Research Proposal to the Geothermal Division
Energy Research and Development Administration

from

University of Hawaii
Honolulu, Hawaii 96822

HAWAII GEOTHERMAL PROJECT - PHASE II
FINAL REPORT ON WELL HGP-A
EXTENSION TO CONTRACT E(04-3)-1093

Amount Requested: $362,886
Proposed Duration: Fifteen Months
Requested Starting Date: July 1, 1976
Submittal Date: May 17, 1976

Principal Investigator

Name: John W. Shupe [redacted]

Title: Dean of Engineering

Telephone: (808) 948-7727

Signature: John W. Shupe

Geosciences Coordinator

Charles E. Helsley [redacted]

Director of the Hawaii Institute of Geophysics

(808) 948-8760

Signature: Charles E. Helsley

Approving Administrative Official:

Name: Keith E. Chave

Title: Acting Associate Dean for Research

Telephone: (808) 948-8658

Signature: _____

DISCLAIMER

HAWAII GEOTHERMAL PROJECT - PHASE II

FINAL REPORT ON WELL HGP-A

INTRODUCTION

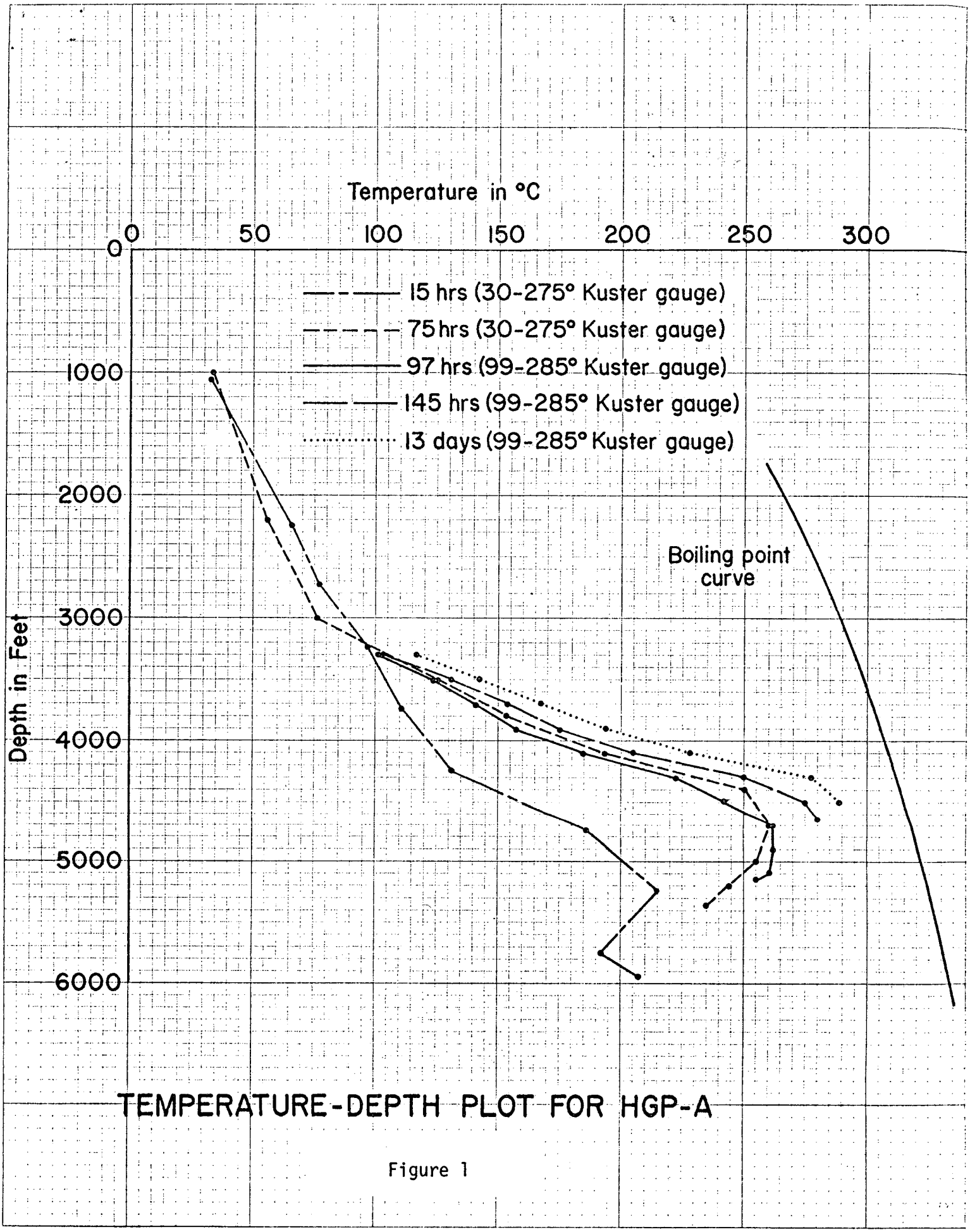
Drilling was completed on HGP-A to a depth of 6445 feet on April 27, 1976. A final core was taken; a series of logging runs performed, both with Gearhart-Owen equipment and with the Kuster temperature gauge; and the drill stem was withdrawn and layed down on the site adjacent to the rig -- as a safety measure against possible volcanic tremors. This completed the drilling-logging-coring program for HGP-A.

Kuster temperature measurements indicate that this is a hot well. A maximum temperature to date of 288°C (550°F) was recorded on May 13 at 4500 feet. The weighted temperature probe would penetrate no deeper into the drilling mud, which apparently is stiffening. Figure 1 illustrates the temperature-depth relationship developed in HGP-A.

Once it was demonstrated that a downhole temperature exists that is well within the range for commercial power generation, it was decided that a comprehensive well-testing program was warranted to verify if sufficient permeability is present to support a geothermal reservoir. ERDA provided an additional $258,560 to prepare the well and to complete the initial testing phase. Tasks to be funded include:

1. Perforating and cementing voids between casings.
2. Installation of slotted liner, well head, and auxiliary equipment.
3. Initial well testing and analysis.
4. Environmental baselines and assessment.

The slotted liner has been ordered for delivery in Hawaii on May 23; the crew will be mobilized on May 24 to begin perforating, cementing, and installation of liner and wellhead; and well testing should commence by the second week in June.



TEMPERATURE-DEPTH PLOT FOR HGP-A

Figure 1

SUMMARY OF PROPOSAL

Now that high temperatures have been encountered in HGP-A, additional importance is placed on a comprehensive analysis of all of the scientific data that has been accumulated by the Project over the last three years. Pertinent information from the USGS, State agencies, and other University projects must also be evaluated and related to actual subsurface conditions. This is an essential phase of this scientific endeavor, if maximum benefit is to be derived from the significant investment of public and private funds that have gone into this project. The analysis and synthesis of this information should provide valuable insight into the understanding of potential geothermal reserves not only in Hawaii, but for volcanic geothermal regimes in the Western United States and throughout the world.

The purpose of the funds requested in this proposal is to provide support with which to complete analysis and interpretation of the data and, through comparison with actual subsurface conditions, develop correlations on the reliability of the various methods of prediction. A synthesis of all pertinent data -- from geosciences, from mathematical modeling, from drilling, from well-testing -- will contribute to a more complete understanding of the geothermal regime associated with this well.

Discussions with members of the ERDA Geothermal Division limited this proposal for an extension of support for the HGP to those tasks directly related to an analysis and an interpretation of data relating to the exploratory and drilling programs. Completely eliminated in this proposal is continuing support for environmental, socioeconomic, regulatory, and energy conversion projects.

Tasks to be completed in this fifteen-month study, and a related budget for each, are as follows:

	Transition Period	FY 77	Total
Management and Support	$ 5,276	$32,375	$37,651
Geosciences			
Coordination and Support	11,345	28,812	40,157
Gravity, Magnetics	10,434	27,587	38,021
Seismic Studies	5,221	25,011	30,232
Geoelectric Surveys	11,719	11,459	23,178
Geochemistry	7,067	12,791	19,858
Well Temperature Analysis	3,450	8,090	11,540
Physical Properties of Rocks	4,366	21,347	25,713
Hydrology	10,095	16,122	26,217
Numerical Modelling	19,165	31,294	50,459
Well Test and Analysis	16,326	43,534	59,860
TOTAL	$104,464	$258,422	$362,886

Brief narrative summaries for each task, with associated budget sheets for the three-month transition period and for FY 77, are attached. Also attached is a copy of biodata for Dr. Charles E. Helsley, new Director of the Hawaii Institute for Geophysics, who will coordinate the geoscience tasks.

Hawaii Geothermal Project
Budget Worksheet

Program: Management

July 1, 1976-September 30, 1977	Estimated Requirements 7/1-9/30/76	10/1/76-9/30/77
1. Salaries and Wages	$ 2,571	$14,532
Scientific Discipline Personnel Principal Investigator, J. Shupe, Dean of Engineering -100% of time for 1 summer month @ $3990 per month		3,990
Support Personnel Administrative Assistant	2,571	10,542
2. Fringe Benefits	$ 592	$ 2,588
3. Equipment	-0-	-0-
4. Travel	$ 180	$1070
Domestic	180	1070
Foreign		
5. Other Direct Costs	$ 750	$ 7,500
Supplies and Materials	150	600
Publications		4,500
Machine Shop Services		
Computer Services		
Other: communications, xeroxing, miscellaneous	600	2,400
6. Indirect charges: 46.00% of Salaries and Wages.	$ 1,183	$ 6,685
Total Project Costs	$ 5,276	$32,375

Task 2.1
COORDINATION AND GENERAL SERVICES

A. S. Furumoto

Wide dissemination of the information acquired during the Hawaii Geothermal Project is necessary to utilize the data acquired and to provide maximal transfer of information to other geothermal projects.

The reports of the geological, geochemical and geophysical tasks are being published in a series of HIG reports as the Geothermal Resources Exploration Series. These reports differ from journal articles in that more data and details are included than in journal articles. The usual practice is to publish as HIG Reports first and then to submit a polished and refined manuscript to a journal.

The publication of HIG Reports runs about $400 per volume. We anticipate publishing an eight volume series, one of which has been published in 1975.

At the end of the field project the various instruments and equipment used in the field must be repaired and calibrated before storage. Many instruments in years past have not been maintained after completion of projects, resulting in losses amounting to hundreds of thousands of dollars. The technician of the project will require three months to complete this task with the assistance of a student help.

Travel to the east coast in 1977 is anticipated to present the overall results of the geophysical program to the AGU annual meeting.

This task also includes the budget for the wrap up of the Drilling Support Program.

Hawaii Geothermal Project
Budget Worksheet

Program Geoscience - Task 2.1

July 1, 1976-September 30, 1977	Estimated Requirements 7/1-9/30/76	10/1/76-9/30/77
1. Salaries and Wages	$ 6,345	$14,640
Scientific Discipline Personnel Faculty Associate, G. Macdonald, Senior Professor-100% of time for 1 summer month @ $3,705 per month		3,705
Support Personnel Administrative Assistant Technician Pre-Baccalaureate Student	6,345	10,935
2. Fringe Benefits	$ 1,321	$ 2,678
3. Equipment	-0-	-0-
4. Travel	$ 160	$ 760
Domestic	160	760
Foreign		
5. Other Direct Costs	$ 600	$ 4,000
Supplies and Materials	200	800
Publications		2,400
Machine Shop Services		
Computer Services		
Other: communications, car rental, xeroxing	400	800
6. Indirect charges: 46.00% of Salaries and Wages.	$ 2,919	$ 6,734
Total Project Costs	$11,345	$28,812

Task 2.2
GRAVITY, MAGNETICS AND THERMAL MODELING

R. Norris

Gravity

An approximately uniform distribution of 167 measurements of gravity have been made and have been considered for subaerial and submarine terrain variations. The resulting Bouguer gravity was mapped and contoured both by hand and by computer. A square-grid sampling of the contour map was used to compute polynomial trend surfaces. Upward continuation of the field was computed and examined for depth perspective and downward continuation was used to outline any anomalous masses. Anomaly maps were generated for some models.

We propose to do more modeling and interpretation using the results of borehole logging, coring and cutting analysis, then to write a complete report.

Magnetics

Nine thousand measurements of the total magnetic field intensity have been made over a hundred miles of road network in the area east and south of Pahoa. The data and positions were punched into cards. Heading corrections and averaging were done by computer to yield one thousand points which were contour mapped by computer. Some interpretation and modeling of a significant anomaly has been done.

We propose to do more modeling and interpretation, to obtain and work up A. Malahoff's low-level aeromagnetic survey data, and to write a complete report.

Mathematical Modeling of Heat Transfer

The thermal process in the Puna area is by far a conductive process, in regards to the high temperature regions of the East rift. Hence a model of

heat transfer by conduction from intruded magma through the dike complex to the shield rock will be studied by numerical models. The various geophysical tasks will provide information on the dimension of the geological formation and will be constrained by the borehole temperature data from the well. Laboratory studies will provide the thermal conductivity values of the dikes and shield rocks.

Hawaii Geothermal Project
Budget Worksheet

Program Geosciences - Task 2.2

July 1, 1976-September 30, 1977	Estimated Requirements 7/1-9/30/76	10/1/76-9/30/77
1. Salaries and Wages	$ 6,037	$15,651
Scientific Discipline Personnel		
R. Norris, Post-Doctorate Assistant-100% of time for 3 summer months @ $1329 per month	3,987	
R. Norris, Post-Doctorate Assistant-100% of time for 9 academic months @ $1329 per month		11,961
1 Graduate Assistant @ $820 per month-100% of time for 2 summer months and 50% of time for 1 academic month	2,050	
1 Graduate Assistant @ $820 per month-50% of time for 9 months		3,690
2. Fringe Benefits	$ 1,020	$ 2,936
3. Equipment	-0-	-0-
4. Travel	-0-	-0-
Domestic		
Foreign		
5. Other Direct Costs	$ 600	$ 1,800
Supplies and Materials	100	
Publications		800
Machine Shop Services		
Computer Services	500	1,000
Other:		
6. Indirect charges: 46.00% of Salaries and Wages.	$ 2,777	$ 7,200
Total Project Costs	$10,434	$27,587

Task 2.3
SEISMIC STUDIES

A. S. Furumoto

The following field projects have been carried out under the Seismic Studies Task:

(a) Microearthquake monitoring over a period of about three weeks in 1974

(b) Groundnoise survey in 1974

(c) Seismic refraction-reflection survey in 1976

Data processing for the microearthquake survey and the groundnoise survey has been completed but interpretation in conjunction with the other surveys has yet to be made.

In regards to the groundnoise survey, the field work consisted of recording groundnoise for any given station for about twenty minutes. About thirty to forty stations were occupied. The results showed an area of higher intensity (about 9 db above average) in the 4 hz band.

The above results will be checked by analyzing the tape recordings collected from the microearthquake surveillance project. The network for the microearthquake survey consisted of seven stations scattered over the Puna area. Each station had a 1 hz vertical component geophone as transducer. Signals from each station were telemetered by hardwire or radio links to a central recording station, where the signals were recorded on magnetic tapes. The telemetry links were all carefully calibrated and their transducer functions were measured.

As any one station has 20 days of data, day and night, we shall use electronic methods for processing. We shall pass the data through various bandpass filters and see how the intensity of the band varies during the days.

As this involves a lot of electronic work in the laboratory, the electronic design technician will carry out the data processing. He may have to design new techniques for processing.

The records of the active seismic experiment have been looked over for refraction arrivals. These arrivals did not outline the high density rocks under the east rift. We shall now go through the records to pick out the reflection arrivals. As the signals were recorded wideband on tape, various filter techniques will be used to ferret out the reflection arrivals. With reflection data we hope to outline at least the top of the high density rocks.

Data from the seismic program will be incorporated in the final interpretation to obtain the structure of the east rift.

Hawaii Geothermal Project
Budget Worksheet

Program Geosciences - Task 2.3

July 1, 1976-September 30, 1977	Estimated Requirements 7/1-9/30/76	10/1/76-9/30/77
1. Salaries and Wages	$ 3,005	$13,747
1 Graduate Assistant @ $914 per month- 100% of time for 2 summer months and 50% of time for 1 academic month	2,285	
1 Graduate Assistant @ $914 per month- 50% of time for 9 months		4,113
Support Personnel. Technician Pre-Baccalaureate Student	720	9,634
2. Fringe Benefits	$ 114	$ 2,330
3. Equipment	-0-	-0-
4. Travel	$ 160	$ 160
Domestic	160	160
Foreign		
5. Other Direct Costs	$ 560	$ 2,450
Supplies and Materials	200	600
Publications		800
Machine Shop Services		
Computer Services	200	600
Other: communications, drafting, car rental.	160	450
6. Indirect charges: 46.00% of Salaries and Wages.	$ 1,382	$ 6,324
Total Project Costs	$ 5,221	$25,011

Task 2.4
GEOELECTRIC SURVEYS

D. P. Klein

Our final budget request, roughly $23,200, is minimized to produce the following:

1. A final HGP report detailing our survey methods, analysis and interpretation for geothermal resources on Hawaii Island. This will supplement Klein and Kauahikaua (1975). The latter outlined the reconnaissance results which lead to more concentrated surveys in the Puna Region (the subsequent drill site). The computer funds requested are essential for a final analysis and evaluation of our time-domain (transient induction) surveys (see item 2). Our primary goal in this wrapup will be to compare the information available in the various data sets [time-domain, 2-loop (frequency-domain, see item 3) dipole mapping and Schlumberger sounding] with each other and with the results of other geophysical surveys and the final drilling.

2. A comprehensive publication in a refereed journal describing our deep penetrating surveys. This will be a condensation of item 1 but concentrated primarily on the interpretation of time-domain data. In a thesis in preparation, Kauahikaua has developed a rigorous approach to time-domain data interpretation based on digital signal processing and partial inversion. He uses the data statistics to demonstrate the maximum information content of the data. This differs from standard modeling of time-domain data which does not, in our viewpoint, provide adequate indications of the data limitations. This approach to data analysis has the possibility of being incorporating directly into field systems by using the latest mini- or micro-computer technology. Our experience will have direct application to other geoelectric studies in basaltic terrain and general application to time-domain surveys.

3. A publication in a refereed journal describing our shallow penetrating surveys (Kauahikaua, et al., in preparation). We learned early in the project that direct evidence regarding geothermal resources in the Hawaii environment is not available by using 2-loop and Schlumberger sounding techniques with feasible power sources. Nevertheless, these results do constrain the shallow conductivity structure in interpretation of deep sounding data. Also, these surveys proved to be highly effective in evaluating the hydrologic conditions of the area surveyed. This result has application to economic hydrologic investigations on oceanic island and in continental basaltic regimes.

1. Kauahikaua, J., D. Klein, C. Zablocki, 1975, Electromagnetic Induction Sounding Measurements in the Puna District, Hawaii. (in preparation)

2. Klein, D., J. Kauahikaua, 1975, Geoelectric-Geothermal Exploration on Hawaii Island: Preliminary Results. Hawaii Institute of Geophysics Rept. 75-6.

Hawaii Geothermal Project
Budget Worksheet

Program Geosciences - Task 2.4

July 1, 1976-September 30, 1977	Estimated Requirements 7/1-9/30/76	10/1/76-9/30/77
1. Salaries and Wages	$ 6,671	$ 5,709
Scientific Discipline Personnel		
D. Klein, Post-Doctorate Assistant-100% of time for 2 summer months @ $1104 per month	2,208	
D. Klein, Post-Doctorate Assistant-100% of time for 1 academic month @ $1104 per month		1,104
1 Non-Faculty Professional @ $921 per month-100% of time for 3 months	2,763	
1 Non-Faculty Professional @ $921 per month-100% of time for 3 months		2,763
1 Non-Faculty Professional @ $921 per month-100% of time for 2 months		1,842
1 Graduate Assistant @ $850 per month-100% of time for 2 summer months	1,700	
2. Fringe Benefits	$ 1,229	$ 1,314
3. Equipment	-0-	-0-
4. Travel	-0-	$ 560
Domestic		560
Foreign		
5. Other Direct Costs	$ 750	$ 1,250
Supplies and Materials		
Publications		1,000
Machine Shop Services		
Computer Services	750	250
Other:		
6. Indirect charges: 46.00% of Salaries and Wages.	$ 3,069	$ 2,626
Total Project Costs	$11,719	$11,459

Task 2.5
GEOCHEMISTRY

P. F. Fan

We propose to conduct the following research on the basalt cores and cuttings obtained during drilling of Hawaii Geothermal Well A:

1. Major chemical analyses using an ARL X-ray Fluorescence Quantometer.
2. Petrography and mineralogy by studying thin sections and computing model and normative analyses.
3. Study of hydrothermal alteration products using an X-ray Diffractometer.
4. Trace element analyses for Ni, Co. Cr. Rb, Sr. Zr and V using Atomic Absorption.

Justification for the above studies is based on the paucity of data, both practical and theoretical, relating geothermal resources to basaltic volcanism. Today only Iceland has successfully derived geothermal energy from a predominantly basaltic field. Data from the basalt cores of Hawaii Geothermal Well A would enable us to compare and contrast our findings with theirs. More importantly, this data would aid in searching for additional geothermal sites in Hawaii suitable for energy production.

Specifically, secondary mineral assemblages act as geothermometers and with the aid of petrographic and mineralogic data it can be determined whether the alteration products are a result of former hydrothermal activity or present-day conditions. Major chemical analyses and modal and normative analyses are necessary to accurately identify the rock suite so that the study of alteration products is valid and significant. Furthermore, major and minor element analyses will be valuable in correlating data from this well with data obtained from future wells.

Because of the depth of the well, all of the data will add to our knowledge of subaqueous volcanism, the formation of oceanic islands, and magma genesis in general.

Hawaii Geothermal Project
Budget Worksheet

Program Geosciences - Task 2.5

July 1, 1976-September 30, 1977	Estimated Requirements 7/1-9/30/76	10/1/76-9/30/77
1. Salaries and Wages	$ 3,848	$ 6,484
Scientific Discipline Personnel		
Faculty Associate, P. Fan, Associate Professor-50% of time for 1 summer month @ $2125 per month	1,063	
1 Graduate Assistant @ $914 per month-100% of time for 2 summer months and 50% of time for 1 academic month	2,285	
1 Graduate Assistant @ $914 per month-50% of time for 12 months		5,484
Support Personnel. Pre-Baccalaureate Student	500	1,000
2. Fringe Benefits	$ 149	$ 274
3. Equipment	-0-	-0-
4. Travel	$ 600	$ 750
Domestic	600	750
Foreign		
5. Other Direct Costs	$ 700	$ 2,300
Supplies and Materials	700	2,300
Publications		
Machine Shop Services		
Computer Services		
Other:		
6. Indirect charges: 46.00% of Salaries and Wages.	$ 1,770	$ 2,983
Total Project Costs	$ 7,067	$12,791

Task 2.6
WELL TEMPERATURE ANALYSIS

D. Epp

There are two projects that need to be completed by this subtask between now and September 1977. The first is the final report on well temperature data collected during the last two years. This will be completed within the transitional fiscal year 1976. The second is a long-term monitoring of the temperatures in the HGP well. The present temperature measurements indicate that the temperature in the well is increasing. This is expected because cold surface water was circulated in the well during drilling. If the temperature in the well exceeds the boiling temperature and the well produces steam, then this part of the project will probably not be necessary. If the well does not produce steam, then it will be desirable to monitor the temperatures in the well over a period of several months; at least until the well reaches an equilibrium temperature distribution. This equilibrium temperature distribution will be valuable information for any thermal modeling of active volcanoes, and should precede any future geothermal exploration on active volcanoes.

Hawaii Geothermal Project
Budget Worksheet

Program Geosciences - Task 2.6

July 1, 1976-September 30, 1977	Estimated Requirements 7/1-9/30/76	10/1/76-9/30/77
1. Salaries and Wages	$ 2,285	$ 5,027
1 Graduate Student @ $914 per month- 100% of time for 2 summer months and 50% of time for 1 academic month	2,285	
1 Graduate Student @ $914 per month- 50% of time for 11 months		5,027
2. Fringe Benefits	$ 114	$ 251
3. Equipment	-0-	-0-
4. Travel	$ -0-	$ -0-
Domestic		
Foreign		
5. Other Direct Costs	-0-	$ 500
Supplies and Materials		
Publications		500
Machine Shop Services		
Computer Services		
Other:		
6. Indirect charges: 46.00% of Salaries and Wages.	$ 1,051	$ 2,312
Total Project Costs	$ 3,450	$ 8,090

Task 2.7
PHYSICAL PROPERTIES OF ROCKS

M. Manghnani, C. S. Rai, T. Hanada

We propose here a twofold program, the first part of which will be to investigate the physical, elastic, electrical and thermal properties of core drill samples that have been obtained from the recently drilled hole to $\sim$ 6,455 ft. The properties include density (ρ) and porosity (ϕ). The elastic properties of interest are: compressional (V_p) and shear wave (V_s) velocities as a function of modest pressure (200 bars) and temperature to 300°C. The electrical properties of these rocks will be investigated as a function of porosity, fluid content, pressure and temperature. The thermal properties include thermal conductivity (and diffusivity) as a function of porosity and temperature.

These studies will be followed by a completion of the on-going laboratory measurements of various physical, elastic, electrical, and thermal properties, and interpretation of the data in terms of the overall program.

Mr. Rai, a graduate student who is working on this project, will complete his Ph.D. thesis in about a year's time.

Hawaii Geothermal Project
Budget Worksheet

Program Geosciences - Task 2.7

July 1, 1976-September 30, 1977	Estimated Requirements 7/1-9/30/76	10/1/76-9/30/77
1. Salaries and Wages	$ 2,050	$11,274
Scientific Discipline Personnel		
T. Hanada, Post-Doctorate Assistant- 100% of time for 4 months @ $1281 per month		5,124
1 Graduate Assistant @ $820 per month- 100% of time for 2 summer months and 50% of time for 1 academic month	2,050	
1 Graduate Assistant @ $820 per month- 50% of time for 9 academic months and 100% of time for 3 summer months		6,150
2. Fringe Benefits	$ 123	$ 1,487
3. Equipment	-0-	-0-
4. Travel	$ 350	$ 700
Domestic	350	700
Foreign		
5. Other Direct Costs	$ 900	$ 2,700
Supplies and Materials	900	2,200
Publications		200
Machine Shop Services		
Computer Services		200
Other: communications		100
6. Indirect charges: 46.00% of Salaries and Wages.	$ 943	$ 5,186
Total Project Costs	$ 4,366	$21,347

Task 2.8
HYDROLOGY

P. M. Kroopnick, R. W. Buddemeier, L. S. Lau

In order to fulfill the original objectives of our hydrological, isotopic and geochemical surveys, six subtasks need to be completed. These are:

1. Completion of analyses of samples taken during winter and spring 1976 before the well was completed.

2. Down-hole sampling:

   a. One set of samples will be taken as soon as the well is cleared and logged, and appears to have stabilized. Exact samples will depend on logging results, but will include a vertical profile of at least 6 samples. This will probably occur in summer 1976.

   b. At least one set of samples (vertical profile) will be taken 6-9 months after the first set. In addition to checking on the first set of results, this second set will permit sampling based on a more detailed assessment of the logs, cores, and results of the first samples.

   c. Other sampling may be indicated, depending on the nature and results of the pumping and development tests conducted.

3. The samples collected will be analyzed for at least, major and minor elements, nutrients, heavy metals and isotopes (^{18}O, ^{2}H, ^{3}H).

4. Pumped sample collection and analysis (if feasible): If substantial volumes of water are pumped from the well during clearing or testing, we will obtain samples of opportunity from these fluids for all analyses specified above, plus ^{14}C measurement (which requires a volume too large to be obtained by down-hole sampling).

5. Integration and analysis of data: Hydrologic, rain, surface water and test well analytical results will be correlated with each other and with

the results of the petrologic, mineralogical and geochemical analyses of the drill cores and surface rocks in the area.

6. Interpretation and publication of results: Assessment and analysis of the surface hydrology and deep groundwater systems and their relations to each other, the geology and the thermal system. At least one journal article to be prepared as well as technical reports.

Hawaii Geothermal Project
Budget Worksheet

Program Geosciences - Task 2.8

July 1, 1976-September 30, 1977	Estimated Requirements 7/1-9/30/76	10/1/76-9/30/77
1. Salaries and Wages	$ 5,922	$ 9,095
Scientific Discipline Personnel		
Faculty Associate, P. Kroopnick, Associate Professor-50% of time for 1 summer month @ $2051 per month	1,026	
Faculty Associate, R. Buddemeier, Associate Professor-100% of time for 1 summer month @ $2051 per month	2,051	
1 Graduate Assistant @ $914 per month-100% of time for 2 summer months and 50% of time for 1 academic month	2,285	
1 Graduate Assistant @ $914 per month-50% of time for 9 academic months and 100% of time for 3 summer months		6,855
Support Personnel. Pre-Baccalaureate Student	560	2,240
2. Fringe Benefits	$ 149	$ 343
3. Equipment	-0-	-0-
4. Travel	$ 800	$ 1,100
Domestic	800	1,100
Foreign		
5. Other Direct Costs	$ 500	$ 1,400
Supplies and Materials	500	1,000
Publications		400
Machine Shop Services		
Computer Services		
Other:		
6. Indirect charges: 46.00% of Salaries and Wages.	$ 2,724	$ 4,184
Total Project Costs	$10,095	$16,122

Task 3.1
NUMERICAL MODELLING

P. Cheng, K. H. Lau

Inputs from geophysicists and geologists on the Hawaii Geothermal Project will be incorporated to provide the boundary conditions and physical properties to be used in the numerical simulation of the geothermal field in the Puna area. The existing computer codes developed during the past two years will be modified to include the layered structure and anisotropic properties of the rock formations found. The effect of withdrawal of fluids in the Puna area will also be studied numerically. Results will be compared with data obtained from draw-down and build-up tests to predict the capacity of the reservoir.

Work started during the last three months on numerical studies of the environmental impact associated with the reinjection and withdrawal of geothermal fluids on the Ghyben-Herzberg lens and coastal waters will be carried to its completion during the next year. Analytical solutions for the prediction of the fate of injected residual water will also be obtained. The results of these studies will also be applicable to geothermal areas along the West Coast.

Results of the investigation will be presented in a series of papers which will be submitted for publication to leading scientific and professional journals.

Hawaii Geothermal Project
Budget Worksheet

Program Numerical Modelling

July 1, 1976-September 30, 1977	Estimated Requirements 7/1-9/30/76	10/1/76-9/30/77
1. Salaries and Wages	$10,662	$17,302
Scientific Discipline Personnel		
Faculty Associate, P. Cheng, Professor-100% of time for 2 summer months @ $2564 per month	5,128	
Faculty Associate, P. Cheng, Professor-100% of time for 2 summer months @ $2924 per month		5,848
Faculty Associate, K. H. Lau, Associate Professor-100% of time for 1 summer month @ $1844 per month	1,844	
Faculty Associate, K. H. Lau, Associate Professor-100% of time for 1 summer month @ $2104 per month		2,104
2 Graduate Assistants @ $820 per month-50% of time for 3 months	2,460	
1 Graduate Assistant @ $820 per month-50% of time for 2 months	820	
1 Graduate Assistant @ $820 per month-50% of time for 1 month	410	
1 Graduate Assistant @ $850 per month-50% of time for 12 months		5,100
1 Graduate Assistant @ $850 per month-50% of time for 10 months		4,250
2. Fringe Benefits	$ 298	$ 633
3. Equipment	-0-	-0-
4. Travel	$ 400	$ 1,500
Domestic	400	1,500
Foreign		
5. Other Direct Costs	$ 2,900	$ 3,900
Supplies and Materials	1,500	200
Publications	200	700
Machine Shop Services		
Computer Services	1,000	3,000
Other: consultant (Dr. Wooding)	200	
6. Indirect charges: 46.00% of Salaries and Wages.	$ 4,905	$ 7,959
Total Project Costs	$19,165	$31,294

Task 3.2
WELL TEST AND ANALYSIS

P. Takahashi, B. Chen

Static tests for downhole temperature, pressure and water sample wil continue. Flow test equipment will be installed.

The well will be discharged at various determined flowrates (pressures) and wellhead flowrate and enthalpy will be monitored. At regular intervals downhole drawdown pressure and temperature will be taken. Water samples will be drawn as required by the geochemical group.

The well will be shut-in and build-up pressure will be measured at the producing zone on the following days: 0, 1, 2, 4, 8 days, then weekly. Temperature and pressure vs. depth measurements will also be regularly taken.

A series of drawdown and build-up tests will be taken. A computer program developed earlier by the HGP will then be used to analyze the data. An attempt will be made to determine the extent of the geothermal resource and well performance will be predicted. Optimal production rates will be suggested.

The computer program will be extended to include fluid salinity and other important parameters. The prediction package will be further improved by the inclusion of considerations for well placement. In conjunction with the geophysical program, analysis will be undertaken to determine the location of the next hole in the present field and/or the next drill site.

The laboratory physical modelling studies will be continued. In particular, emphasis will be placed on the pressurized model. Self-sealing will be investigated.

A final report will be written.

Budget Worksheet

Program Well Test & Analysis

July 1, 1976-September 30, 1977	Estimated Requirements 7/1-9/30/76	10/1/76-9/30/77
1. Salaries and Wages	$ 4,410	$16,852
Scientific Discipline Personnel		
Faculty Associate, B. Chen, Associate Professor-100% of time for 1 summer month @ $1997 per month	1,997	
Faculty Associate, B. Chen, Associate Professor-100% of time for 1 summer month @ $2276 per month		2,276
Faculty Associate, P. Takahashi, Associate Professor-100% of time for 1 summer month @ $2276 per month		2,276
1 Graduate Assistant @ $850 per month-50% of time for 2 1/2 months	1,063	
2 Graduate Assistants @ $850 per month-50% of time for 1 month	850	
2 Graduate Assistants @ $850 per month-50% of time for 11 months		9,350
Support Personnel	500	2,950
Pre-Baccalaureate Student		
2. Fringe Benefits	$ 95	$ 650
3. Equipment	$ 4,367	$ 5,000
Measurement Spool	500	
Air Compressor Rental	1,500	
Additional Kuster Equipment	1,867	
Physical Model Equipment		4,000
Miscellaneous	500	1,000
4. Travel	$ 4,425	$ 5,780
Domestic	2,925	5,780
Foreign	1,500	
5. Other Direct Costs	$ 1,000	$ 7,500
Supplies and Materials	1,000	1,000
Publications		1,000
Machine Shop Services		500
Computer Services		2,000
Other: contingency		3,000
6. Indirect charges: 46.00% of Salaries and Wages.	$ 2,029	$ 7,752
Total Project Costs	$16,326	$43,534

University of Hawaii at Manoa
Hawaii Institute of Geophysics

HELSLEY, Charles E.
Professor
Director

DEGREES

B.S., Geology, California Institute of Technology, 1956
M.S., Geology, California Institute of Technology, 1957
Ph.D., Geology, Princeton University, 1960

FIELDS OF RESEARCH SPECIALIZATION

Paleomagnetism and Rock Magnetism
Crustal Seismology and Marine Geophysics

ACTIVE RESEARCH SPECIALIZATION

Studies of the past behaviour of the earth's magnetic field and their implications regarding polar wander and continental drift.
Geophysical studies of crustal structure at continental margins
Magnetic reversal stratigraphy of Mesozoic and Paleozoic rocks
Energy Resources - Geothermal and Wind

EXPERIENCE

1956-1957, California Institute of Technology, Field Geology, Graduate Teaching Assistant. Summers: Shell Oil Company, Los Angeles, Exploitation Engineer
1957-1958, Princeton University, Graduate Teaching Assistant, Instructor in Beginning Physical Geology
1960-1962, California Institute of Technology, Geology, Assistant Professor
1962-1963, Western Reserve University, Geology, Assistant Professor
1963-1976, Southwest Center for Advanced Studies (now the University of Texas at Dallas)
1964-1976, Southern Methodist University, Department of Geophysics, Adjunct Professor
1969-1970, University of Texas at Austin, Visiting Professor
1970-1971, Acting Division Head, Geosciences, The University of Texas at Dallas
1971-1973, Associate Head, Geosciences, The University of Texas at Dallas
1973-1976, Program Head and Institute Director, Institute for Geosciences, The University of Texas at Dallas
1974-1976, The University of Texas Medical Branch at Galveston, Marine Biomedical Institute, Earth and Planetary Sciences Division, Adjunct Professor
1976- , Director, Hawaii Institute of Geophysics, University of Hawaii

SOCIETIES

Geological Society of America
American Geophysical Union
American Association for the Advancement of Science
Sigma Xi
Royal Astronomical Society

AWARDS AND FELLOWSHIPS

1957-58 Woodward Foundation Fellowship, Princeton
1958-59 Class of 1873 Fellowship
1959-1960, Peter B. Freling Huysen Fellowship
1962, Summer, Western Reserve University, Research Fellow

PUBLICATIONS

"Summary of the Geology of the British Virgin Islands", Proceedings of the 5th Caribbean Geological Conference, #5, 69-76, 1971.

"Comparison of Permian Magnetic and Zoogeographic Poles", with F. G. Stehli, in Nairn, A.E.M., Editor, Problems in Paleoclimatology: N.A.T.O. Paleoclimates Conf., Newcastle upon Tyne and Durham, England, 1963 Proc., Interscience Publishers, p. 705, London, 1964.

"Paleontologic Technique for Defining Ancient Pole Positions", with F. G. Stehli, Science, 142, 1057, 1963.

"Determination of the Relative Positions of Continents from Paleomagnetic Data", with K. W. T. Graham and A. L. Hales, J. Geophys. Res., 69, 18, pp. 3894-3900, 1964.

"Paleomagnetic Results from the Lower Permian Dunkard Series of West Virginia", J. Geophys. Res., Vol. 70, 2, January 15, 1965.

"Advantages of Field-Drilling Samples for Paleomagnetic Studies", Methods in Paleomagnetism, D. W. Collinson, K. M. Creer and S. K. Runcorn, editors, Elsevier Publishing Co., Amsterdam, pp. 26-30, 1967.

"Design of a Transistorized Portable Air Turbine Spinner Magnetometer", Methods in Paleomagnetism, D. W. Collinson, K. M. Creer and S. K. Runcorn, Editors, Elsevier Publishing Co., Amsterdam, pp. 142-148, 1967.

"Design of Spinner Magnetometers", Methods in Paleomagnetism, D. W. Collinson, K. M. Creer and S. K. Runcorn, editors, Elsevier Publishing Co., Amsterdam, pp. 115-118, 1967.

"The Taxonomic Diversity of Recent Bivalves and Some Implications for Geology", with F. G. Stehli and A. Lee McAllister, Bull. Geol. Soc. Am., 78, pp. 455-466, 1967.

"Polar Wandering and Continental Drift", 1966 McGraw-Hill Yearbook of Science and Technology, McGraw Hill Co., New York, 1966.

"Some Logistics of the East Coast On-shore Off-shore Experiment", (ECOOE), with A. L. Hales, J. J. Dowling, and J. B. Nation, Earthquake Notes, XXXVII, pp. 25-32, 1966.

"The Gulf Coast On-shore Off-shore Experiment: Some Preliminary Results", with A. L. Hales and J. B. Nation, Trans. Am. Geophys. U., 48, 2, pp. 753-756, 1967.

"The East Coast On-shore Off-shore Experiment, 1. The First Arrival Phases", with A. L. Hales, J. J. Dowling and J. B. Nation, Final Report, Contract No. AF 49(638)-1542 to the U.S. Air Force Officer of Scientific Research, 31 March 1967.

"Paleomagnetism of Cretaceous Rocks from North America", Okla. Geol. Surv., 28, 3, pp. 116-117, 1968b.

"Magnetic Reversal Stratigraphy of the Lower Triassic Moenkopi Formation of Western Colorado", Bull. Geol. Soc. Am., 80, pp. 2431-2450, 1969.

"Remanent Magnetization of the Permian Cutler Formation of Western Colorado", J. Geophys. Res., 76, 20, 4842, 4848, 1971.

"The Paleomagnetism of Cretaceous Rocks from Israel", with A. Nur, Earth and Planet. Sci. Letters, 8, 6, pp. 403-410, 1970.

PUBLICATIONS (continued)

"Evidence for long intervals of normal polarity during the Cretaceous period", with M. B. Steiner, Earth and Planet. Sci. Letters, 5, 325-332, 1969.

"A Crustal Structure Study on the Gulf Coast of Texas", with A. L. Hales and J. B. Nation, Bull. AAPG, 54, 11, Nov. 1970.

"Magnetic Properties of Lunar Dust and Rock Samples", Science, 167, 693-695, January 30, 1970.

"Paleomagnetism of Tertiary and Recent Lavas of Israel", Physics of the Earth and Planetary Science Letters, 10, 375-379, 1971.

"Magnetic Properties of Apollo 11 Samples 10022, 10069, 10084, and 10085", in Proc. of the Apollo 11 Lunar Science Conference, A. A. Levinson, Ed., Pergamon Press, New York/London, 3, p. 2213, 1971.

"Jurassic Polar Movement Relative to North America", with M. G. Steiner, Journal of Geophysical Research, 77, no. 26, pp. 4981-4993, 1972.

"Paleomagnetic and Rockmagnetic Studies of the Permian Cutler and Elephant Canyon Formations, Utah", with W. A. Gose, Jour. Geophys. Res., 77, 8, 1534-1548, 1971.

"Evidence for an Ancient Lunar Magnetic Field", Proceedings of the Second Lunar Sci. Conf., Vol. 3, 2485-2490, The M.I.T. Press, 1971.

"Paleomagnetism of the Lower Triassic Moenkopi Formation", with M. B. Steiner, Bull. Geol. Soc. Am., V 85, 457-464, 1974.

"Magnetic Reversal Sequence in the Upper Portion of the Chinle Formation, Montoya, New Mexico", with S. C. Reeve, Bull. Geol. Soc. Amer., 82, no. 12, 1972.

"The Significance of the Magnetism Observed in Lunar Rocks", The Moon, An International Journal of Lunar Studies, (Ed. Hannes Alfven, Zdenek Kopal, and Harold C. Urey), 1972.

"Paleomagnetism of 1140 to 1150 Million-Year Diabase Sills from Gila County, Arizona", with Henry Spall, Jour. Geophys. Res., 77, no. 11, pp. 2115-2128.

"Remanent Magnetization of A Long Core from the Moenkopi Formation", with Czang-go Baag, Bull. Korean Geological Soc., 60th Birthday Memorial Edition of Prof. Chi-Mu Son.

"Geomagnetic Secular Variation Model E", with Czang-go Baag, in press Journal of Geophysical Research, 1974.

"Remanent Magnetization of a 50m Core from the Moenkopi Formation, Western Colorado", with Czang-go Baag, Geophysical Journal of the Royal Astrological Society, 37, 245-262, 1974.

"Evidence for Penecontemporaneous Magnetization of the Moenkopi Formation", with C. Baag, Journal of Geophysical Research, 79, 3308-3320, 1974.

"Reproducible Anomalous Upper Triassic Magnetization", with M. B. Steiner, Geology, 2, 191-194, 1974.

"Magnetic Polarity Sequence of the Upper Triassic Kayenta Formation", with M. B. Steiner, Geology 2, 195-198, 1974.

"Paleomagnetic Results from the Upper Triassic of East Greenland", with S. C. Reeve, D. Leythauser and K. Bay, JGR 79, 3302-3307, 1974.

"Shape Analysis of Paleosecular Variation Data with C. Bagg, JGR, in press 1974.

"P Travel Times for an Oceanic Path" with A. L. Hales and J. Nation, JGR 75 7362-7381, 1970.

"Are Lunar Rilles Inverted Eskers" GSA Memoir #132 661-668, 1972.

"Jurassic Polar Movement Relative to North America" JGR 77 4891-4993, 1972.

PUBLICATIONS (continued)

"Paleomagnetism of the Lower Triassic Moenkopi Formation", with M. B. Steiner, GSA Bull 85, 457-464, 1974.
"Reverse Pattern and Apparent Polar Wander for the Upper Jurassic" with M. B. Steiner submitted to GSA Bull. 1974.
"Late Jurassic Magnetic Polarity Sequence" with M. B. Steiner, submitted to GSA Bull. 1974.

PRESENTATIONS AT NATIONAL MEETINGS

"Remanent Magnetism of Some Jurassic Red Limestrones from the Alps", (A) American Geophysical Union, 1962.
"Paleomagnetic Results from Precambrian Rocks of Central Arizona and Duluth, Minnesota", (abstract) Trans. Amer. Geophys. Un., 46, 1, p. 67, 1965.
"A Compilation of Paleomagnetic Investigations of Rocks from North America", with H. R. Spall, Trans. A.G.U., 47, 1, March 1966.
"Normal and 'Anomalous' Paleomagnetic Results from the Tertiary and Recent Lavas of Israel", (abstract) with Amos Nur, Trans. Am. Geophys. U., 48, 1, p. 82, 1967.
"Paleomagnetism of Cretaceous Rocks from North America", (abstract) Trans. Am. Geophys. U., 48, 2, p. 73, 1967.
"Paleomagnetic Evidence for Time-Transgressive Lithologic Units in Moenkopi Formation", (abstract) Trans. A.G.U., 50, p. 607, 1969.
"Secular Variation in the Lower Triassic Moenkopi Formation", (abstract) with M. B. Steiner, Trans. A.G.U., 52, 4, pp. 189, 1971.
"Remanent Magnetization of a Long Core from the Moenkopi Formation", (abstract) with C. Baag, Trans. A.G.U., 1971.

OUTSIDE ACTIVITIES

Chairman, JOIDES Gulf Advisory Subpanel 1970-
Member, NSF Advisory Panel, Earth Sciences 1971-1974
Member, Board of Trustees, GURC 1973-
Member, IASPEI Crustal Seismology Group 1973-
Member, IUGS Subcommission on The Magnetic Polarity Time Scale 1972-
Correspondent, U. S. Geodynamics Committee 1973-
Reporter, Magnetic Problems, U. S. Geodynamics Committee 1974-
Member, COCORP Site Selection Committee 1974-

CONTRACTS AND GRANTS

National Science Foundation Grant #GP-2205, "The Spatial Relationships of the Earth's Major Surficial Features During Portions of Cretaceous Time", October 1, 1963 to September 30, 1965, $49,000.

National Science Foundation Grant #GP-590, "Paleomagnetism of Cretaceous Rocks", August 1, 1966 to July 31, 1967, $34,500.

National Science Foundation Grant #1304, "Paleomagnetism of Paleozoic and Late Precambrian Rocks", October 1, 1967 to September 30, 1968, $30,000.

CONTRACTS AND GRANTS (continued)

National Science Foundation Grant #GA15999, "Paleomagnetic Studies of Continuous Stratigraphic Sequences of Paleozoic and Mesozoic Age", October 1, 1969 to September 30, 1971, $80,000.

National Science Foundation Grant #GA15999, Amtd. #1, "Paleomagnetic Studies on Stratigraphic Sequences of Paleozoic and Mesozoic Ages from Western U. S., November 1, 1971 to July 31, 1974. $80,000.

Southern Methodist University (Am. Chem. Soc.) Grant No. PRF 1829-A-2, "A Study of the Paleomagnetism of Permian and Precambrian Rocks in North America", June 1, 1964 to August 31, 1966, $18,335.

NASA/Manned Spacecraft Center Contract NAS9-8767, "Investigation of the Maximum Magnetic Field Ever Present on the Moon", July 1, 1968 to January 31, 1971, $82,714.

NASA/Manned Spacecraft Center Contract NGR 44-004-117, "Evidence of an Ancient Lunar Magnetic Field, February 1, 1971 to March 31, 1973. $35,000.

National Science Foundation Grant #GA41698, "A Land Sea Seismic Refraction Experiment Along the South Coast of Mexico", February 1, 1974 to January 31, 1975. $16,100.

Atomic Energy Commission Contract No. AT(05-1)1629, "Application of Paleomagnetic Methods to the Detection of Epigenetically Altered Sediments Associated with Uranium Ore Deposits in the Morrison Formation", May 1, 1974 to April 30, 1975, $14,749.

National Science Foundation Grant No. GA43299, "Paleomagnetic Studies on Stratigraphic Sequences of Paleozoic and Mesozoic Ages from North America", August 1, 1974 to July 31, 1976. $82,300.

Chevron Oil Field Research Grant #17-72, "Paleomagnetic Research", July 10, 1972 to June 30, 1975, $7,500.