, to the U.S. Geological Survey, September (1978).

"Numerical Modeling and Interpretation of Dipole-Dipole Resistivity Data, Lakes District, Ethiopia," Ross, H. P., Smith, Christian and Atwood, J. W., University of Utah Research Institute, Earth Science Laboratory, Rept. No. 15, to the United Nations, December (1978).

"Numerical Modeling and Interpretation of Dipole-Dipole Resistivity Data, Olkaria Field, Kenya," Ross, H. P., Smith, Christian, Glenn, W. E., Atwood, J. W. and Whipple, R. W., University of Utah Research Institute, Earth Science Laboratory, Rept. No. 16, to the United Nations, February (1979).

"Geothermal Well Drilling Estimates Based on Past Well Costs," Chappell, R. N., Prestwich, S. J., Miller, L. G. and Ross, H. P., Geothermal Resources Council Trans., September, 3, 99-102 (1979).

"Interpretation of Resistivity and Induced Polarization Profiles With Severe Topographic Effects, Yucca Mountain Area, Nevada Test Site," Smith, Christian and Ross, H. P., University of Utah Research Institute, Earth Science Laboratory, Rept. No. 21, to the U.S. Geologic Survey, October (1979).

"Numerical Modeling and Interpretation of Dipole-Dipole Resistivity and IP Profiles, Cove Fort-Sulphurdale KGRA, Utah, Ross, H. P., UURI/ESL Report, DOE/DGE Contract No. DE-AC07-78ET28392 (1979).

"A Summary of the Geology and Geophysics of the San Emidio KGRA, Washoe County, Nevada, Mackelprang, C. E., Moore, J. N., and Ross, H. P., Geothermal Resources Council Trans., v. 4, p. 221-224 (1980).

"Review of Well Logging in the Basin and Range Known Geothermal Resource Areas, Glenn, W. E., Ross, H. P., and Atwood, J. W., paper SPE 9496, 55th annual meeting, SPE/AIME, Dallas, 16 p. (1980).

"A Strategy of Exploration for High Temperature Hydrothermal Systems in the Basin and Range Province, Ward, S. H., Ross, H. P., and Nielson, D. L., Bull. AAPG, v. 65, no. 1 (1981).

"Interpreted Resistivity and IP section, Line W1, Wahomonie Area, Nevada Test Site, Nevada", Smith, C., Ross, H. P., and Edquist, R., U.S.G.S. Open-File Report 81-1350, 8 p. (1981).

"Exploration Strategies for Regional Assessment of Hydrothermal Resources", Ward, S. H., Foley, D., Moore, J. N., Nielson, D. L., Ross, H. P., and Wright, P. M.: in Geothermal Energy Technology, J. C. Bresee and P. A. Witherspoon, eds. (1984, in press).

"The Cove Fort-Sulphurdale KGRA-A Geologic and Geophysical Case Study", Ross, H. P., Moore, J. N., Christensen, O. D., UURI/ESL Report No. 90, 32 p. (1982).

"Roosevelt Hot Springs Geothermal System, Utah-Case Study", Ross, H. P., Nielson, D. L., and Moore, J. N., AAPG Bull., v. 66, n. 7, p. 879-902 (1982).

"Interpretation of Resistivity and Induced Polarization Profiles with Severe Topographic Effects, Yucca Mountain area, Nevada Test Site," Smith, C., and Ross, H. P.: with introduction by D. B. Hoover, U.S.G.S. Open-File Report 82-182, 19 p. (1982).

"Review of Well Logging in the Basin and Range Known Geothermal Resource Areas", Glenn, W. E., Ross, H. P., and Atwood, J. W., Jour. Petroleum Tech., May, p. 1104-1118 (1982).

"A Study of Well Logs from Cove Fort-Sulphurdale KGRA, Millard and Beaver Counties, Utah", Glenn, W. E., and Ross, H. P., UURI/ESL Report No. ESL-75, 39 p. (1982).

"Aeromagnetic map of Ascension Island, South Atlantic Ocean", Ross, H. P., Nielson, D. L., and Green, D. J., UURI/ESL Report, in prep. (1984).

"Electrical resistivity studies, Ascension Island, South Atlantic Ocean," Ross, H. P., Green, D. J., Sibbett, B. S., and Nielson, D. L., UURI/ESL Report, in prep. (1984).

"Interpretation of a detailed aeromagnetic study, Ascension Island, South Atlantic Ocean", Ross, H. P., and Nielson, D. L., UURI/ESL Report, in prep. (1984).

PATENT:

"A Bidirectional Reflection Attachment for a Double Beam Spectrophotometer," Hunt, G. R. and Ross, H. P., submitted October 1966, U.S. Patent No. 3,506,365.

ABSTRACTS AND PRESENTATIONS:

"The Roosevelt Hot Springs, Utah Geothermal Resource - An Integrated Case Study," Ross, H. P., Nielson, D. L., Glenn, W. E., Moore, J. N., Smith, Christian and Christensen, O. D., 66th Annual AAPG Meeting, San Francisco, June (1981).

"Reflection Seismic Surveys for Basin and Range Geothermal Areas - An Assessment," Ross, H. P., Glenn, W. E. and Swift, C. M., Jr., 66th Annual AAPG Meeting, San Francisco, June (1981).

"The Cove Fort-Sulphurdale KGRA - A Geological and Geophysical Case Study (abs.)," Ross, H. P., Moore, J. N. and Glenn, W. E., Geophysics, 46, No. 3 (1981).

"An Examination of 2-D Earth Model Resolution With the Dipole-Dipole Resistivity Method (abs.)," Smith, Christian, Glenn, W. E., Tripp, A. C. and Ross, H. P., Geophysics, 46, No. 3 (1981).

"A Strategy of Exploration for High Temperature Hydrothermal Systems in the Basin and Range Province," Ward, S. H., Ross, H. P. and Nielson, D. L., 65th Annual AAPG meeting, Denver, June (1980).

"Review of Well Logging in the Basin and Range Known Geothermal Resource Areas," Glenn, W. E., Ross, H. P. and Atwood, J. W., Paper SPE 9496, 55th Annual Meeting, SPE/AIME, Dallas, 16 p. (1980).

"Dipole-Dipole Resistivity Survey of a Portion of the Coso Hot Springs, KGRA, Inyo County, California", Fox, R. C., Ross, H. P., and Wright, P. M., (abs) Geophysics, v. 44, no. 3, p. 405 (1979).

"Aeromagnetics in Porphyry Copper Exploration," GSA Penrose Conference on Geologic Interpretation of Magnetic Data (unpublished), Reston, Virginia, April (1974).

"An Integrated Magnetic Study of Intrusive and Altered Sedimentary Rock of the Santa Rita, New Mexico Porphyry Copper Deposit," Trans. AIME, Dallas, February (1974).

RESUME

Stanley H. Ward

BIRTHPLACE AND DATE: Vancouver, B.C., Canada, January 16, 1923

POSITION: Professor, Department of Geology and Geophysics, College of Mines and Mineral Industries, University of Utah, Salt Lake City, Utah
Director, University of Utah Research Institute, Earth Science Laboratory, Salt Lake City, Utah

EDUCATION: 1940, John Oliver High School, Vancouver, Canada
B.A.Sc., Engineering Physics, 1949, University of Toronto, Toronto, Ontario, Canada
M.A., Geophysics, 1950, University of Toronto
Ph.D., Geophysics, 1952, University of Toronto

SOCIETY AFFILIATIONS: Fellow, Royal Astronomical Society
Fellow, Institute of Electrical and Electronic Engineers
Fellow, Geological Society of America
Member, Society of Exploration Geophysicists
Member, Geothermal Resources Council

Member, European Association of Exploration Geophysicists
Member, Canadian Institute of Mining and Metallurgy
Member, American Geophysical Union
Member, International Union of Geodesy and Geophysics
Member, Society of Sigma Xi
Member, Professional Engineers of the Province of Ontario
Member, Australian Society of Exploration Geophysicists

PROFESSIONAL EXPERIENCE:

4/78-present Director, Earth Science Laboratory, University of Utah Research Institute. Responsible for the management of research activities of a professional staff of 29 and a support staff of 30. Responsible for administration of funds totalling $10,000,000.

7/73-6/80 Director, University of Utah Seismograph Stations. Responsible for the management of research activities of a professional staff of 6 and a support staff of 8. Responsible for administration of funds totalling $132,000.

7/70-6/80 Professor, Department of Geology and Geophysics, University of Utah. Research and teaching concerned with electromagnetic exploration with the objectives including the search for minerals, oil and gas, and geothermal energy, deep probing of the earth's crust, and study of the lunar interior.

1959-1970 University of California, Berkeley, Professor of Geophysical

Engineering. Research and teaching concerned with electromagnetic exploration with the objectives including the search for minerals and oil, deep probing of the earth's crust, study of the earth's magnetosphere, and study of the lunar interior.

1958-present Consulting Geophysical Engineer. Consults to mining, petroleum, geothermal, aerospace and instrument companies and to governmental agencies; designs, supervises, and interprets data from exploration campaigns; originates, invents, advises regarding hardware and software utilized in mining exploration, petroleum exploration, and geothermal exploration; primarily concerned with electromagnetic exploration; consults on special government problems; clients have included:

Phelps Dodge Corporation
Kennecott Copper Corp.
Noranda Mines Ltd. - Canada
Placer Development Ltd. - Canada
Brenda Mines Ltd. - Canada
Craigmont Mines Ltd. - Canada
Endako Mines Ltd. - Canada
Scurry Rainbow Oil Co. - Canada
Pure Oil Company
Amax Exploration, Inc.
Commonwealth Scientific and Industrial Research Organization, Australia
Colonial Sugar Refining Co., Australia
Sinclair Oil and Gas Co.
United States Steel Corp.
Varian Associates
The Bunker Hill Co.
Peerless Gas and Oil Co.
The U.S. Dept. of Justice
Cyprus Mines Corp.
Morrison-Knudson Co., Inc.
The National Aeronautics and Space Administration
Westinghouse Electric Corp.
Universidade Federal Do Bahia Instituto de Geosciencias E Instituto de Fisico-Brazil
Engenheiros Consultores Associados, S.A. - Brazil
Exxon Corporate Research Laboratory, Newark
Atlantic Richfield Co., Dallas
Greatland Exploration Ltd., Anchorage
McPhar Instrument Corporation, Toronto
Exxon Production Research Laboratory, Houston
Quintana Minerals Corp. Houston
General Electric Corporate Laboratory, Schnectady
CRA Exploration Pty. Ltd., Melbourne
Royal Dutch Shell, Amsterdam
Houston Oil and Gas Corporation, Denver
SERU Nucleaire (Canada) Limitee, Montreal, Canada
Getty Oil Co., Salt Lake City
Anglo American of South Africa, Johannesburg
BP Minerals, Vancouver

1953-1958 Managing Director and Chief Geophysicist, Nucom Ltd. (subsidiary of American Metal Climax Inc.). Supervised geophysical aspects of exploration program involving as many as 275 men; supervised operation of three helicopter-borne electromagnetic prospecting units; supervised gravity, magnetic, electromagnetic surveys; prepared budgets of $500,000 yearly for research and operations; interpreted data from mining geophysical surveys; collaborated in design of airborne, ground and drill hole prospecting systems; prepared reports on surveys and papers for publication in scientific and professional journals.

1949-1953 Managing Director and Chief Geophysicist, McPhar Geophysics Ltd. Directed operations and research of geophysical contracting firm; interpreted data from mining geophysical surveys; supervised staff of forty engineers, technicians, clerical staff; prepared cost estimates for surveys; collaborated in design of airborne, ground and drill hole electromagnetic prospecting systems; prepared reports on surveys and papers for publication in scientific and professional journals.

PUBLICATIONS AND REPORTS:

113 Publications
31 Abstracts
14 Contract Reports

Mainly in geophysical exploration and exploration strategies for minerals and geothermal energy.

RESUME

Phillip M. Wright

BIRTHPLACE AND DATE: Park City, Utah, March 14, 1938

POSITION: Technical Vice President, University of Utah Research Institute, Salt Lake City, Utah

EDUCATION: B.S. (High Honors), Geological Engineering, 1960, University of Utah, Salt Lake City, Utah
Ph.D., Geophysics, 1966, University of Utah, Salt Lake City, Utah,
Title of Ph.D. Thesis: Heat Flow and Geothermal Gradients in Utah

SHORT COURSES: Motivation and Management: Practical Management Associates, Salt Lake City, Utah, 1969 and 1973.

Engineering and Management: University of California at Los Angeles, 1971.

Mineral Deposits and Mineral Exploration: University of Nevada at Reno, 1973.

Geostatistics in the Mining Industry: Colorado School of Mines Alumni Association, Tucson Arizona, 1976.

Geothermal Resources and the Institutional Maze: Geothermal Resources Council, 1979.

SOCIETY AFFILIATIONS:
- American Geophysical Union
- Society of Exploration Geophysicists
- Society of Economic Geologists
- Geothermal Resources Council
- Utah Geological Association

HONORS AND AWARDS:
- United Park City Mines Scholarship, 1956-1960
- United States Steel Foundation Fellowship, 1961-1963
- National Science Foundation Regular Graduate Fellowship, 1964-1966

Elected to:
- Tau Beta Pi, 1960
- Phi Kappa Phi, 1960
- Phi Beta Kappa, 1960
- Sigma Xi, 1965

PROFESSIONAL EXPERIENCE:

5/84-present Technical Vice President, University of Utah Research Institute. Responsible for administering and directing technical work performed by UURI and for development and maintenance of technical and scientific capabilities within UURI.

9/82-12/82	Taught course GG521, Gravity and Magnetic Methods of Exploration, a graduate-level course at the Department of Geology and Geophysics, University of Utah.
9/78-5/84	Associate Director for Technology, Earth Science Laboratory Division, University of Utah Research Institute. Reported to Director of the Earth Science Laboratory. Assumed about half of Director's functions during academic year. Coordinated, reviewed and ensured quality of all scientific and engineering work performed at ESL. Responsible for technical work on budgets of about $3 million per year. Portion of work involved geothermal research and management assistance programs on behalf of the U.S. Department of Energy. Geothermal work encompassed entire U.S. Also worked at the Ahuachapan geothermal field in El Salvador. Another portion of work involved minerals exploration projects, services and research. Project Manager for Solution Mining and Hydrometallurgy project at UURI, supported by industry and designed to improve solution mining technology.
5/77-9/78	Senior Geophysicist/Project Manager, Earth Science Laboratory Division, University of Utah Research Institute. Responsible for assembling a multidisclipinary, high-quality earth science staff and installation of appropriate laboratory facilities. Reviewed work of less senior geophysicists on numerous geothermally related projects. Participated in planning for all ESL projects. Project Manager for State Coupled Geothermal Resource Assessment Program under contract to U. S. Department of Energy.
1969-5/77	Chief, Geophysics Division - U.S. Operations, Kennecott Exploration, Inc., Salt Lake City, Utah. Reported to Director, Exploration Services and to Vice-President, Exploration. Responsible for budgets up to $800,000 per year. Supervised professional geophysical staff, field geophysical crews and contract geophysical services. Interacted with worldwide exploration offices to provide geophysical input to exploration programs. Designed, supervised and interpreted broad range of geophysical surveys. Generated exploration targets. Project manager on reconnaissance induced polarization project in Western U.S. and Canada which led to discovery of a new, major covered porphyry copper sulfide system. Managed projects in seismic research, field and office interpretation of large aeromagnetic data base, and others. Field experience and interpretative work in Arizona, New Mexico, Nevada, Utah, Montana, Washington, Wisconsin, Minnesota, Colorado, British Colombia, South Africa and Botswana.
1966-1969	Senior Geophysicist, Kennecott Exploration Services, Salt Lake City, Utah. Reported to Chief Geophysicist. Responsible for exploration geophysical programs in Arizona, Nevada and Utah. Worked closely with geologists in Bear Creek Mining Co., a Kennecott subsidiary. Designed, supervised and interpreted geophysical surveys. Generated targets.

1956-1966 Undergraduate and Graduate Student, University of Utah, Salt Lake City, Utah.

1956-1966 (part-time) United Park City Mines Company, Park City, Utah. Worked as underground miner. Later worked with Chief Engineer and Chief Geologist as assistant. Experienced in all types surface and underground survey work, geologic mapping and interpretation. Directed underground long-hole drilling program which aided in discovery of new lead-zinc mineralization. Ore reserve calculations.

1961 (summer) The Anaconda Company, Salt Lake City, Utah. Worked as assistant geologist on a beryllium prospect near Ely, Nevada. Underground geologic mapping sampling. Ore reserve calculations.

1957 (summer) Bush and Gudgell, Engineers, Salt Lake City, Utah. Member of survey crew.

PUBLICATIONS:

"Heat Flow and Precision Temperature Measurements in Boreholes," Costain, J. K. and Wright, P. M., Soc. Prof. Well Log Anal. Annu. Logging Symp., Trans. No. 10, J1 (1969).

"Heat Flow at Spor Mountain, Jordan Valley, Bingham, and LaSal, Utah," Costain, J. K. and Wright, P. M., J. Geophys. Res., 78, No. 35, 8637 (1973).

"Annual Review of Geophysics," Mining Engineering, 25, No. 2 (1973).

"Frontiers of Mining Geophysics," Ward, S. H., Campbell, R. E., Corbett, J. D., Hohmann, G. W., Moss, C. K. and Wright, P. M., Geophysics, 41, No. 2 (1977).

"Western States Cooperative Direct Heat Geothermal Program of DOE," Wright, P. M., Foley, D., Nichols, C. R., Grim, P. J. and Swanson, Jim, Geoth. Resources Council, Trans., 2, Sec. 1, 739 (1978).

"Nature, Occurrence and Utilization of Geothermal Energy," Commercialization of Geothermal Resources, Geoth. Resources Council, 1 (1978).

"Nature and Occurrence of Geothermal Resources," Commercial Uses of Geothermal Heat, Geoth. Resources Council Spec. Report No. 9, 123-134 (1980).

"State Coupled Resource Assessment Program - An Update," Foley, Duncan, Wright, P. M., Struhsacker, D. W., Nichols, C. R., Mink, L. L., Brophy, G. P., Grim, P. J. and Berry, George, Geothermal Resources Council, Transactions, vol. 3, 1979.

"Gravity and Magnetic Methods in Mineral Exploration," Seventy-Fifth Anniversary Volume, Economic Geology, Society of Economic Geologists, 1981.

"Seismic Methods in Mineral Exploration," Seventy-Fifth Anniversary Volume, Economic Geology, Society of Economic Geologists, 1981.

"Tracer Recovery and Mixing from Two Geothermal Injection-Backflow Studies", Capuano, R. M., Adams, M. C., and Wright, P. M., Proceedings, Ninth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA, Dec. 1983.

"Uses of Geochemistry with Injection-Backflow Testing in Geothermal Reservoir Studies", Wright, P. M., Capuano, R. M., Adams, M. C. and Moore, J. N., Geothermal Resources Council, Transactions, vol. 8, 1984 (in press).

MAJOR ORAL PRESENTATIONS:

Determining Variations in the Thickness of Recent Cover with Gravity: to AIME Annual Meeting, New York, New York, 1968.

Educating Tomorrow's Earth Scientist for Industry: to Southwest Section, AIME, Las Vegas, Nevada, 1972.

Integration of Geophysical Data into Mining Exploration Programs: to Society of Economic Geologists Annual Meeting, New York, New York, 1975.

Mining Geophysics: taught a one-day mining geophysics course as part of a course entitled "A Total Concept of the Mining Industry", a summer course taught by the Colorado School of Mines, each year 1970-1976.

Dipole-dipole Resistivity of a Portion of the Coso Hot Springs KGRA, Inyo County, California: to Society of Exploration Geophysicists 48th Annual Meeting, San Francisco, California, 1978.

Use of Geophysics in Geothermal Exploration: A short course sponsored by CEL and the United Nations in El Salvador, C.A. for delegates from Central and South American in June 1979.

Geothermal Geophysics: to National Conference on Renewable Energy Technologies, Honolulu, Hawaii, 1980.

Nature and Occurrence of Geothermal Resources: to Geothermal Resources Council Symposium on Commercial Uses of Geothermal Heat, Boise, Idaho, 1980.

Nature and Occurrence of Geothermal Resources in the United States: to the First Sino/US Geothermal Resources Conference, Tianjin, People's Republic of China, 1981.

Geochemistry in Geothermal Exploration: to the First Sino/US Geothermal Resources Conference, Tianjin, People's Republic of China, 1981.

Uses of Geochemistry with Injection-Backflow Testing in Geothermal Reservoir Studies: to Geothermal Resources Council Annual Meeting, Reno, NV, August, 1984.