STATEWIDE GEOTHERMAL RESOURCE ASSESSMENT

Circular C-103

State of Hawaii
DEPARTMENT OF LAND AND NATURAL RESOURCES
Division of Water and Land Development

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Division of Water and Land Development

Honolulu, Hawaii
September 1984

GEORGE R. ARIYOSHI
Governor

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Division of Water and Land Development

Honorable Susumu Ono, Chairperson
Board of Land and Natural Resources
State of Hawaii
Honolulu, Hawaii

Dear Mr. Ono:

Transmitted herewith for your consideration is the Statewide Geothermal Resource Assessment report prepared in response to your charge that the Technical Committee review available information and recommend areas in the State where geothermal resources might be available for electrical power generation.

The report makes a statewide, county-by-county assessment of Hawaii's potential geothermal resource areas, based on currently available geotechnical information.

Presented are the Committee's recommendations for high temperature geothermal resource areas having the potential for electrical power generation. High temperature is defined to be greater than 125 degree celsius (250 degree fahrenheit) at depths less than 3 kilometers (9800 feet). These areas have been mapped and identified as potential geothermal resource areas. Also identified in the assessment process were low temperature (less than 125 degree celsius) geothermal resource areas. Further research may be directed in these areas to determine the availability of geothermal resources for future consideration in identifying potential geothermal resource areas.

The Committee has completed its work in time for initiating impact analysis by the Department of Land and Natural Resources and will continue to be available to assist the Department throughout the process of designating geothermal resource subzones.

Respectfully submitted,

Manabu Tagomori, Chairman

Donald Thomas, Technical Leader

Bill Chen

Daniel Lum

Dallas Jackson

Richard Moore

James Kauahikaua

John Sinton

ACKNOWLEDGMENT

The Geothermal Resources Technical Committee acknowledges the assistance of the individuals listed below who provided geotechnical information, participated in technical sessions, and assisted in field visits of sites by the Committee.

BILL CRADDICK	Barnwell Geothermal Corporation
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REGGIE OKAMURA	Hawaiian Volcano Observatory
C. PARDEE ERDMAN	Ulupalakua Ranch

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PREFACE

Act 296, Session Laws of Hawaii 1983, as amended by Act 151, SLH 1984, required that the Board of Land and Natural Resources examine various factors when designating subzone areas for the exploration, development, and production of geothermal resources. These factors include potential for production, prospects for utilization, geologic hazards, social and environmental impacts, land use compatibility, and economic benefits. The Department of Land and Natural Resources has prepared a series of reports which addresses each of the subzone designation factors. This report assesses the potential for production of geothermal energy throughout the State of Hawaii.

The Geothermal Resources Technical Committee, formed by the Department, has selected areas within the State which have the greatest potential to produce geothermal energy. The participation of the Committee members, who have volunteered their time and effort, is greatly appreciated.

This report was prepared by Dean Nakano, Geologist, with the assistance of Joseph Kubacki, Energy Specialist, and under the general direction of Manabu Tagomori, Chief Water Resources and Flood Control Engineer, Division of Water and Land Development, Department of Land and Natural Resources.

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SUMMARY

A Geothermal Resources Technical Committee was formed to assist the Department of Land and Natural Resources in locating geothermal resources for electrical power generation. Participants were selected on the basis of their expertise in the field of geothermal resources in Hawaii.

Technical Committee members met in a series of meetings held on the islands of Oahu, Maui and Hawaii to evaluate currently available geotechnical data relevant to the assessment and identification of potential geothermal resource areas.

The statewide geothermal resource assessment, as mandated by Act 296, SLH 1983, was made on a county-by-county basis and was based on a qualitative interpretation of regional surveys and available exploratory drilling data.

The Technical Committee has identified seven High Temperature and five Low Temperature Potential Geothermal Resource Areas that are listed below:

Potential Geothermal Resource Areas

High Temperature Resource Areas
(greater than 125°C at depths less than 3 km)

Area	Percent Probability
Haleakala S.W. Rift Zone, Maui	25% or less
Haleakala East Rift Zone, Maui	25% or less
Hualalai, Hawaii	35% or less
Mauna Loa S.W. Rift Zone, Hawaii	35% or less
Mauna Loa N.E. Rift Zone, Hawaii	35% or less
Kilauea S.W. Rift Zone, Hawaii	Greater than 90%
Kilauea East Rift Zone, Hawaii	Greater than 90%

Low Temperature Resource Areas
(less than 125°C at depths less than 3 km)

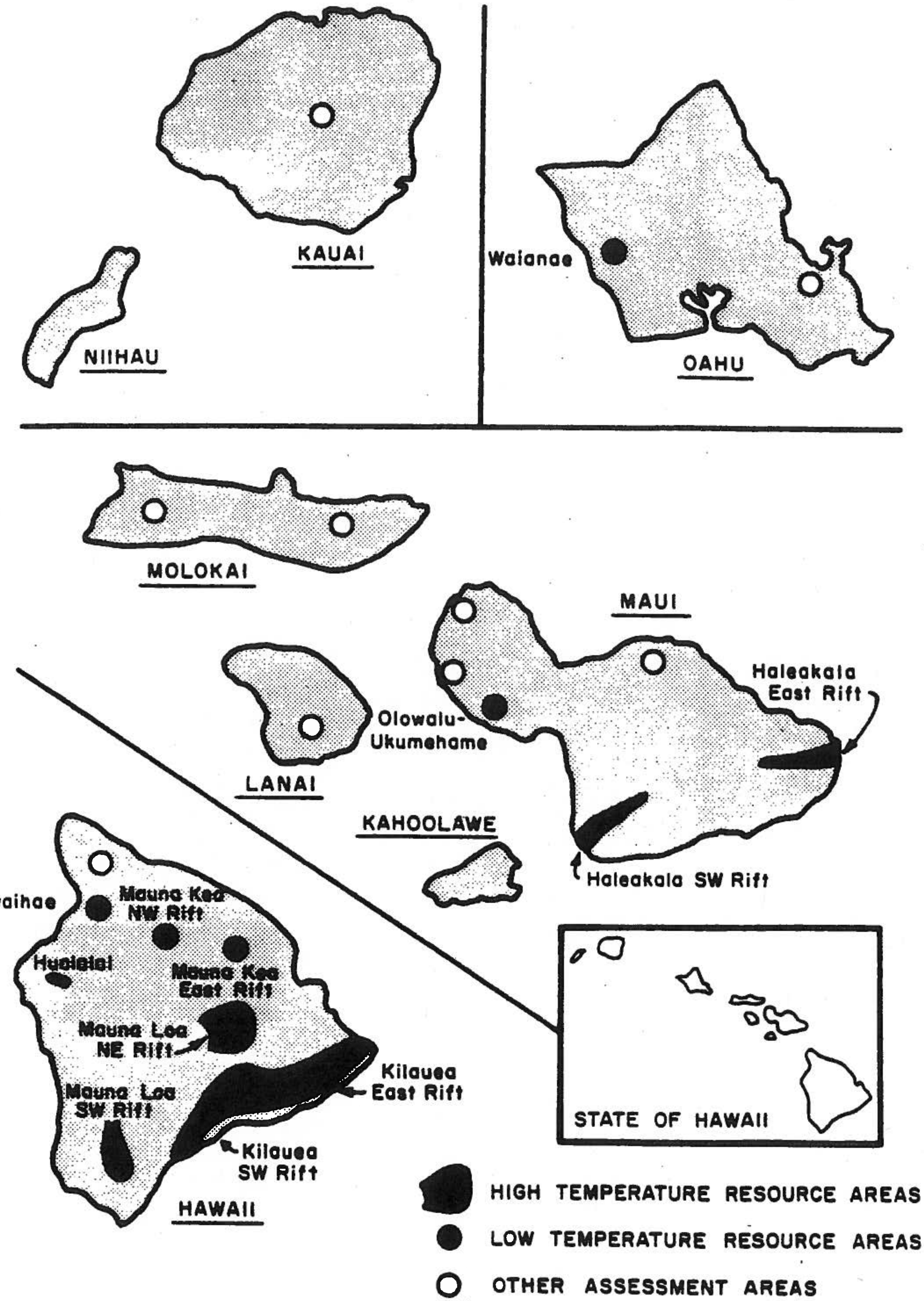
Area	Percent Probability
Waianae, Oahu	15% or less
Olowalu-Ukumehame, Maui	75% or less
Kawaihae, Hawaii	45% or less
Mauna Kea N.W. Rift Zone, Hawaii. . .	Less than 50%
Mauna Kea East Rift Zone, Hawaii . . .	Less than 30%

The selection of a high temperature resource area was based on the area's potential for production of electrical energy. The consensus of the Technical Committee was that present day technology requires a geothermal resource to have a temperature greater than 125°C at a depth of less than 3 km. Subsequent analysis of social, economic, environmental and hazards impacts will be conducted on these site specific areas.

Also identified were low temperature resource areas that have a number of feasible direct-heat applications and may warrant future research to re-evaluate their potential for high temperature electrical power generation.

These potential geothermal resource areas are identified on the following map.

STATEWIDE GEOTHERMAL RESOURCE ASSESSMENT



INTRODUCTION

The Board of Land and Natural Resources is charged with the responsibility of designating geothermal resource subzones in the State of Hawaii by Act 296, SLH 1983, signed into law on June 14, 1983 by Governor George R. Ariyoshi.

The statewide geothermal resource assessment is the first phase in the process of designating geothermal resource subzones on a county-by-county basis pursuant to the Plan of Study prepared by the Department of Land and Natural Resources.

Act 296, SLH 1983 mandated that this subzone work be done by utilizing available information. Therefore, this assessment phase will focus upon current geotechnical data, its interpretation and identification of potential geothermal resources areas on all of the major islands. The initial assessment based on the estimated percent probability of geothermal resources will be mapped to conclude this phase of the designation process.

GEOTHERMAL RESOURCES TECHNICAL COMMITTEE

The Department of Land and Natural Resources has selected a committee of technical experts who are closely associated with the field of geothermal research in the State of Hawaii. This Geothermal Resources Technical Committee upon evaluation of currently available information, has identified potential geothermal resource areas on a county-by-county basis.

The members of the Geothermal Resources Technical Committee were selected on the basis of their area of expertise and their availability to assist DLNR in the evaluation of technical data relevant to the identification of potential geothermal resource areas.

It should be noted that other technical experts were considered during the committee selection process, but due to individual problems in scheduling and the projected workload increase, those contacted declined DLNR's request for assistance.

A list of the participating committee members and their area of technical expertise is described below:

Mr. Manabu Tagomori Area of expertise: Engineering
Chief Water Resources and Flood Control Engineer
Division of Water and Land Development
Department of Land and Natural Resources

Dr. Donald Thomas Area of expertise: Geochemistry
Project Leader, Direct Heat Resources Assessment Project
Hawaii Institute of Geophysics, University of Hawaii

Dr. Bill Chen Area of expertise: Reservoir engineering
Project Manager, HGP-A Wellhead Generator Project
Participated in the Hawaii Geothermal Project as reservoir engineer.
University of Hawaii - Hilo

Mr. Dallas Jackson Area of expertise: Geology and Geophysics
Principle investigator for geoelectrical studies at HVO.
Participated in self-potential research related to geothermal resource.
U.S. Geological Survey, Hawaiian Volcano Observatory.

Dr. James Kauahikaua Area of expertise: Geophysics
Research includes geoelectrical studies such as resistivity surveys related to the identification of geothermal resource.
U.S. Geological Survey

Mr. Daniel Lum Area of expertise: Geology - Hydrology
Head, Geology and Hydrology Section
Division of Water and Land Development
Department of Land and Natural Resources

Dr. Richard Moore Area of expertise: Geology
Chief of "Geology and Petrology of Hualalai Volcano" project.
Research includes geological mapping and the study of geothermal potential on Hualalai and Kilauea Volcanoes.
U.S. Geological Survey, Hawaiian Volcano Observatory.

Dr. John Sinton Area of expertise: Geology
Participated in geological mapping studies for the preliminary State-wide Geothermal Assessment Program.
Hawaii Institute of Geophysics, University of Hawaii

A more detailed resume of each committee member can be found in Appendix C.

ASSESSMENT APPROACH AND CRITERIA

A series of committee meetings were scheduled during the Statewide Geothermal Resource assessment phase. The first organizational meeting addressed the provisions of Act 296, the administrative rules, plan of study, and the assessment of available information. The committee members were asked to review the bibliography of available information to see if any significant literature had been omitted. It was also agreed that official notice be given to all newspaper agencies inviting the public to submit any additional data relevant to the assessment of potential geothermal resource. Subsequent committee meetings were scheduled to evaluate each island's potential for geothermal resource on a county-by-county basis. The following is a list of the Geothermal Resources Technical Committee meetings:

Date	Place
March 16, 1984	Honolulu, Hawaii
March 30, 1984	Maui, Hawaii
April 9, 1984	Honolulu, Hawaii
April 18, 19, 1984	Hilo, Hawaii
April 23, 1984	Honolulu, Hawaii
May 11, 1984	Honolulu, Hawaii
June 8, 1984	Honolulu, Hawaii

Due to the complexity of Hawaii's geologic structure and the variable nature of groundwater hydrology and geochemistry, the committee did not rely on just one set of data or a single set of rules. Therefore, the assessment of potential for each island was based on a qualitative interpretation of several regional surveys conducted in Hawaii during the last 15 to 20 years and any available deep exploratory drilling data. It was further noted that the use of probability ranges was more appropriate in assessing geothermal resource, in that probabilities would be more accurate than other subjective wording.

The committee's assessment was based on the following types of geological, geophysical and geochemical data:

1. Groundwater temperature data. Near surface water having temperatures significantly above ambient, indicative of a possible nearby geothermal reservoir.

2. Geologic age. Recent eruptive activity and the evidence of surface features such as rift zones, calderas, vents and active fumaroles.

3. Geochemistry. Groundwater having geochemical anomalies related to the interaction between high temperature rock and water. Some of the indicators of thermally altered groundwater are anomalously high silica (SiO_2), chloride (Cl) and magnesium (Mg) concentrations. In addition, the evidence of above normal concentrations of trace and volatile elements such as mercury (Hg) and radon (Rn) may indicate leakage of geothermal fluids into nearby rock structures.

4. Resistivity. The electrical resistivity of the subsurface rock formation is affected by the salt content and temperature of circulating groundwater. Therefore rocks saturated with warm saline groundwater have lower resistivities than rocks saturated with colder groundwater.

5. Infrared surveys. Infrared studies of land surface and coastal ocean water can identify thermal spring discharges and above ambient ground temperatures.

6. Seismic. Seismic monitoring of the frequency and clustering of earthquakes can identify earthquake concentrations that may be related to geothermal systems.

7. Magnetics. Aeromagnetic surveys have identified magnetic anomalies associated with buried rift zones and calderas. Also, rocks at high temperature or those that have been thermally altered, have substantially different magnetic properties than normal rock strata.

8. Gravity. Gravity surveys can provide information on the location of subsurface structural features such as dense intrusive bodies and dike zones.

9. Exploratory drilling. Data acquired from deep exploratory wells can confirm the existence of high temperatures and determine if there is adequate permeability necessary for development.

10. Self potential. Self potential anomalies (natural voltages at the earth's surface) have been found to be highly correlated with subsurface thermal anomalies along the Kilauea east rift.

A more in-depth description of the various types of geothermal exploration techniques can be referred to in the earlier DLNR report titled, "Assessment of Available Information Relating to Geothermal Resources in Hawaii", Circular C-98.

STATEWIDE RESOURCE ASSESSMENT

The preliminary phase in the Designation of Geothermal Resource Subzones is the determination of Potential Geothermal Resource Areas on a county-by-county basis. Upon evaluation of currently available geotechnical data, the Geothermal Resources Technical Committee identified the location and percent probability of finding Low Temperature (less than 125°C) Resources and High Temperature (greater than 125°C) Resources at depths less than 3 km.

A county-by-county listing of the areas that were evaluated and the committee's conclusions follows:

HAWAII COUNTY

Kawaihae:

On the basis of groundwater temperature and chemical anomalies and the resistivity interpretation indicating the presence of an intrusive body associated with the Puu Loa cinder cone; and taking into consideration the geologic age of this vent, the following probabilities are estimated:

- o 45% or less chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- o Less than 10% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

Hualalai:

Based on positive geothermal indications from geophysical data (resistivity, magnetics, and self potential) and the geologically young age of vents along the upper rift and summit, the following probabilities are estimated:

- o 70% or less chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- o 35% or less chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

Mauna Loa Southwest Rift:

On the basis of recent historic volcanic eruptions, seismic activity and taking into consideration the absence of any other significant geophysical or geochemical anomalies, the following probabilities are estimated:

- o 60% or less chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- o 35% or less chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

It should be noted that due to the limited amount of data, additional studies are warranted in the future in order to update our current assessment.

Mauna Loa Northeast Rift:

On the basis of geochemical and geophysical data for the lower rift near the vicinity of Mountain View and Keaau, it is unlikely that a geothermal resource would be found.

While upper-elevation seismic and self potential data and the recent 1984 Mauna Loa eruption indicate a geothermal resource, it should be noted that current drilling technology limits development to elevations of less than 7,000 feet above sea level. Based on available data the following probabilities are estimated:

- o 60% or less chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- o 35% or less chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

Kohala:

On the basis of the limited amount of geochemical and geophysical data, the geologic age of the Kohala volcano, and the fact that no significant anomalies were observed, the following probabilities are estimated:

- Less than 10% chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- Less than 5% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

It was noted by the Committee that, due to the limited amount of information, future studies are warranted in order to update our current assessment.

Mauna Kea Volcano:

Strictly on the basis of geologic age and one groundwater temperature anomaly recorded at Waikii well No. 5239-01, the following probabilities are estimated:

Mauna Kea Northwest Rift Zone:

- Less than 50% chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- Less than 20% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

Mauna Kea East Rift Zone:

- Less than 30% chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- Less than 10% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

It is noted again, that due to the limited amount of available data, further studies are warranted in the future to update our current assessment.

Kilauea Southwest Rift:

On the basis of positive geophysical data, recent volcanic activity, and consideration given to the absence of any significant groundwater chemical anomalies, the following probabilities were concluded:

- Greater than 90% chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- Greater than 90% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

It should be noted than although the majority of the southwest rift zone is situated within the Hawaii Volcanoes National Park and is therefore off-limits to geothermal development, the potential for geothermal resource of the entire Kilauea Southwest Rift Zone was assessed by the Committee.

Kilauea East Rift:

Currently available studies indicate that a geothermal resource is present along the entire length of the Kilauea East Rift Zone. Commerically feasible quantities of steam have been confirmed by deep exploratory drilling on the lower rift zone. Therefore, on the basis of positive geochemical and geophysical data and the recent eruptive and intrusive activity along the Kilauea East Rift Zone, the following probability is estimated:

- Greater than 90% chance of finding a low temperature (50-125°C) and high temperature (greater than 125°C) resource at depths less than 3 km.

MAUI COUNTY

Olowalu-Ukumehame Canyon:

Based on currently available data (groundwater temperature, resistivity, magnetics, groundwater chemistry and rift zone structure) that can identify geophysical and geochemical anomalies, and taking into consideration the geologic age of West Maui, the following probabilities are estimated:

- 75% or less chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- Less than 15% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

Lahaina-Kaanapali:

Based on the absence of any positive geochemical or geophysical data indicating above ambient subsurface temperatures, the following probability was concluded:

- Less than 5% chance of finding a low (50-125°C) or high (greater than 125°C) temperature resource at depths less than 3 km.

Honolua:

Due to the limited amount of data for the Honolua area and the absence of any positive geophysical or geochemical anomalies, the following probability was concluded:

- Less than 5% chance of finding a low (50-125°C) or high (greater than 125°C) temperature resource at depths less than than 3 km.

Haleakala Southwest Rift:

On the basis of currently available data, there is no direct evidence of warm water. However, based on the historic 1790 eruption and results of deep resistivity soundings, the following probabilities were concluded:

- o 35% or less chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- o 25% or less chance of finding high a temperature (greater than 125°C) resource at depths less than 3 km.

Haleakala Northwest Rift:

Based on the absence of any significant geochemical or geophysical anomalies other than a weak resistivity anomaly, and due to the geologic age of the last eruption, the following probabilities were concluded:

- o Less than 10% chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- o Less than 5% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

Haleakala East Rift:

The limited amount of available data did not identify any significant anomalies; however, based on the geologic age of the Hana Series lava flows, the following probabilities for the Haleakala East Rift Zone were concluded:

- o 35% or less chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- o 25% or less chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

Molokai and Lanai:

On the basis of currently available data and the absence of any positive geophysical or geochemical anomalies, the probability of a geothermal resource is as follows:

- o Less than 5% chance of finding a low (50-125°C) or high temperature (greater than 125°C) resource at depths less than 3 km.

However, additional studies are warranted in the future in order to update our current assessment.

CITY AND COUNTY OF HONOLULU

Waianae Volcano:

On the basis of geologic age and weak resistivity, groundwater temperature, and geochemical anomalies, the probabilities for a geothermal resource are estimated as follows:

- 15% or less chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- Less than 5% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

Koolau Volcano:

Due to the geologic age of the Koolau Volcano and the absence of any significant geochemical, self potential, magnetic or resistivity anomalies, the following probabilities were concluded:

- Less than 10% chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- Less than 5% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

KAUAI COUNTY

Kauai:

On the basis of currently available information, the geologically old age of Kauai's volcanic activity and the absence of any significant geothermal related anomalies, the probabilities for a geothermal resource are as follows:

- Less than 5% chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- Less than 5% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

Minutes of the Geothermal Resources Technical Committee meetings provide a more detailed analysis of the statewide assessment and can be referred to in Appendix B.

A complete list of the percent probabilities for potential High and Low Temperature Geothermal Resource Areas in the State of Hawaii is presented on a county-by-county basis below:

PERCENT PROBABILITIES
(County-by-County)

Island/Area	High Temperature (greater than 125°C at depths less than 3 km)	Low Temperature (less than 125°C at depths less than 3 km)
KAUAI	Less than 5%	Less than 5%
OAHU		
Waianae	Less than 5%	15% or less
Koolau	Less than 5%	Less than 10%
MOLOKAI	Less than 5%	Less than 5%
LANAI	Less than 5%	Less than 5%
MAUI		
Olowalu-Ukumehame	Less than 15%	75% or less
Lahaina-Kaanapali	Less than 5%	Less than 5%
Honolua	Less than 5%	Less than 5%
Haleakala S.W. Rift	25% or less	35% or less
Haleakala N.W. Rift	Less than 5%	Less than 10%
Haleakala East Rift	25% or less	35% or less
HAWAII		
Kawaihae	Less than 10%	45% or less
Hualalai	35% or less	70% or less
Mauna Loa S.W. Rift	35% or less	60% or less
Mauna Loa N.E. Rift	35% or less	60% or less
Kohala	Less than 5%	Less than 10%
Mauna Kea N.W. Rift	Less than 20%	Less than 50%
Mauna Kea East Rift	Less than 10%	Less than 30%
Kilauea S.W. Rift	Greater than 90%	Greater than 90%
Kilauea East Rift	Greater than 90%	Greater than 90%

POTENTIAL GEOTHERMAL RESOURCE AREAS

The conclusions of the Technical Committee demonstrated that no single geothermal exploration technique, except for exploratory drilling, is capable of positively identifying a subsurface geothermal system, instead it is based on several methods resulting in an estimate of geothermal potential for a given area.

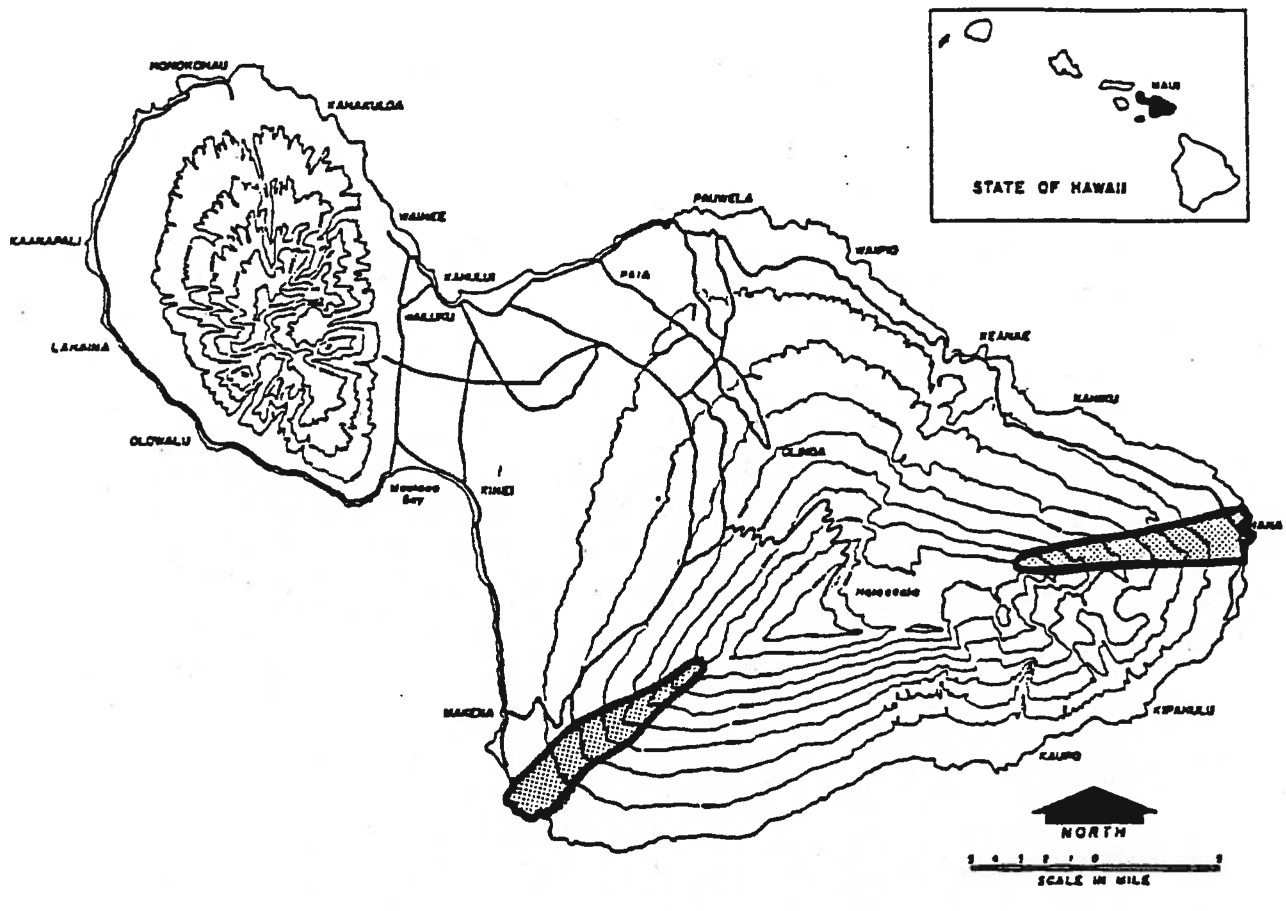
The results of the technical committee's evaluation of currently available data provides an estimate of percent probability for high temperature (greater than 125°C) and low temperature (less than 125°C) geothermal resources.

The key criterion in the preliminary subzone designation is the assessment of an area's geothermal potential for production of electrical energy, as mandated by Act 296. The consensus of the technical committee was that current technology would require the resource to have a temperature greater than 125°C at a depth of less than 3 km.

One of the most important conditions in a productive geothermal system is a permeable zone that permits adequate recharge of water to the reservoir. This criterion was not addressed during the resource assessment process, since only exploratory drilling and flow testing of deep exploratory wells can confirm the nature of the aquifer.

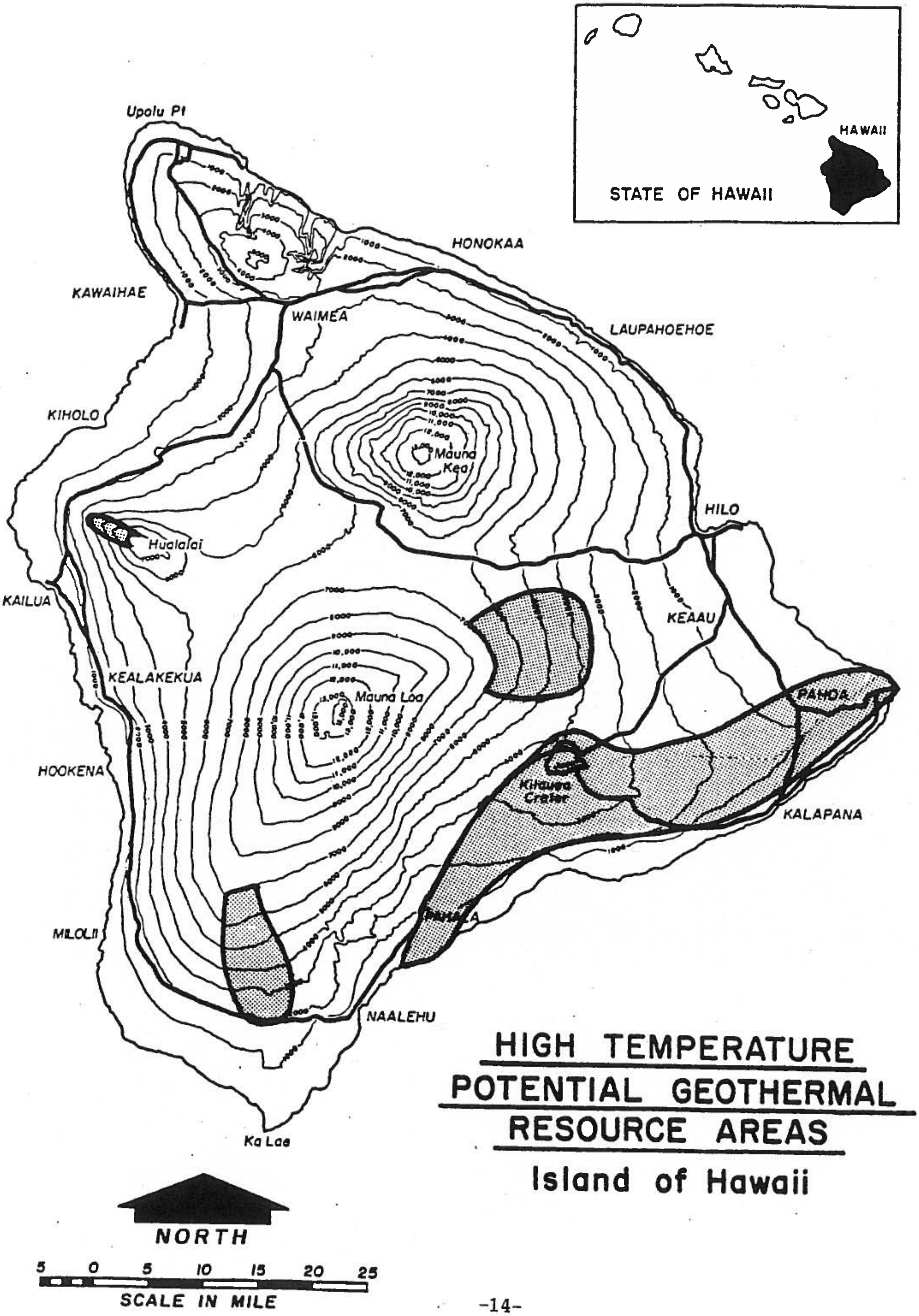
Upon evaluation of the data and review of the list of percent probabilities, the technical committee identified seven High Temperature Potential Geothermal Resource Areas. The criterion for selection of high temperature resource areas was agreed to be those areas having an assessed probability of at least 25% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

Two location maps for the island of Maui and Hawaii and a list of these High Temperature Potential Geothermal Resource Areas follows:



HIGH TEMPERATURE POTENTIAL GEOTHERMAL RESOURCE AREAS

Island of Maui



HIGH TEMPERATURE POTENTIAL GEOTHERMAL RESOURCE AREAS

Island of Hawaii

High Temperature Potential Geothermal Resource Areas
(greater than 125°C at depths less than 3 km)

	Percent Probability
Maui:	
Haleakala S.W. Rift Zone	25% or less
Haleakala East Rift Zone	25% or less
Hawaii:	
Hualalai	35% or less
Mauna Loa S.W. Rift Zone	35% or less
Mauna Loa N.E. Rift Zone	35% or less
Kilauea S. W. Rift Zone	Greater than 90%
Kilauea East Rift Zone	Greater than 90%

On the basis of the committee's conclusions and the specific provision for electrical power generation set forth in Act 296, these seven High Temperature Potential Geothermal Resource Areas were identified and mapped. The technical members agreed that equal weight would be given to all positive data and the probability areas mapped would be below the 7000-foot elevation due to the limits of current drilling technology.

The use of dashed lines in identifying certain Potential Geothermal Resource Areas indicated that mapping was based on a limited amount of data. The committee could not scientifically justify using a solid line to clearly locate certain resource areas on the basis of such sparse data. The use of a solid line to draw a boundary of percent probability was restricted to those resource areas having a substantial data base upon which to make a decision as to the location of the resource.

Site location and sectional maps of Maui (scale 1"= 1 mile) and Hawaii (scale 1" = 2 miles) showing High Temperature Potential Geothermal Resource Areas and the boundary lines of percent probability are included in Appendix B (meeting No. 6).

OTHER GEOTHERMAL RESOURCE AREAS

Low Temperature Potential Geothermal Resource Areas, although not yet viable for electrical energy production based on current geothermal utilization technology, have a number of feasible direct-heat applications. Marketing opportunities for geothermal heat in the near future will be dependent upon the identification of low temperature resource areas. In addition, future site-specific surveys are warranted in these areas to re-evaluate their potential for high temperature electrical power generation.

The Geothermal Resources Technical Committee identified twelve Low Temperature Potential Geothermal Resource Areas. The basis for selection was agreed to be those areas having an assessed probability of at least 15% chance of finding a low temperature (less than 125°C) resource at depths less than 3 km. A list of five selected areas and a location map follows:

Low Temperature Potential Geothermal Resource Areas
(less than 125°C at depths less than 3 km)

Statewide	Percent Probability
Waianae, Oahu	15% or less
Olowalu-Ukumehame, Maui	75% or less
Kawaihae, Hawaii	45% or less
Mauna Kea N. W. Rift, Hawaii	Less than 50%
Mauna Kea East Rift, Hawaii	Less than 30%

Note: Not included in the list are the seven High Temperature Potential Geothermal Resource areas that also have low temperature potential.

A brief abstract of various types of direct-heat applications for geothermal energy follows:

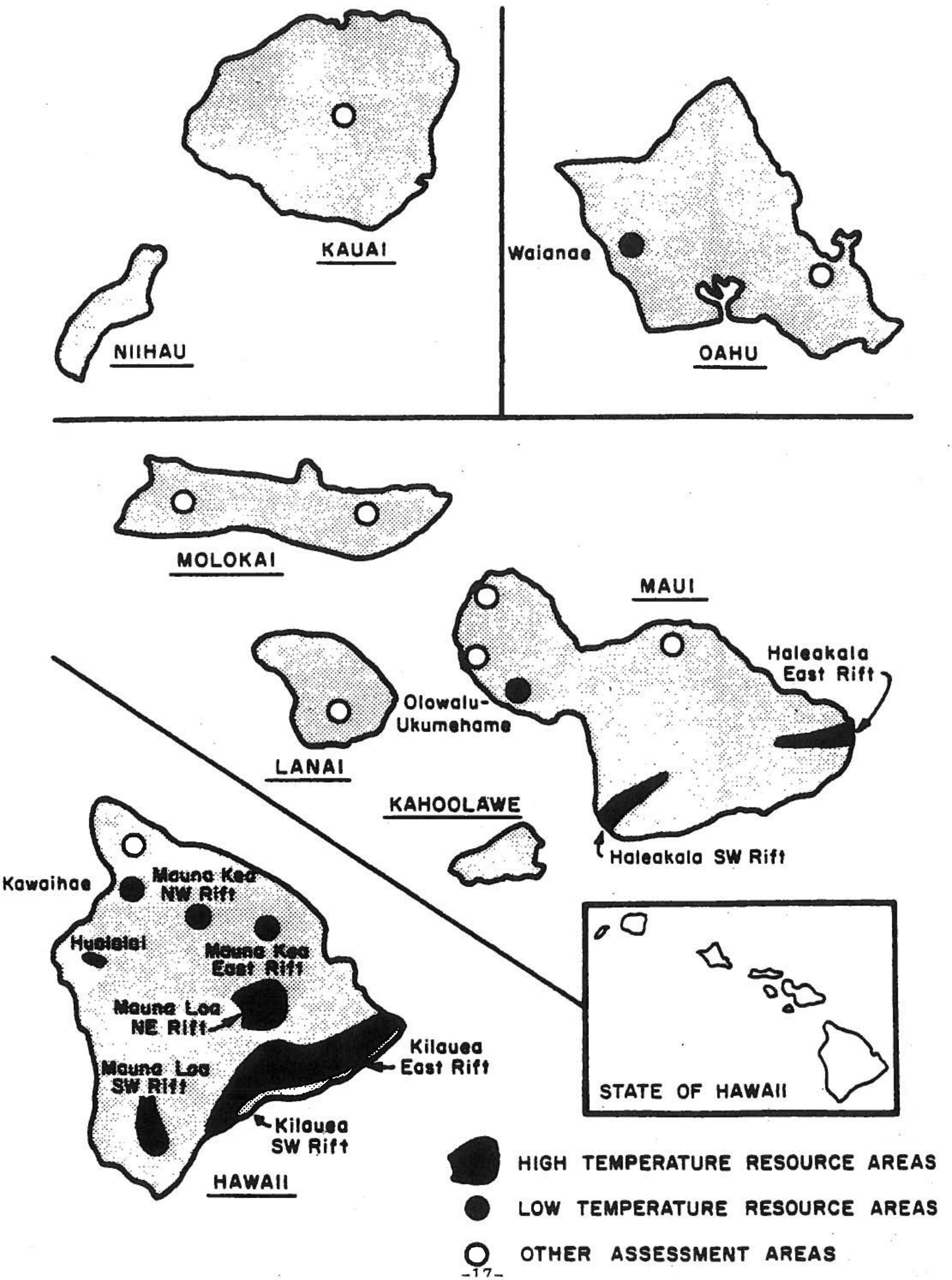
Tourism/spa:

The visitor trade may find a market for geothermal resources in the form of spas or the heating and cooling of hotel complexes.

Agriculture:

The processing of sugarcane and the heating of greenhouses and poultry operations could benefit from direct heat utilization.

STATEWIDE GEOTHERMAL RESOURCE ASSESSMENT



Food Processing:

The use of a moderate temperature resource in the processing of fruits and vegetables is another possible market in Hawaii. The food processing industry could utilize geothermal energy for the processing of macadamia nuts, coffee, guava, papaya and bananas.

Aquaculture:

Aquaculture activities can benefit from low temperature resources. Geothermal fluids can be used to maintain optimum growing temperatures for farming operations.

Existing activities that are not energy-intensive may be able to use waste heat produced during electrical power generation. Multiple applications of direct-heat may reduce some of the costs and result in a more efficient use of geothermal energy.

CONCLUSIONS

The results of the Statewide Geothermal Resource Assessment has identified several areas in the State of Hawaii that may have significant geothermal potential. Evaluation and identification of these potential geothermal resource areas were based on currently available information on geology, geophysics, geochemistry and deep exploratory drilling data.

A committee of technical experts was selected, on the basis of experience and area of expertise, to identify and provide an estimate of the percent probabilities for finding high temperature (greater than 125°C) and low temperature (less than 125°C) geothermal resources at depths less than 3 km.

The findings of the committee resulted in the identification of seven High Temperature and five Low Temperature Potential Geothermal Resource Areas. These areas and their respective percent probability are presented as follows:

Location	High Temp. Resource	Low Temp. Resource
Hawaii County:		
1) Hualalai	35% or less	70% or less
2) Mauna Loa S.W. Rift	35% or less	60% or less
3) Mauna Loa N.E. Rift	35% or less	60% or less
4) Kilauea S.W. Rift	Greater than 90%	Greater than 90%
5) Kilauea East Rift	Greater than 90%	Greater than 90%
6) Kawaihae	--	45% or less
7) Mauna Kea N.W. Rift	--	Less than 50%
8) Mauna Kea East Rift	--	Less than 30%
Maui County:		
9) Haleakala S.W. Rift	25% or less	35% or less
10) Haleakala East Rift	25% or less	35% or less
11) Olowalu-Ukumehame	--	75% or less
City and County of Honolulu:		
12) Waianae	--	15% or less

The Statewide Geothermal Resource Assessment is the first phase in the plan of study for Designating Geothermal Resource Subzones, and these first-cut subzones based solely on the availability of geothermal resources capable of electrical power generation have been mapped. Subsequent analysis of social, economic, environmental and hazards impacts will be conducted on these site specific areas having significant potential for the production of electricity from geothermal energy.

APPENDIX A

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APPENDIX B

MINUTES OF TECHNICAL COMMITTEE MEETINGS

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

SUSUMU ONO, CHAIRMAN
BOARD OF LAND & NATURAL RESOURCES
EDGAR A. HAMASU
DEPUTY TO THE CHAIRMAN

DIVISIONS:
AQUACULTURE DEVELOPMENT PROGRAM
AQUATIC RESOURCES
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FORESTRY AND WILDLIFE
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF WATER AND LAND DEVELOPMENT
P. O. BOX 373
HONOLULU, HAWAII 96809

Agenda

Geothermal Resource Subzone Technical Committee Meeting

March 16, 1984

Part I: 9:00 am to 12:00 Noon - Room 227, Kalanimoku Building
Session Leader: Manabu Tagomori

- Call to order
- Introductions
- Purpose and scope of work
- Committee meetings
- Administrative matters
- Review Plan of Study
- Review resource assessment of available information

Part II: 1:30 to 3:30 pm - HIG, University of Hawaii
Session Leader: Dr. Donald Thomas

- Geothermal Resources of Hawaii (map)
- Contribution by members
- Summary of discussions
- Directions for future meetings

MINUTES
(Amended)

Geothermal Resources Technical Committee
Meeting No. 1

Date: March 16, 1984

Time: 9:30 am - 12:00 Noon; 1:30 pm - 4:00 pm

Place: Div. of Water & Land Development Conference Room (morning); Hawaii Institute of Geophysics (afternoon).

Participants:

Manabu Tagomori, Chairman, DOWALD (548-7619)
Donald Thomas, Technical Leader, HIG (948-6482)
Dan Lum, DOWALD (548-7643)
Jim Kauahikaua, USGS-Honolulu (546-8331)
John Sinton, HIG (948-7751)
Dallas Jackson, HVO (967-7328)
Dick Moore, HVO (967-7328)
William Chen, UH-Hilo (not present)
Joe Kubacki, DOWALD (548-7466)
Dean Nakano, DOWALD (548-7541)

Agenda is attached.

Morning

Manabu Tagomori called the meeting to order and addressed all points listed in agenda. Manabu, with staff assistance, reviewed the provisions of Act 296, SLH 1983, the administrative rules; plan of study; assessment of available information; public participation program; and a report on geothermal resource developments.

Don Thomas suggested that committee members read the DOWALD assessment of available information to see if any significant literature was omitted. It was also suggested that newspaper notice be given to the public inviting them to submit any pertinent literature.

The key criteria in the preliminary subzone designation is assessing an area's geothermal potential for production of electricity. It was agreed that current technology would require the resource to have a temperature of more than 125°C at a depth of less than 3 km.

Don Thomas is to supply the committee with his latest HIG report assessing Hawaiian Geothermal resources.

Committee members may be asked to participate in a public informational meetings.

Afternoon

The meeting was reconvened by Don Thomas, the committee technical leader. Dates, locations, and topics of future meetings were scheduled.

Date	Place	Topic of Discussion
March 16 (Fri.)	Honolulu	Scope of work, administrative matters, assessment of Kauai, Oahu, Molokai, Lanai
March 30 (Fri.)	Maui	Assessment of west Maui and east Maui
April 6 (Fri.)	Honolulu	Assessment of Big Island, including Hualalai, Kawaihae, South Point, and Kilauea's SW rift zone
April 19 (Thurs)	Hawaii	Assessment of Kilauea's east rift zone
May 4 (Fri.)	Honolulu	Assessment review session

Travel and accommodations is to be arranged by Dean Nakano.

The above schedule is subject to change depending on the pace of the assessment process and other commitments of committee members.

It was suggested that the first of two public informational meetings be scheduled between April 19 and May 4, possibly April 23 or 24. Two meetings each will be held on both Maui and the Big Island.

It was agreed that the use of probability ranges was appropriate in assessing resource areas. Probabilities, though not precise, would be less ambiguous than other subjective wording. Groundwater temperatures were determined to be the most significant surface indicator of geothermal resources in most cases.

I. ASSESSMENT OF KAUAI

Groundwater Temperature. No significant data indicating above ambient temperatures.

Geologic Age. Earlier island building activity 5.6 to 3.3 million years ago (mya); post erosional activity 1.4 to 0.6 mya.

Geochemistry. Some ground water anomalies have been noted but are likely to be caused by facts other than geothermal, e.g. irrigation return.

Resistivity. No significant data.

Infrared Surveys. No significant data.

Gravity/Magnetic. Available data pertinas to identification of deep structural features (Krivoy, 1965; Malahoff and Woolard, 1965).

Seismic. No significant data.

Exploratory Drilling. No deep exploratory well data available.

Self Potential. No significant data.

KAUAI CONCLUSION:

On the basis of available data, the geologic age of Kauai's volcanic activity and the absence of any significant geothermally related anomalies, the probabilities of a geothermal resource are as follows:

- Less than 5% chance of finding low temperature (50-125°C) resource at depths less than 3 km.

- Less than 5% chance of finding high temperature (greater than 125°C) resource at depths less than 3 km.

II. ASSESSMENT OF OAHU

A. Waianae Volcano

Groundwater Temperature. Weak anomaly noted at well 2808-01 where the temperature of dike impounded water is 27°C. Temperatures in nearby wells are about 19°C.

Geologic Age. The main shield building volcanism on Waianae has been dated about 2.4 million years old. Post erosional activity has occurred but no shallow magma chamber is associated with the Waianae Volcano.

Geochemistry. Some anomalous concentrations of sulfate and calcium at well 2808-01. Radon and mercury anomalies give some indication of fracture zones.

Resistivity. Some low resistivity anomalies, but inconclusive as to presence of geothermal resource.

Infrared Surveys. No significant data.

Seismic. Some seismic studies considered (Furumoto, 1970) but inconclusive as to presence of geothermal resource.

Gravity/Magnetic. Available data pertains to the identification of deep structural features (Malahoff, 1965; Strange, et al, 1965).

Exploratory Drilling. Reference is made to 3 deep wells (800 ft., 1000 ft. and 1200 ft. depths) but no significant data is available (Macdonald and Abbott, 1970; Stearns, 1935).

Self Potential. Available data has no positive indications of geothermal resource (Grose and Keller, 1975).

B. Koolau Volcano

Groundwater Temperature. Slight temperature anomalies noted in 2 wells. Well No. 2043-01 (30°C) and Well No. 2042-05 (30°C).

Geologic Age. Post-erosional volcanism occurred until possibly 30,000 years ago.

Geochemistry. Available data has no positive indications of geothermal resource.

Resistivity. Available data has no positive indications of geothermal resource.

Infrared Surveys. No significant data.

Seismic. Data suggests that the Koolau magma chamber is relatively shallow, being about 1.6 km below the surface (Adams and Furumoto, 1965) (Furumoto, 1976).

Magnetic. Available data pertains to deep structures (Malahoff, 1965).

Gravity. Provides depth estimate to Koolau plug of 1.5 to 2 km (Strange et al., 1965).

Exploratory Drilling. No deep exploratory well data available.

Self Potential. Available data has no positive indications of geothermal resource.

OAHU CONCLUSION:

WAIANAE VOLCANO

On the basis of geologic age and some resistivity, groundwater temperature and geochemical anomalies, the probabilities for a geothermal resource are as follows:

- 15% or less chance of finding low temperature (50-125°C) resource at depths less than 3 km.
- Less than 5% chance of finding high temperature (greater than 125°C) resource at depths less than 3 km.

KOOLAU VOLCANO

Due to the geologic age and the absence of any significant geochemical, self potential, magnetic or resistivity anomalies, the following probabilities have been concluded:

- Less than 10% chance of finding low temperature (50-125°C) resource at depths less than 3 km.

- Less than 5% chance of finding high temperature (greater than 125°C) resource at depths less than 3 km.

III. ASSESSMENT OF MOLOKAI AND LANAI

Groundwater Temperature.

West Molokai - Reported but unconfirmed anomaly in Well No. 1011-01 having a temperature of 30-33°C. Well presently is collapsed.

East Molokai and Lanai - Available data has no positive indications of geothermal resource.

Geologic Age.

West Molokai - About 8 million years old.

East Molokai - About 1.5 to 1.3 million years old, with post erosional activity at Kalaupapa Peninsula about 400,000 years ago.

Lanai - About 1.6 to 1.8 million years old.

Geochemistry.

Molokai - Some weak ground water chemistry anomalies but probably due to irrigation water return or soil types.

Lanai - Available data has no positive indications of geothermal resource.

Resistivity. No significant data.

Infrared. No data available.

Seismic. No data available.

Gravity/Magnetic. Available data pertains to identification of deep structural features. The central caldera and rift systems of West Molokai are well defined by gravity highs, with marginal coverage over the eastern end of the island (Moore and Krivoy, 1965; Malahoff, 1976).

Exploratory Drilling. No deep exploratory well data available.

Self Potential. No data available.

MOLOKAI AND LANAI CONCLUSION:

On the basis of available data and the absence of any positive geophysical or geochemical anomalies the probability for a geothermal resource is as follows:

- Less than 5% chance of finding a low (50-125°) or high (greater than 125°)temperature resource at depths less than 3 km. It should be noted that due to the limited data, future studies are warranted in order to update our current assessment.

Recommended references for Maui:

Diller Thesis
Brill
Horton
Kennedy
Lienert
Mattice Thesis
Sinton Maps
HVO records for Maui Seismometer
Crandell Map

JOSEPH KUBACKI

DEAN NAKANO

APPROVED:

MANABU TAGOMORI

Agenda

Geothermal Resources Technical Committee
Meeting No. 2

March 30, 1984
Maui Electric Company
210 Kamehameha Avenue
Kahului, Maui

9:00 am to
12:00 N -

- Call to order: Dan Lum
- Remarks by Arden Henderson, Maui Electric Co.
- Approval of minutes

Session Leader: Donald Thomas

- Review Conclusions on Kauai, Oahu, Molokai, and Lanai
- Assessment of Geothermal Resources on Maui
  * West Maui
  * East Maui, generally
  * Haleakala S.W. Rift Zone
- Review key references for Hawaii

12:00 N to
12:30 pm -

- Lunch and 15 minute geothermal video presentation by Maui Electric Co.

2:00 pm to
2:30 pm -

- Presentation by R.B. Moss, Mid-Pacific Geothermal, Inc. and Allan Kawada, True Geothermal Energy Co.

2:30 pm to
4:30 pm -

- Field trip to Haleakala South West Rift Zone (Ulupalakua Ranch, Maui Electric Company, Mid-Pacific Geothermal, Inc., Technical Comm.) Field trip leader: R.B. Moss

4:30 pm -

- Adjournment

MINUTES
(Amended)

Geothermal Resources Technical Committee
Meeting No. 2

Date: March 30, 1984

Time: 9:00 am - 2:00 pm; 2:30 pm - 4:30 pm

Place: Maui Electric Co. Conference Room (morning)
Ulupalakua Ranch (afternoon)

Participants: Dan Lum, DOWALD
Donald Thomas, HIG
Jim Kauahikaua, USGS
John Sinton, HIG
Joe Kubacki, DOWALD
Dean Nakano, DOWALD

Morning

Meeting called to order by Dan Lum, followed by opening remarks from Arden Henderson of Maui Electric Co. who reported briefly on the importance of geothermal development on Maui. Mr. Henderson stressed the desire for electrical production from geothermal energy rather than fossil fuel, thereby reducing Hawaii's dependence on imported oil and creating less pollution in the environment. Maui Electric Co.'s present electrical output is 96 megawatts and the initial goal at the proposed Ulupalakua Ranch site would be 13 megawatts with a maximum production set at 50 megawatts.

A 15-minute video film presentation produced by Maui Electric Co. was viewed by the members of the technical committee. The video briefly described geothermal development and interviewed various members of the community and government officials whose general consensus was in favor of geothermal energy as an alternate resource.

The minutes of the March 16, 1984 meeting and the Committee's conclusions on Kauai, Oahu, Molokai and Lanai were revised and approved by the Technical Committee.

The next meeting was tentatively scheduled for April 6, 1984 at 9:00 am in the HIG conference room in Honolulu.

The meeting was turned over to Don Thomas who divided the assessment of Maui into six (6) general locations:

West Maui: (Olowalu-Ukumehame, Lahaina, Honolua); and

East Maui: (Haleakala S.W. Rift Zone, Haleakala East Rift, Haleakala N.W. Rift Zone)

Based upon the available information, the following assessment and probability ranges were concluded by the Technical Committee:

I. ASSESSMENT OF WEST MAUI

A. OLOWALU-UKUMEHAME CANYON

Groundwater Temperature. Confirmed low temperature anomalies noted in two wells: Well No. 4937-01 (25.6°C) and Well No. 4835-01 (35°C).

Geologic Age. The main shield building volcanism on West Maui has been dated between 1.15 to 1.30 million years ago (mya) and some post erosional activity has occurred. Data indicates that the southeast rift migrated from a southeasterly strike to a southwesterly strike. Structural features such as dikes, plugs and vents have been identified within the canyon (Macdonald and Abbott, 1970; McDougall, 1964; Diller, 1982; Stearns, 1942).

Geochemistry. Some minor mercury and radon anomalies noted, but unable to make any firm conclusions due to the limited amount of data (Cox and Cuff, 1981). Some anamolous calcium and sulfate concentrations recorded at well No. 4937-01. Recent water samples confirmed silica and chloride/magnesium ratio anomalies possibly indicating thermal alteration. Spring and stream water samples indicate a difference in groundwater chemistry between those taken near the back of Olowalu Canyon and those found at the mouth of Ukumehame Canyon. It should be noted that tritium levels (Kennedy, 1983) indicate rapid circulation of above ambient groundwater, possibly indicating a shallow, low temperature resource.

Resistivity. Schlumberger surveys indicate an anomalous layer of seawater having low resistivity. This anomalous resistivity layer (approximately 4.3 ohm-m) has been estimated to be up to 500 m thick and located 80-200 m below sea level. Based on 20% porosity, fluid temperature has been estimated at 90°C (Mattice, 1981; Mattice and Lienert, 1980).

Infrared Surveys. No available data.

Seismic. No significant data.

Magnetic. Available data pertains to the identification of deep structural features. A magnetic anomaly identified an intrusive body in the canyon, possibly indicating a reversal of polarity or temperatures above the Curie point (543°C) (Malahoff and Woolard, 1965; Lienert, 1983).

Gravity. Available data has no positive indications of geothermal resource (Kinoshita and Okamura, 1965).

Exploratory Drilling. No deep exploratory well data available.

Self Potential. Available data has no positive indications of geothermal resource (Kauahikaua and Mattice, 1981).

Conclusion:

Based on available data (groundwater temperature, resistivity, magnetics, groundwater chemistry and rift zone structure) that identify geophysical and geochemical anomalies and taking into consideration the geologic age of West Maui, the following probabilities were concluded:

- 75% or less chance of finding low temperature (50-125°C) resource at depths less than 3 km.
- Less than 15% chance of finding high temperature (greater than 125°C) resource at depths less than 3 km.

B. LAHAINA-KAANAPALI

Groundwater Temperature. Weak groundwater temperature anomalies noted in 3 wells: Well No. 5240-01 (26.82°C); Well No. 5240-03 (24.93°C); and Well No. 5340-01 (25.20°C).

Geologic Age. Lahaina-Kaanapali area located to the northwest of Olowalu Canyon. Two post erosional vents have been identified (Puu Laina and Kekaa Point) but there does not appear to be any relationship between these vents and the West Maui Rift Zones (Macdonald and Abbott, 1970; Diller, 1982).

Geochemistry. Available data has no positive indications of geothermal resource. Results of mercury and radon survey similar to Olowalu-Ukumehame, indicated few minor anomalies, but unable to draw any firm conclusions (Cox and Cuff, 1981).

Resistivity. Schlumberger survey data available but no positive indications of geothermal resource (Mattice, 1981; Mattice and Lienert, 1980).

Infrared Surveys. No available data.

Seismic. No significant data.

Magnetic. Available data pertains to the identification of deep structural features (Malahoff and Woolard, 1965).

Gravity. Available data has no positive indications (Kinoshita and Okamura, 1965; Malahoff and Woolard, 1965).

Exploratory Drilling. No deep exploratory well data available.

Self Potential. Available data has no positive indications of geothermal resource (Kauahikaua and Mattice, 1981).

Conclusion:

Based on the absence of any positive geochemical or geophysical data indicating above ambient subsurface temperatures, the following probability was concluded:

- Less than 5% chance of finding a low (50-125°C) or high (greater than 125°C) temperature resource at depths less than 3 km.

C. HONOLUA

Groundwater Temperature. Available data does not report any groundwater temperature anomalies.

Geologic Age. Although Honolua is located near the northwest rift zone, no post erosional activity has been recorded (Macdonald and Abbott, 1970).

Geochemistry. No significant groundwater chemistry anomalies (Thomas et al, 1979).

Resistivity. Schlumberger survey data report no significant resistivity anomalies (Mattice, 1981).

Infrared Surveys. No data available.

Seismic. No data available.

Magnetic. Available data pertains to the identification of deep structural features (Malahoff and Woolard, 1965).

Gravity. Available data has no positive indications (Kinoshita and Okamura, 1965; Malahoff and Woolard, 1966).

Exploratory Drilling. No deep exploratory well data available.

Self Potential. No data available.

Conclusion:

Based on the absence of any positive geophysical or geochemical anomalies, the following probability was concluded:

- Less than 5% chance of finding a low (50-125°C) or high (greater than 125°C) temperature resource at depths less than 3 km.

II. ASSESSMENT OF EAST MAUI

A. HALEAKALA SOUTHWEST RIFT ZONE

Groundwater Temperature. All wells sampled were located outside of the rift zone and many of these wells tapped into perched aquifers rather than the local basal lens. Available data indicates no significant groundwater temperature anomalies.

Geologic Age. Haleakala is the younger and larger of the two volcanoes that formed the island of Maui. Three eruptive phases have been identified: The Honomanu Phase (approximately 750,000 years ago); the Kula Series (approximately 500,000-600,000 years ago); and more recently the Hana Series that began about 70,000 years ago. Six to seven eruptions have occurred on the S.W. Rift within the last 1000 years and the lava's crystal formation suggests that these flows came from a magma chamber at moderate depth. The most recent post erosional eruption occurred in 1790 on the lower S.W. Rift of Haleakala from 2 vents located at elevations 155 m and 472 m above sea level (Macdonald and Abbott, 1970; Crandell, 1983; Sinton, 1983).

Geochemistry. Soil mercury and radon emanometry surveys identified some anomalies, but due to wide variations in soil and rock types no definite conclusions could be drawn (Cox and Cuff, 1981).

Resistivity. Schlumberger surveys indicated high resistivities and yielded little information regarding thermal conditions (Mattice, 1981). Electromagnetic soundings indicated moderate to low resistivity (6 to 7 ohm-m) to depths of 1 Km on the lower rift zone and higher resistivities (12 to 16 ohm-m) beneath the upper rift zone (Lienert, 1983). Subsurface temperature has been estimated at 57°C based on 20% porosity within 500-800 meters below sea level.

Infrared Surveys. No available data.

Seismic. No significant data having positive indications of geothermal resource.

Gravity/Magnetic. Available data pertains to the identification of the rift zone (Kinoshita and Okamura, 1965; Malahoff and Woolard, 1966).

Exploratory Drilling. No deep exploratory well data available.

Self Potential. Available data has no positive indications of geothermal resource (Mattice and Kauahikaua, 1981).

Conclusion:

On the basis of available data, there is no direct evidence of warm water. However, due to the young geologic age of the recent 1790 eruption and the results of the deep resistivity soundings, the following probabilities have been concluded:

- 35% or less chance of finding low temperature (50-125°C) resource at depths less than 3 km.
- 25% or less chance of finding high temperature (greater than 125°C) resource at depths less than 3 km.

B. HALEAKALA NORTHWEST RIFT ZONE

Groundwater Temperature. Water temperatures ranged from 21°C to 24°C but are related to perched ash bed aquifers rather than basal ground water.

Geologic Age. Some Kula Series vents (about 500,000 years old) have been located on the lower N.W. Rift, but no Hana Series vents have been identified (Macdonald and Abbott, 1970; McDougall, 1964).

Geochemistry. Soil mercury and radon emanometry surveys indicated above ambient levels but may be due to wide variation in soil and rock type. Groundwater chemistry anomalies are related to perched ash bed aquifers rather than basal ground water (Cox and Cuff, 1981).

Resistivity. Schlumberger soundings indicated a weak resistivity anomaly at a depth of about 20 meters (Mattice and Lienert, 1980; Mattice, 1981).

Infrared Survey. No available data.

Seismic. No available data.

Gravity/Magnetics. Available data pertains to the identification of the rift zone (Kinoshita and Okamura, 1965; Malahoff and Woolard, 1965).

Exploratory Drilling. No deep exploratory well data available.

Self Potential. Available data has no positive indications of geothermal resource (Mattice and Kauahikaua, 1981).

Conclusion:

Based on the absence of any geochemical or geophysical anomalies other than a weak resistivity anomaly and due to the geologic age of the last eruption, the following probabilities were concluded:

- Less than 10% chance of finding low temperature (50-125°C) resource at depths less than 3 km.
- Less than 5% chance of finding high temperature (greater than 125°C) resource at depths less than 3 km.

C. HALEAKALA EAST RIFT ZONE

Groundwater Temperature. Water temperatures ranged from 18.5°C to 20.2°C, well within the normal range.

Geologic Age. The East Rift Zone has had recent (Kula and Hana Series) volcanism similar to the S.W. Rift Zone. Lava has been dated between 490 to 10,000 years ago (Crandell, 1983; Macdonald and Abbott, 1970).

Geochemistry. Some data indicated chloride/magnesium and sulfate anomalies, but these wells are reportedly not pumped on a regular basis; therefore, no positive indications can be confirmed.

Resistivity. Available data has no positive indications of geothermal resource (Mattice, 1981; Mattice and Kauahikaua, 1981).

Infrared Surveys. No available data.

Seismic. No available data.

Gravity/Magnetics. Available data pertains to identification of the rift zone (Kinoshita and Okamura, 1965; Malahoff and Woolard, 1966).

Exploratory Drilling. No deep exploratory well data available.

Self Potential. No available data.

Conclusion.

Taking into consideration the limited amount of available data and based solely on the geologic age of the Hana Series lava flows, the following probabilities for the Haleakala East Rift Zone were concluded:

- 35% or less chance of finding low temperature (50-125°C) resource at depths less than 3 km.
- 25% or less chance of finding high temperature (greater than 125°C) resource at depths less than 3 km.

Afternoon

Rod Moss from Mid-Pacific Geothermal, Inc. and Allan Kawada from True Geothermal Energy Co. gave a short presentation on their proposed geothermal venture on Ulupalakua Ranch lands. Although no new technical data was submitted, Mr. Moss indicated that the Maui area being considered is along the S.W. rift zone; identified (Crandell, 1983) as having the most potential for volcanic activity on dormant Haleakala. A leasing agreement has been reached between Ulupalakua Ranch and True/Mid-Pacific. It was also noted that other areas on East Maui (Haleakala N.W. rift and Haleakala East Rift) had been seriously considered, but failed to materialize due to the problems associated with the leasing of contiguous land.

During our afternoon field trip, the Technical Committee was able to view the proposed drilling sites on Ulupalakua Ranch, running from about the 6,000-foot elevation down to about a mile and a half from Cape Kinau. Mr. Moss emphasized the availability of land, the limited number of residents and indicated that the nearest populated spot was Kainao Homesteads.

Upon completion of the field trip the meeting was adjourned at 4:30 pm.

DEAN NAKANO

APPROVED:

MANABU TAGOMORI

AGENDA

Geothermal Resources Technical Committee
Meeting No. 3

April 9, 1984
Hawaii Institute of Geophysics
(Conference Room)
University of Hawaii
Honolulu, Hawaii

9:00 am — Call to Order: Manabu Tagomori

- Approval of minutes (to be circulated at the meeting)

Technical Session Leader: Donald Thomas

- Review Conclusions on Maui
- Assessment of geothermal resources on Hawaii, generally

12:00 noon - Lunch

1:00 pm — Continue morning session

- Review key references for Kilauea East Rift Zone
- Review future meeting schedule

3:00 pm — Adjournment

MINUTES
(Amended)

Geothermal Resources Technical Committee
Meeting No. 3

Date: April 9, 1984

Time: 9:00 am - 12:00 Noon; 1:30 pm - 3:30 pm

Place: HIG Conference Room, University of Hawaii

Participants: Manabu Tagomori, Chairman, DOWALD
Donald Thomas, HIG
Dan Lum, DOWALD
John Sinton, HIG
Dallas Jackson, HVO
Richard Moore, HVO
Joe Kubacki, DOWALD
Dean Nakano, DOWALD

Morning Session

Manabu Tagomori called the meeting to order and thanked all of the Technical Committee members for their continued assistance in this assessment program. The Committee was informed that the administrative rules have been approved by the Governor and is to be reviewed by the Land Board on Friday, April 13, 1984, and scheduled for public hearings in all counties on May 22, 1984.

Public participation and information meetings have been tentatively set for May 1 and 2, 1984 at Kihei and Puna, respectively and again on May 30 and 31, 1984.

Copies of the approved minutes for the March 16, 1984 meeting along with minutes of the March 30, 1984 meeting were distributed to the committee. The minutes of the last meeting and the committee's conclusions on Maui were briefly reviewed and discussed. Although there were no major objections to the conclusions drawn, it was suggested that approval of the minutes be deferred to later, subject to any revisions that the committee may recommend.

It was noted and approved that the subheading titled Honokawai should be more accurately labeled as Honolua rather than Honokawai.

The meeting was turned over to Don Thomas who divided the evaluation of Hawaii into nine general locations. Based upon the assessment of available information, the following probability ranges were concluded by the Technical Committee:

ASSESSMENT OF THE ISLAND OF HAWAII

A. KAWAIHAE

Groundwater Temperature. Groundwater temperature anomalies were noted in 4 wells: Well No. 6048-02 (26°C), Well No. 5745-01 (26°C), Well No. 5745-02 (26.5°C), and Kawaihae 3, Well No. 6147-01 (37°C), which is clearly above ambient temperature.

Geologic Age. The limited data available indicates that the most recent post erosional activity (Hawi Volcanic Series) occurred at Puu Loa and has been estimated at about 80,000 years ago. Kawaihae is located on the saddle between the Mauna Kea and Kohala volcanoes and is not situated within a recently active rift zone (Macdonald and Abbott, 1970; Malinowski, 1977).

Geochemistry. Available soil mercury and radon emanometry data show no positive geothermal indications. Some minor anomalies were noted but did not lead to any firm conclusions (Cox and Cuff, 1981). Well No. 6147-01 indicated an anomalous chloride/magnesium ratio and several other wells had slight chemical variations.

Resistivity. Schlumberger soundings did not identify any low resistivity anomalies indicating geothermal resource. High basement resistivities recorded were interpreted to indicate a dense intrusive body (Kauahikaua and Mattice, 1981).

Infrared Surveys. No thermal anomalies were noted having any positive geothermal indications (Fischer, et al, 1966).

Seismic. Data indicates that earthquakes of magnitudes greater than 4.0 have occurred near Kawaihae at least once a year. Earthquakes have been scattered without any significant cluster recorded, therefore no positive indications.

Magnetic. Aeromagnetic survey indicated an anomaly between Waimea and Kawaihae Bay and has been interpreted to correspond to an intrusive body rather than a Curie point temperature (Malahoff and Woolard, 1965; Godson, et al, 1981).

Gravity. No positive indications; data pertains to the identification of deep structural features (Kinoshita, 1965).

Exploratory Drilling. No deep exploratory well data.

Self Potential. No available data.

Conclusion:

On the basis of groundwater temperature, chemical anomalies and the resistivity interpretation indicating the presence of an intrusive body associated with the Puu Loa cinder cone and taking into consideration the geologic age of this vent, the following probabilities have been concluded:

- 45% or less chance of finding low temperature (50-125°C) resource at depths less than 3 km.

- Less than 10% chance of finding high temperature (greater than 125°C) resource at depths less than 3 km.

B. HUALALAI SUMMIT AND UPPER FLANK (above 4000-foot elevation)

Groundwater Temperature. No available data.

Geologic Age. Hualalai is situated to the northwest of Mauna Loa and is considered to be in a mature post-caldera stage of activity. Twelve to 15 vents have been identified that have erupted within the last 1,000 years, with the youngest vent being less than 200 years old. Volcanic activity along the north trending rift near Puu Waawaa last occurred about 2,000 years ago (Macdonald and Abbott, 1970; Moore, 1983).

Geochemistry. Available data indicates that hydrothermal activity has occurred due to evidence of copper sulfide and potassium metasomatism.

Resistivity. Schlumberger soundings indicate a low resistivity layer at a depth of about 480 meters which has been interpreted as a perched body of possibly warm water (Kauahikaua and Mattice, 1981).

Infrared Survey. No available data.

Seismic. There has been no concentration of any seismic activity at the summit, therefore no significant conclusions could be drawn.

Magnetics. Aeromagnetic data indicates a magnetic low near the summit that appears to be reversed. This low could be attributed to hydrothermal alteration of intrusive material or to a residual magma body above the Curie point (greater than 543°C), (Malahoff and Woollard, 1965; Godson, et al, 1981).

Gravity. No significant data.

Exploratory Drilling. No deep exploratory well data.

Self Potential. Self potential surveys indicate an anomaly across the summit and along the upper northwest rift and could possibly be due to a high temperature intrusive or dike impounded water (Jackson and Sako, 1982; Jackson, 1983).

Conclusion:

Based on positive geothermal indications from geophysical data (resistivity, magnetics, and self potential) and the geologically young age of vents along the upper rift and summit, the following probabilities were concluded:

- 70% or less chance of finding low temperature (50-125°C) resource at depths less than 3 km.

- 35% or less chance of finding high temperature (greater than 125°C) resource at depths less than 3 km.

C. HUALALAI LOWER FLANK (Below 4000-foot elevation)

Groundwater Temperature. No groundwater anomalies recorded indicating above ambient temperatures. One of the two deep wells at Puu Waawaa, Well No. 4650-01, did indicate above ambient temperature at the bottom of the well (87.6°F, bottom hole temperature).

Geologic Age. Same as Hualalai summit and upper flank. Several vents have been identified that have erupted within the last 1,000 years, the most recent eruption occurring in 1801 (Macdonald and Abbott, 1970; Moore, 1983).

Geochemistry. Soil mercury and radon emanometry surveys identified some anomalies but due to variations in soil type, no definite conclusions could be drawn (Cox and Cuff, 1981).

Resistivity. Schlumberger and time domain electromagnetic soundings were conducted but had no positive indications within 2 km depth (Kauahikaua and Mattice, 1981).

Infrared Survey. Some anomalous coastal water temperatures were reported but have not been confirmed (Fischer, et al, 1966).

Seismic. There has been a concentration of seismic activity along the rift zone near the coast and extends seaward. A recorded 1929 seismic swarm (Macdonald and Abbott, 1970) on the north flank indicated that an intrusive event had occurred, possibly suggesting that Hualalai still be considered active.

Magnetics. Available data shows no positive indications of geothermal resource and pertains to identification of deep structural features (Malahoff and Woollard, 1965; Godson, et al, 1981).

Gravity. No significant data.

Exploratory Drilling. Two deep wells near Puu Waawaa located north of the rift zone (Well No. 4850-01 and Well No. 4650-01). Only Well No. 4650-01 indicated above ambient temperature (87.6°F) at a bottom hole depth of 5,555 feet.

Self Potential. Data from lower elevation self potential surveys did not show any positive indications due to interference from buried conductive objects (Jackson and Sako, 1982; Jackson, 1983).

Conclusion:

Based on the absence of any positive geochemical or geophysical data other than a recorded concentration of seismic activity, it was concluded that the Hualalai lower flank should have a probability lower than the summit region. The Committee agreed that the assignment of a probability percentage would be deferred to later.

D. Mauna Loa Southwest Rift - South Point

Groundwater Temperature. No available data.

Geologic Age. Mauna Loa is the second most active volcano on Hawaii and has erupted during historic time: first recorded in 1868 and most recently in 1950. The 1950 eruption on the southwest rift produced the largest volume of lava (600 million cubic yds.) within the last 1,000 years. All volcanic activity has been situated on the upper rift above the 3000-foot elevation (Macdonald and Abbott, 1970).

Geochemistry. No available data.

Resistivity. Schlumberger and time domain electromagnetic surveys did not detect any significant anomalies. Data suggests that soundings did not penetrate deep enough to the basal water table, but instead terminated in unsaturated basalts (Kauahikaua and Mattice, 1981).

Infrared Survey. No conclusive data indicating geothermal resource, thermal anomaly could be attributed to solar heating of the surface rocks.

Seismic. Data indicates a concentration of seismic activity on the upper southwest rift zone above the 10,000-foot elevation.

Magnetics. Aeromagnetic surveys were flown parallel to the rift zone and therefore were not effective in showing any indications of geothermal resource (Malahoff and Woollard, 1965; Godson, et al, 1981).

Gravity. No significant data other than identification of the rift zone (Kinoshita, 1965).

Exploratory Drilling. No deep exploratory well data.

Self Potential. A negatively polarized anomaly was interpreted as the result of a downward streaming potential, rather than a geothermal heat source that would have a positively polarized self potential anomaly (Kauahikaua and Mattice, 1981).

Conclusion:

On the basis of historic volcanic eruptions, seismic activity and consideration given to the absence of other geophysical or geochemical anomalies, the following probabilities were concluded:

- 60% or less chance of finding low temperature (50-125°C) resource at depths less than 3 km.

- 35% or less chance of finding high temperature (greater than 125°C) resource at depths less than 3 km.

It should be noted that due to the limited amount of data, future studies are warranted in order to update our current assessment.

E. MAUNA LOA NORTHEAST RIFT - KEAAU

Groundwater Temperature. Available data did not indicate any significant temperature anomalies in either the upper, middle, or lower rift.

Geologic Age. The Northeast Rift Zone can be traced by vents or lava flows down to an elevation of about 600 to 900 feet above sea level. The upper northeast rift (above the 6,000-foot elevation) is currently erupting at the 9,000-foot level. Along the middle rift, (4,500 to 6,000-foot elevation) near Kulani prison, a recent vent has been dated at about 800 years old. No eruptions have occurred on the lower rift (below the 4,500-foot elevation) during historic time (Macdonald and Abbott, 1970).

Geochemistry. Soil mercury and radon emanometry surveys and groundwater chemistry data do not indicate any geothermal anomalies.

Resistivity. Resistivity data for the lower rift did not identify any geothermal anomalies. No data available for the upper or middle rift zones (Kauahikaua and Mattice, 1981).

Infrared Survey. No available data.

Seismic. A high concentration of seismic activity has been recorded in the upper and middle northeast rift. There is no significant concentration of similar activity noted in the lower rift zone.

Magnetics. Aeromagnetic data indicates a clear anomaly on the upper rift zone (Godson, et al, 1981).

Gravity. Data does not indicate any significant anomalies on the rift zone (Kinoshita, 1965).

Exploratory Drilling. No deep exploratory well data.

Self Potential. Definite anomaly recorded near site of current eruption but no significant anomalies identified on the lower northeast rift (Jackson, 1983).

Conclusion:

On the basis of geochemical and geophysical data for the lower rift near the vicinity of Mountain View and Keaau, it is unlikely that a geothermal resource would be found.

While upper-elevation seismic and self potential data and the current Mauna Loa eruption indicate a geothermal resource, it should be noted that current drilling technology limits development to elevations of less than 7,000 feet above sea level. Therefore, based on available data the following probabilities were concluded:

Mauna Loa upper northeast rift -

- Less than 90% chance of finding a low (50-125°C) or high (greater than 125°C) temperature resource at depths less than 3 km.

Mauna Loa middle northeast rift -

- 60% or less chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- 35% or less chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

Mauna Loa lower northeast rift -

- Less than 5% chance of finding a low temperature (50-125°C) or high temperature (greater than 125°C) resource at depths less than 3 km.

F. KILAUEA SOUTHWEST RIFT

Groundwater Temperature. A temperature of about 32°C has been reported at a coastal spring at Wai Welawela (Casadevall and Hazlett, 1983).

Geologic Age. Kilauea is the youngest and most active volcano in Hawaii. The Southwest Rift Zone is considered active and has been the site of historic eruptions in 1823 at the 250 to 1700-foot elevation and in 1920 at the 3,000-foot elevation. The presence of steaming ground also indicates substantial geothermal potential on the Southwest Rift Zone (Macdonald and Abbott, 1970; Banks, 1983).

Geochemistry. No significant data.

Resistivity. Schlumberger, di-pole/di-pole and time domain surveys indicate resistivity anomalies on both the upper and lower rift (Hussong and Cox, 1967; Adams, et al, 1970; Keller, et al, 1977; Klein and Kauahikaua, 1975; Kauahikaua and Mattice, 1981).

Infrared Survey. No anomalies were detected, but steaming ground evident since 1971 near Mauna Iki above the 2,500-foot elevation (Fischer, et al, 1966).

Seismic. Seismic activity recorded along the southwest rift follows the gravity high indicating a southward trending rift.

Magnetics. Aeromagnetic data shows no significant anomaly and only a weak expression of the rift zone (Godson, et al, 1981; Malahoff and Woollard, 1965).

Gravity. Gravity highs identify the rift zone and its extension seaward (Kinoshita, 1965).

Exploratory Drilling. No deep exploratory well data.

Self Potential. Strong anomalies noted along the upper rift down to about the 2,000-foot elevation near Yellow Cone (Jackson, 1983).

Conclusion:

On the basis of positive geophysical data, recent volcanic activity, and consideration given to the absence of any significant groundwater temperature or chemical anomalies, the following probabilities were concluded:

- Greater than 90% chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- Greater than 90% chance of finding a high temperature (125°C) resource at depths less than 3 km.

It should be noted that although the majority of the southwest rift zone is situated within the Hawaii Volcanoes National Park and is therefore off-limits to geothermal development, the potential for geothermal resource along the entire Kilauea Southwest Rift Zone was assessed by the Committee.

G. KOHALA VOLCANO

Groundwater Temperature. No positive indications from groundwater data.

Geologic Age. The most recent activity occurred about 60,000 years ago and was most active at least 300,000 years ago (Macdonald and Abbott, 1970).

Geochemistry. No significant data.

Resistivity. Data from Direct Current (DC) soundings did not show any positive indications of geothermal resource (Kauahikaua, et al, 1979).

Infrared Survey. No available data.

Seismic. No concentration of seismic activity.

Magnetics. Aeromagnetic data did not identify any strong anomalies (Godson, et al, 1981).

Gravity. No significant data.

Exploratory Drilling. No deep exploratory well data.

Self Potential. No available data.

Conclusion:

Due to the limited data and the absence of any signficant anomalies and based on the younger age of Kohala relative to Olowalu-Ukumehame on Maui, the following probabilities were concluded:

- Less than 10% chance of finding a low temperature (50-125°C) resource at depths less than 3 km.

- Less than 5% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

It should be noted that due to the limited amount of data, additional studies are warranted in the future in order to update our current assessment.

H. MAUNA KEA

Groundwater Temperature. One groundwater temperature anomaly recorded in a deep well on the Northwest Rift Zone at Waikii, Well No. 5239-01 (104°F at 4240-foot depth) . No temperature anomalies recorded for shallow wells along the coast.

Geologic Age. Mauna Kea volcano is substantially younger than Kohala, having been formed over 200,000 years ago. Mauna Kea is presently in its post-caldera stage of activity with the most recent eruption occurring about 3600 years ago (Macdonald and Abbott, 1970; Porter, 1979).

Geochemistry. No significant data.

Resistivity. No available data.

Infrared Survey. No available data.

Seismic. Definite seismic swarm and deep seismic activity recorded along the East Rift Zone.

Magnetics. Available data shows no positive indication of geothermal resource and pertains to identification of structural features within the summit (Malahoff and Wollard, 1965; Godson, et al, 1981).

Gravity.. No significant data.

Exploratory Drilling. Waikii Well No. 5239-01, drilled at elevation 4260 ft. to a depth of 4,350 feet. A bottom-hole (near sea level) temperature of 104°F recorded.

Self Potential. No available data.

Conclusion:

On the basis of geologic age and one groundwater temperature anomaly recorded at the Waikii well, the following probabilities were concluded:

Mauna Kea Northwest Rift Zone -

- Less than 50% chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- Less than 20% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

Mauna Kea East Rift Zone -

- Less than 30% chance of finding a low temperature (50-125°C) resource at depths less than 3 km.
- Less than 10% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

It was noted again that due to the limited amount of available data, additional studies are warranted in the future in order to update our current assessment.

Afternoon Session

The meeting was reconvened by Manabu Tagomori and dates, locations, and topics of future meetings were discussed and tentatively scheduled as follows:

Date	Place	Topic of Discussion
April 18 (Wed.)	Hawaii	Air inspection of Kilauea Rift Zone. Tour of Puna Geothermal Venture and Barnwell Drilling Sites, and inspection of the HGP-A Facility.
April 19 (Thurs.)	Hawaii	Assessment of Geothermal Resources on Kilauea East Rift Zone. Mapping by the Committee of all potential geothermal resource areas.
May 11 (Fri.)	Honolulu	Assessment Review Session.

It was suggested that an additional meeting be scheduled sometime in May to discuss the impacts of geologic hazards. The committee was also invited to participate in the impact analysis of geothermal development on the environment.

The meeting was adjourned at 3:30 pm.

DEAN NAKANO

APPROVED:

MANABU TAGOMORI

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

SUSUMU ONO, CHAIRMAN
BOARD OF LAND & NATURAL RESOURCES

EDGAR A. HAMASU
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STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF WATER AND LAND DEVELOPMENT
P. O. BOX 373
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AGENDA

Geothermal Resource Subzone Technical Committee

Field Trip to Kilauea East Rift Zone
April 18, 1984

8:00 am	Leave Honolulu
9:00 am	Air inspection No. 1 - Kilauea Rift Zone
10:00 am	Air inspection No. 2 - Kilauea Rift Zone
11:00 am	Ground inspection of Upper Kilauea Rift Zone
12:00 N	Lunch
1:30 pm	Tour of Puna Joint Venture geothermal wells
2:30 pm	Tour of Barnwell geothermal wells
3:30 pm	Tour of HGP-A well
4:30 pm	Adjourn

MINUTES

Geothermal Resources Technical Committee
Meeting No. 4

Date: April 18, 1984

Time: 8:00 am - 12:00 Noon; 1:30 pm - 4:30 pm

Place: USGS Hawaiian Volcano Observatory (morning)
Barnwell and Thermal Power Geothermal Well Sites (afternoon)

Participants: Manabu Tagomori, Chairman, DOWALD
Donald Thomas, HIG
Dallas Jackson, HVO
Richard Moore, HVO
Joe Kubacki, DOWALD
Dean Nakano, DOWALD

Morning

Manabu Tagomori called the meeting to order and addressed the issue regarding the recent eruptive activity. The committee reviewed the middle east rift eruption of Kilauea which began on January 3, 1983 and has continued intermittently throughout 1984. To date, Kilauea erupted at Pu'u O for phase 17 which began at 5:15 am on March 30, 1984 and ended at 3:24 am on March 31, 1984. Seismic data indicated that the magma conduit along the east rift zone has not significantly changed.

The committee discussed the area covered by the recent lava flows and the extent of the phase 17 flow front which reached the 400-foot elevation about 1 km east of Royal Gardens subdivision. The technical group noted the probability of a resumption of eruptive activity and discussed the possible directions that the new lava flows might take with respect to Royal Gardens subdivision. It should be noted that the direction and rate of flow is dependent on many factors such as type of vegetation and the existence of earlier flows.

The technical committee was also briefed on the recent Mauna Loa eruption which began on March 25, 1984. The major portion of lava erupted from a 150-meter long fissure on Mauna Loa's northeast rift zone near the 9,500-foot elevation, about 2 km northeast of Pu'u Ulaula.

A field trip to the visitor center near Wahaula Heiau provided the committee a view of Royal Gardens subdivision and the extent of the lava flows that damaged 15 dwellings and covered about 330 lots and their access roads.

The scheduled air inspection of the Kilauea eruption site was cancelled due to inclement weather.

Afternoon

The meeting was reconvened by Manabu Tagomori at the site of geothermal well, Lanipuna No. 6, followed by a tour of the drilling operation by Bill Craddick from Barnwell Geothermal Corp.

The committee moved to the site of Kapoho State Wells No. 1 and 2 and a briefing was conducted by Joe Iovenitti from Thermal Power Co. Questions were answered regarding the Kapoho State No. 1 blowout and Mr. Iovenitti pointed out that various security devices have been installed at the well site. The site of the future Kapoho State No. 1A, although not finalized, is to be located within the original drill site of Kapoho State No. 1.

Mr. Tagomori thanked the committee again for their continued assistance and the meeting was adjourned at 4:30 pm.

DEAN NAKANO

APPROVED:

MANABU TAGOMORI

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF WATER AND LAND DEVELOPMENT
P. O. BOX 373
HONOLULU, HAWAII 96809

SUSUMU ONO, CHAIRMAN
BOARD OF LAND & NATURAL RESOURCES
EDGAR A. HAMASU
DEPUTY TO THE CHAIRMAN

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STATE PARKS
WATER AND LAND DEVELOPMENT

AGENDA

Geothermal Resource Subzone Technical Committee
Meeting No. 5

April 19, 1984
University of Hawaii, Hilo
Hilo, Hawaii

8:00 am	Call to order: Manabu Tagomori
	Presentation by Mid-Pacific Geothermal, Inc.
8:45 am	Presentation by Barnwell, Inc.
9:30 am	Presentation by Puna Joint Venture
10:15 am	Approval of Minutes
	Announcements
	Technical Session Leader: Donald Thomas
o	Review conclusions on Hawaii, generally
12:00 N	Lunch
1:00 pm	Air Inspection No. 1 - Kilauea Rift Zone
2:00 pm	Air Inspection No. 2 - Kilauea Rift Zone
4:00 pm	Adjourn

MINUTES
(Amended)

Geothermal Resources Technical Committee
Meeting No. 5

Date: April 19, 1984

Time: 8:00 am - 12:00 Noon, 1:00 pm - 5:00 pm

Place: University of Hawaii, Hilo Campus (morning)
Pu'u O Vent, Kilauea East Rift Zone (afternoon)

Participants: Manabu Tagomori, Chairman, DOWALD
Donald Thomas, HIG
John Sinton, HIG
Bill Chen, UH-Hilo
Dallas Jackson, HVO
Richard Moore, HVO
Joe Kubacki, DOWALD
Dean Nakano, DOWALD

A list of developers and their representatives present at the meeting is attached.

Morning

Meeting was called to order by Manabu Tagomori, who briefed the committee on the morning agenda regarding presentation of technical data by the three geothermal developers (True/Mid Pacific, Barnwell, and Puna Geothermal Venture).

True/Mid Pacific

The meeting was turned over to Rod Moss (Mid-Pacific Geothermal) and Allan Kawada (True Geothermal) who introduced Gerald Niimi from Thermasource, Inc. and Sam Keala, Jr., representing Campbell Estate.

Rod Moss emphasized the goal of True/Mid Pacific to drill north of the rift zone rather than to the south. Mr. Niimi stated that Thermasource, Inc. conducted a regional and site specific study of Kahaualea, and data indicated a potential geothermal resource with adequate groundwater recharge. Data was submitted to the committee by Mr. Niimi to support his conclusion that the north side of the rift would have the greatest potential (Holcomb, 1980; Koyanagi, 1978, Godson, et al, 1981; Kinoshita, 1965). Mr. Niimi recommended that his client initially drill close to the rift to observe the reservoir then develop northward away from possible future lava flows. It was noted that the nearest Kilauea lava flow is about 500 feet away from the proposed KA-1 drill site.

True/Mid Pacific has been granted conditional approval of up to 8 exploratory wells within a restricted area containing approximately 800 acres, with long range plans to develop a total of about 7,800 acres within Kahaualea.

Puna Geothermal Venture/Thermal Power

Mr. Iovenitti presented technical data by Howard Ross in addition to a mylar overlay outlining aeromagnetic data (Godson, et al, 1981), mercury and radon data (Cox, 1980), and water well locations with chemical and temperature information.

It was stated by Mr. Iovenitti that a recent aeromagnetic survey (not yet made public) noted areas of low magnetism related to high temperature or hydrothermal alteration and indicated the possibility of a parallel dike complex running along the coast. Based on the data presented, Mr. Iovenitti concluded that the middle rift from Kapoho State No. 1 and 2 north to Lava Tree State Park showed considerable potential.

It was recommended that future exploration be moved away from the dike complex which may restrict permeability although the area may be hot. Mr. Iovenitti further stated that seawater intrusion is not a reservoir problem with regard to precipitation of calcium and anhydrite possibly sealing off the reservoir.

Mr. Iovenitti discussed the difference in geothermal systems between HGP-A (50% water, 50% steam) and Kapoho State Wells (100% steam). It was suggested that the difference could be attributed to the depth of casing; Kapoho State No. 1 and 2 being cased to approximately 4500 feet depth, versus HGP-A which is cased to about 2900 feet depth.

The committee was informed that both wells, Kapoho State No. 1 and 2 had debris (drill rods and wireline) within the casing.

Barnwell

Bill Craddick representing Barnwell Geothermal Corp. and Murray Gardner from Geothermex, Inc., consultant to Barnwell/WRII, presented background information and data to the committee. Mr. Gardner stated the possibility of directional drilling at Ashida No. 1 in the north-northwest direction to locate a zone of permeability. Ashida No. 1 drilled to 8000-foot depth is hot (approximately 543°F) but lacks a permeable reservoir. Lanipuna No. 1 reported to have a well temperature of approximately 685°F also has the problem of low permeability.

It was noted that a minimum temperature of 450°F for deep wells and 350°-400°F for shallow wells are needed to be economically feasible for electrical production.

Mr. Gardner stated that the Halekamahina area, owned by Tokyu Land Development Co. would possibly be the site of future exploration. He also mentioned that a report on rock thin sections had been submitted to DLNR through Barnwell Geothermal Corp.

Mr. Tagomori thanked all of the developers and their representatives for their continued support and invited them to submit any additional information pertaining to the environmental impact of geothermal development.

Afternoon

The meeting was reconvened by Manabu Tagomori at the Hawaiian Volcano Observatory. Arrangements were made by HVO staff geologist Reggie Okamura for use of a helicopter to airlift the technical committee to the site of the recent "1123" vent. From this location and while in flight the committee was able to inspect the Kahaualea area covered by lava flows from the previous 17 phases of the Kilauea eruption.

Phase 18 of volcanic activity had begun at Pu'u O vent on the evening of April 18, 1984. The air inspection provided the committee an excellent overview of the current eruption and the extent of the 3 lava flows that were traveling toward the north, northeast, and south. While situated at the "1123" vent, the committee discussed the probability of future lava flows endangering the Royal Gardens subdivision.

Upon our return to the takeoff and landing area at the Kilauea Military Camp in the National Park, the meeting was adjourned at 5:00 pm.

DEAN NAKANO

APPROVED:

MANABU TAGOMORI

Developers and Consultants at the
Geothermal Resources Technical Committee
Meeting No. 5

April 19, 1984

NAME	ORGANIZATION
Samuel L. Keala, Jr.	Campbell Estate
Allan G. Kawada	True Geothermal Energy Co.
Gerald Niimi	Thermasource, Inc.
Rod Moss	Mid-Pacific Geothermal, Inc.
Joe Iovenitti	Thermal Power Co.
Bill Craddick	Barnwell Geothermal Corp./WRII
Murray C. Gardner	Geothermex, Inc.

GEORGE R. ARIYOSHI
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WATER AND LAND DEVELOPMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF WATER AND LAND DEVELOPMENT
P. O. BOX 373
HONOLULU, HAWAII 96809

AGENDA

Geothermal Resource Subzone Technical Committee
Meeting No. 6

April 23, 1984
Hawaii Institute of Geophysics (Conference Room)
University of Hawaii
Honolulu, Hawaii

9:00 am — Call to order: Manabu Tagomori

- Approval of Minutes
- Assessment of geothermal resources of Kilauea East Rift Zone

12:00 N — Lunch

1:00 pm — Mapping of geothermal resource areas

4:00 pm — Adjournment

MINUTES
(Amended)

Geothermal Resources Technical Committee
Meeting No. 6

Date: April 23, 1984

Time: 9:00 am - 12:00 Noon; 1:15 pm - 4:00 pm

Place: HIG Conference Room, University of Hawaii

Participants: Manabu Tagomori, Chairman, DOWALD
Donald Thomas, HIG
Dan Lum, DOWALD
John Sinton, HIG
Dallas Jackson, HVO
Richard Moore, HVO
James Kauahikaua, USGS
Bill Chen, UH-Hilo
Joe Kubacki, DOWALD
Dean Nakano, DOWALD

Morning

Manabu Tagomori called the meeting to order and thanked the committee members for their continued assistance.

Copies of the amended minutes for the March 30, 1984 meeting along with minutes of the April 9, 1984 meeting were distributed to the committee for their review and comments.

The meeting was turned over to Don Thomas who continued with the assessment of geothermal resources for the Kilauea East Rift Zone. Based upon the evaluation of available information, the following probability for geothermal resource was concluded by the Technical Committee.

ASSESSMENT OF THE ISLAND OF HAWAII

KILAUEA EAST RIFT

Groundwater Temperature. Numerous temperature anomalies recorded in wells along the lower East Rift Zone. Well No. 2686-02 (102°C), Well No. 2982-01 (93°C), Well No. 2685-01 (285°C) (Epp and Halunen, 1979; Macdonald, 1975).

Geologic Age. Frequent activity recorded along the rift zone with many recent eruptions and repeated dike intrusions. Data indicates possible secondary magma chambers capable of substantial magma storage (Moore, 1982, 1983; Wright and Fiske, 1971; Holcomb, 1980, 1981; Swanson et al, 1976).

Geochemistry. Water samples identified numerous geochemical anomalies along the rift zone. Data indicated thermal alteration of the chloride to magnesium ion concentration ratios (McMurty et al, 1977; Kroopnick et al, 1978; Cox and Thomas, 1979; Druecker and Fan, 1976).

Resistivity. Thermally related low resistivity anomalies recorded in many parts of the rift zone (Keller et al, 1977; Kauahikaua and Mattice, 1981).

Infrared Surveys. Some infrared anomalies identified on the rift zone and along the coast (Fischer et al, 1966; Abbott, 1974).

Seismic. Data indicates that the entire rift is extremely active. Numerous seismic events concentrated on the rift have strong indications of magma intrusion (Koyanagi et al, 1981, Furumoto, 1978; Suyenaga et al, 1978; Mattice and Furumoto, 1978; HVO monthly reports; Thermasource, Inc. report).

Magnetic. Major aeromagnetic anomalies were observed, associated with the Kilauea East Rift Zone (Godson et al, 1981; Malahoff and Woollard, 1965; Furumoto, 1978).

Gravity. Strong expression of the rift zone, not particularly related to geothermal potential (Kinoshita, 1965).

Exploratory Drilling. Seven deep wells drilled, all having high temperatures (greater than 125°C), but not all have adequate permeability for development.

Self Potential. Numerous self-potential anomalies observed, possibly associated with fumaroles or intrusives having high temperature or the movement of thermal groundwater (Zablocki, 1976, 1977; Jackson, 1983).

Conclusion:

On the basis of positive geochemical and geophysical data and the recent eruptive and intrusive activity along the Kilauea East Rift Zone, the following probability was concluded:

- Greater than 90% chance of finding a low temperature (50-125°C) and high temperature (greater than 125°C) resource at depths less than 3 km.

Afternoon

The meeting was reconvened by Don Thomas and the technical group began its mapping of High Temperature Potential Geothermal Areas based on the conclusions of the committee. After some discussion by the members, it was agreed that only those areas having an assessed probability of at least 25% chance of finding high temperature (greater than 125°C) resource at depths less than 3 km would be mapped.

It should be noted that there was some disagreement between technical members as to the importance placed on certain data and to the area encircled within the probability lines. After some debate a compromise was reached where equal weight would be given to all positive data and the probability areas mapped would be below the 7000-foot elevation due to the limits of current drilling technology.

Attached are a series of maps showing the following High Temperature Potential Geothermal Resource Areas and their percent probabilities:

	% Probability for High Temperature
Maui	
Haleakala SW Rift Zone	25% or less
Haleakala East Rift Zone	25% or less
Hawaii	
Kilauea East Rift Zone	Greater than 90%
Kilauea SW Rift Zone	Greater than 90%
Mauna Loa NE Rift Zone	35% or less
Mauna Loa SW Rift Zone	35% or less
Hualalai	35% or less

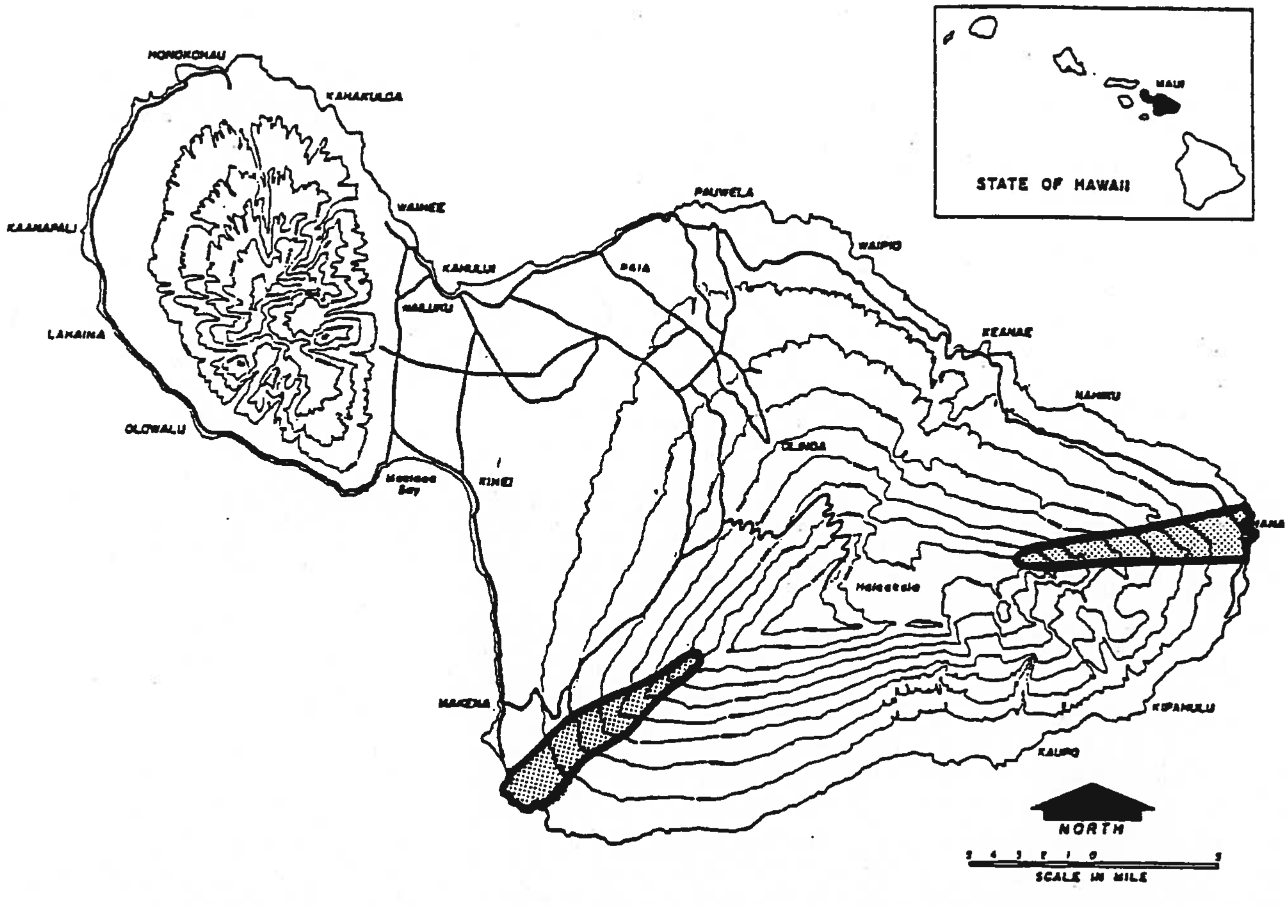
The date for the Assessment Review Session was set for May 11, 1984, to be held at the HIG conference room in Honolulu. It was suggested that an additional meeting be scheduled later in May to discuss the impact of geologic and environmental hazards. The committee members were also invited to participate in the public information meetings set for May 8 and 29 on Hawaii and May 9 and 30 on Maui.

The meeting was adjourned at 4:00 pm.

DEAN NAKANO

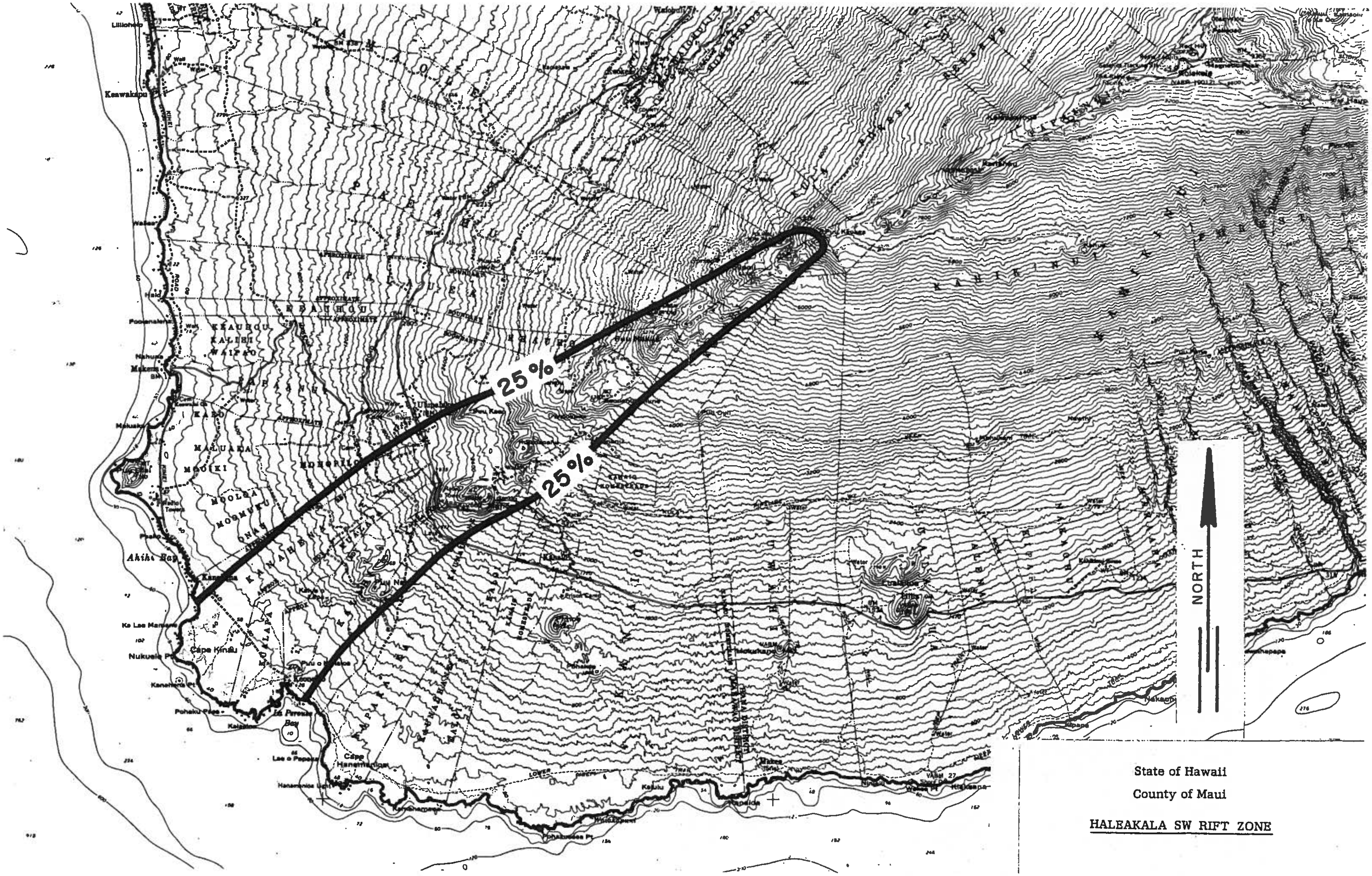
APPROVED:

MANABU TAGOMORI



HIGH TEMPERATURE POTENTIAL GEOTHERMAL RESOURCE AREAS

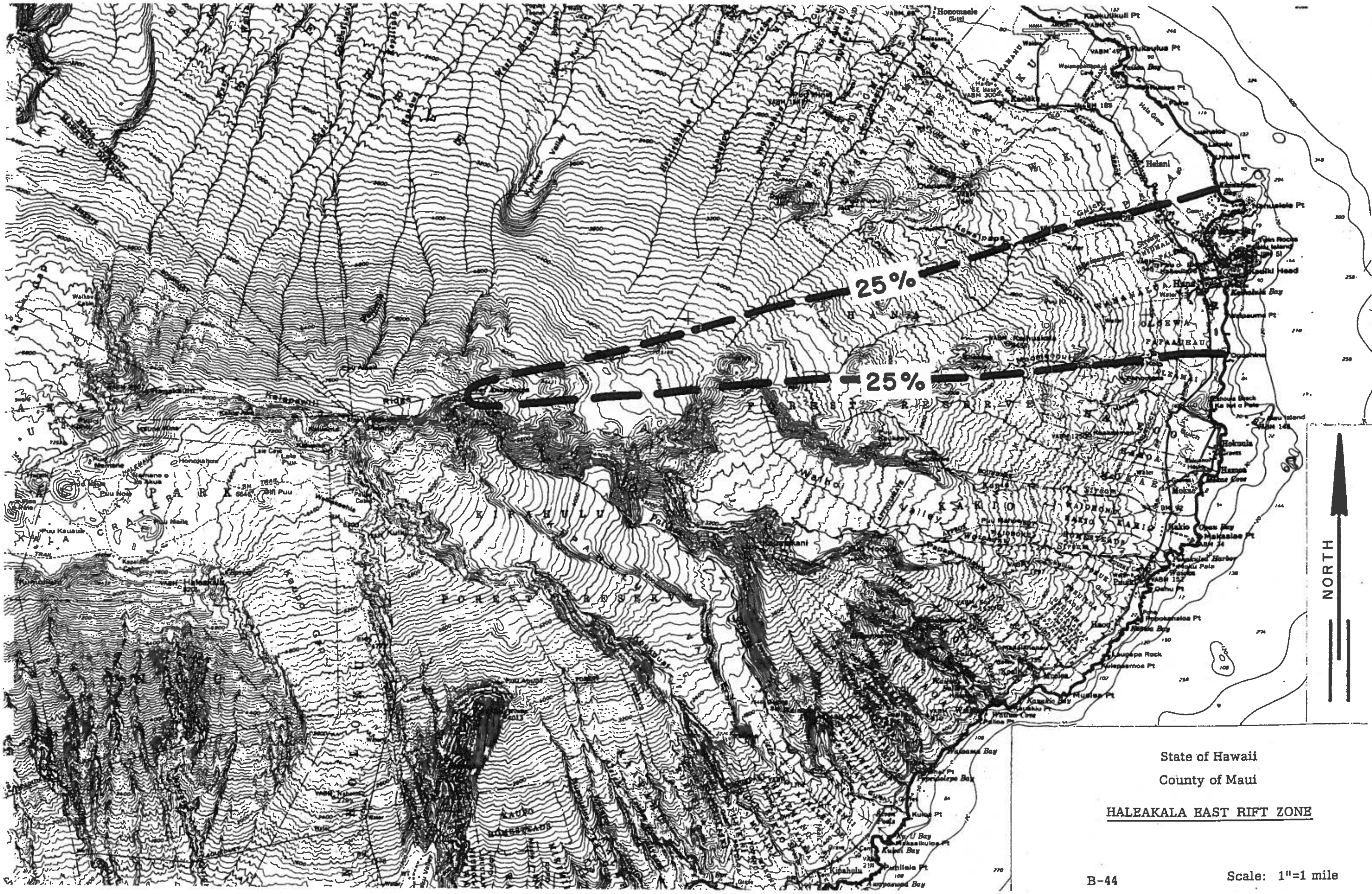
Island of Maui



State of Hawaii

County of Maui

HALEAKALA SW RIFT ZONE



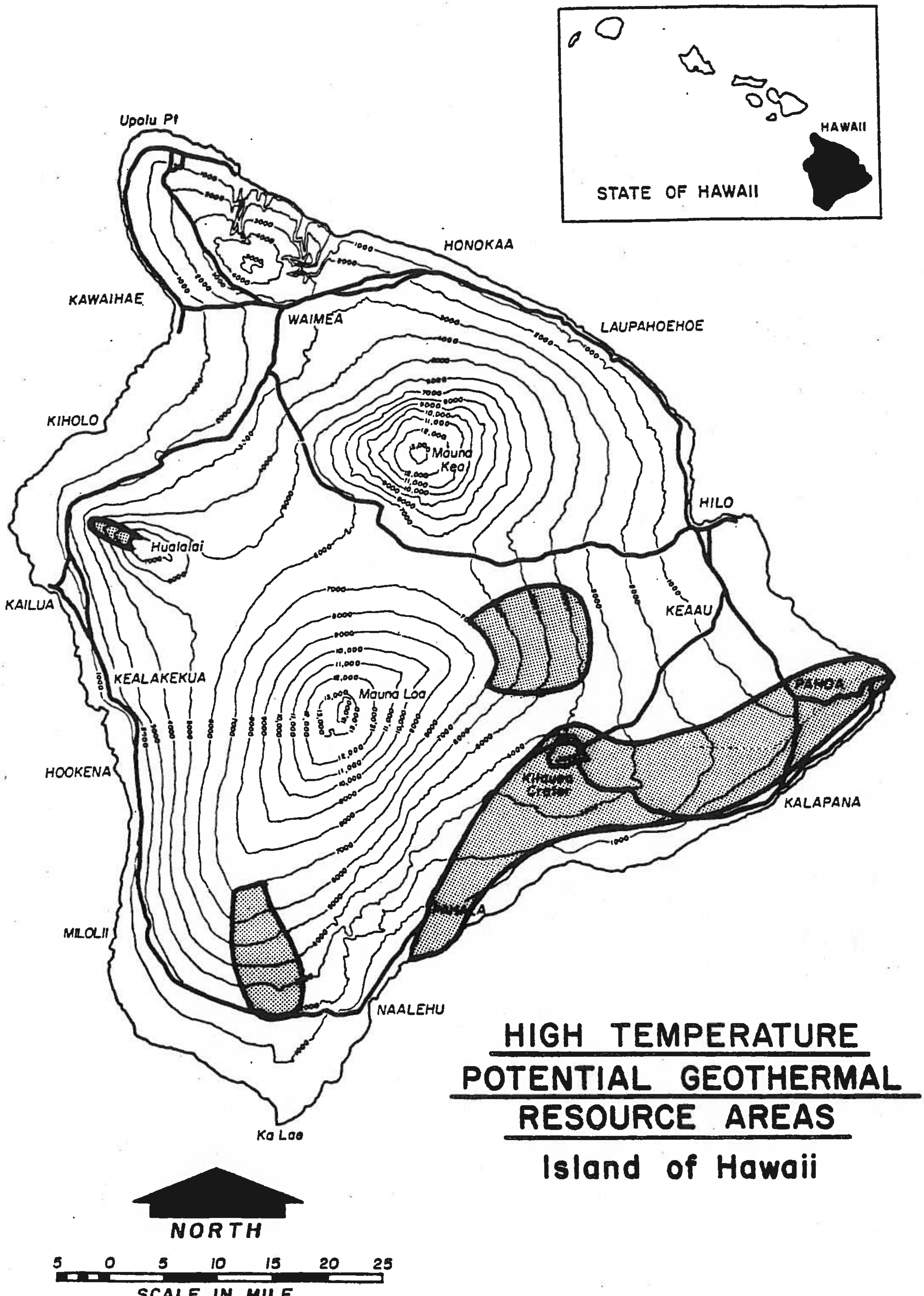
State of Hawaii

County of Maui

HALEAKALA EAST RIFT ZONE

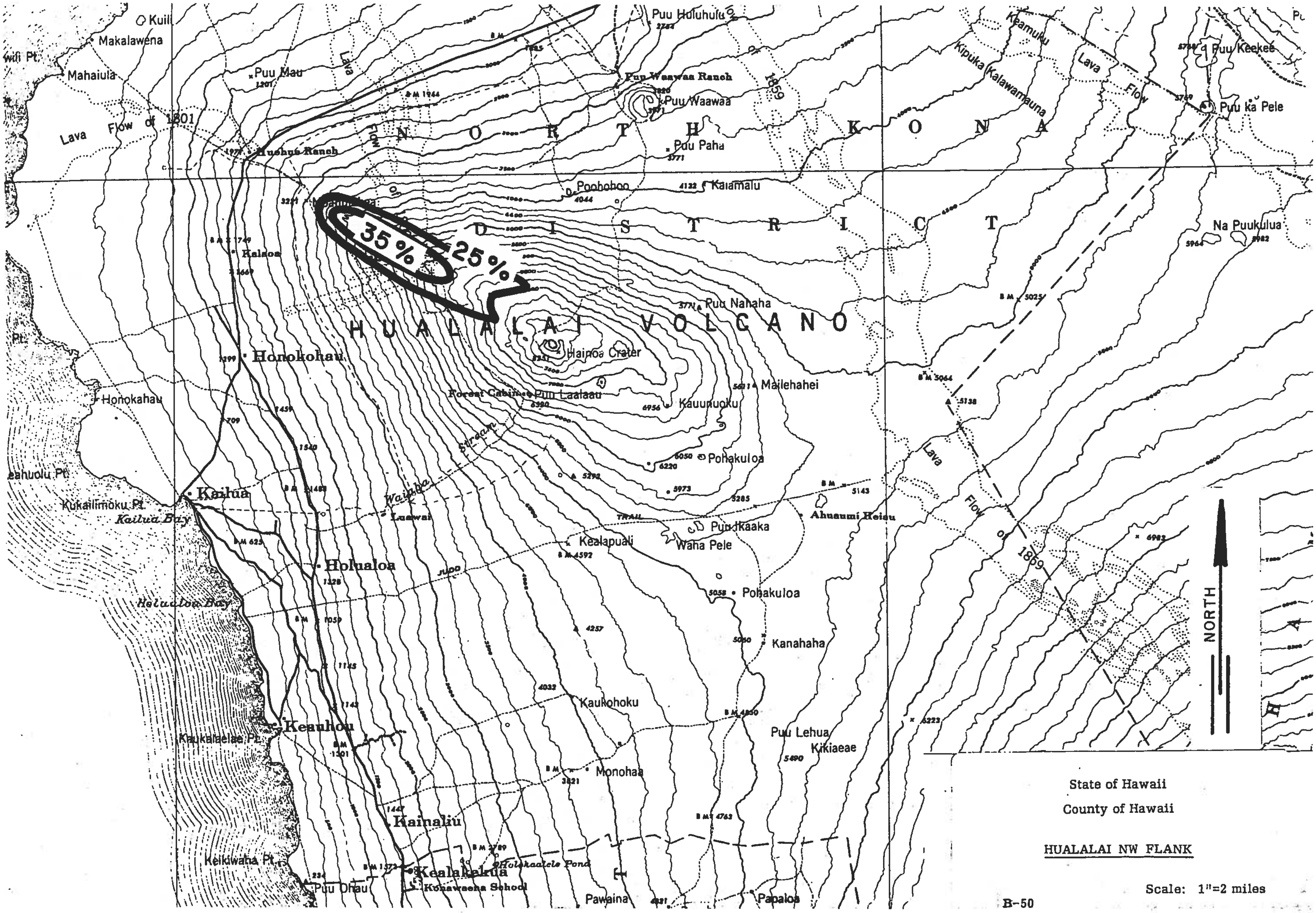
B-44

Scale: 1"=1 mile



HIGH TEMPERATURE POTENTIAL GEOTHERMAL RESOURCE AREAS

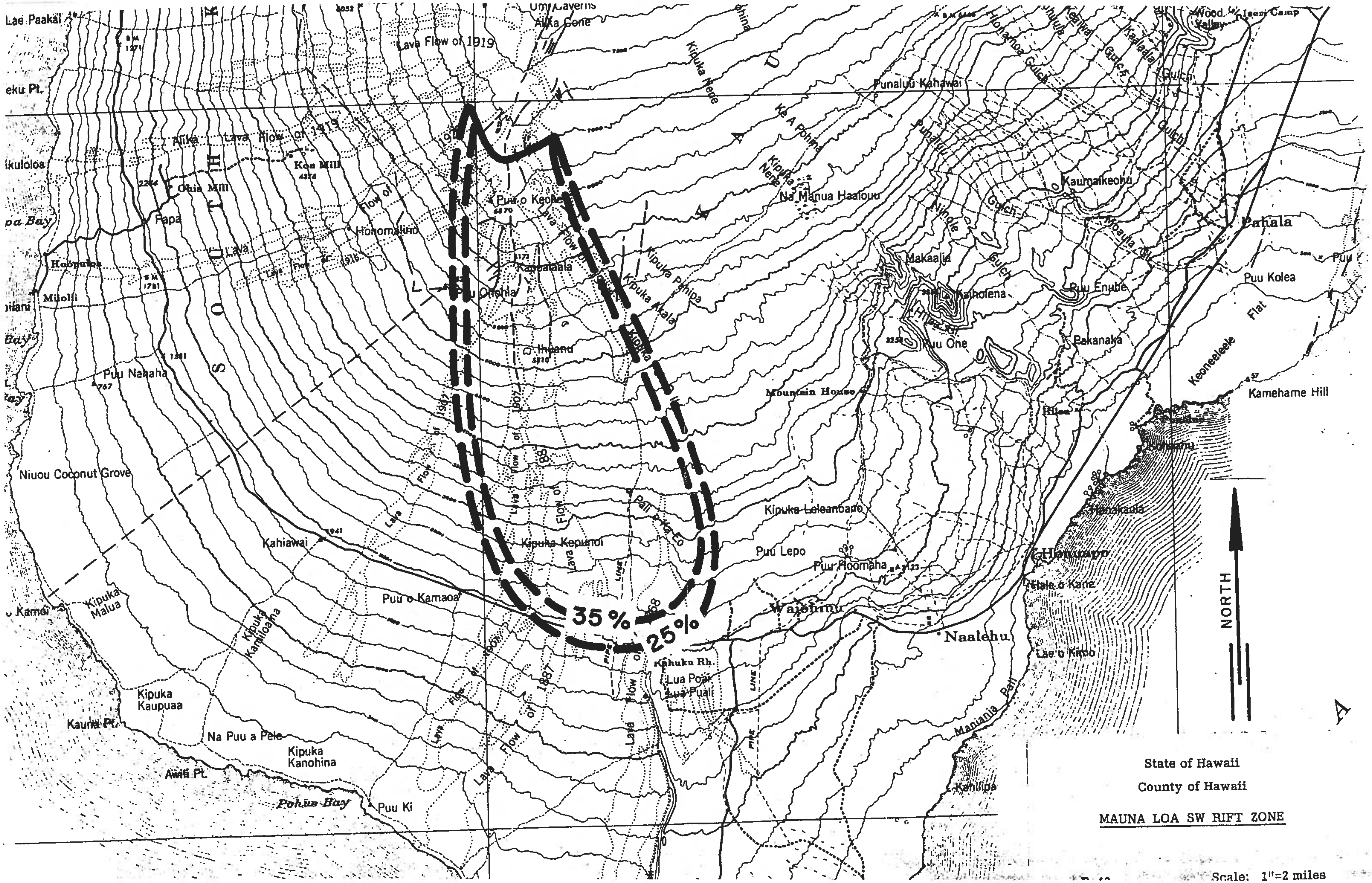
Island of Hawaii



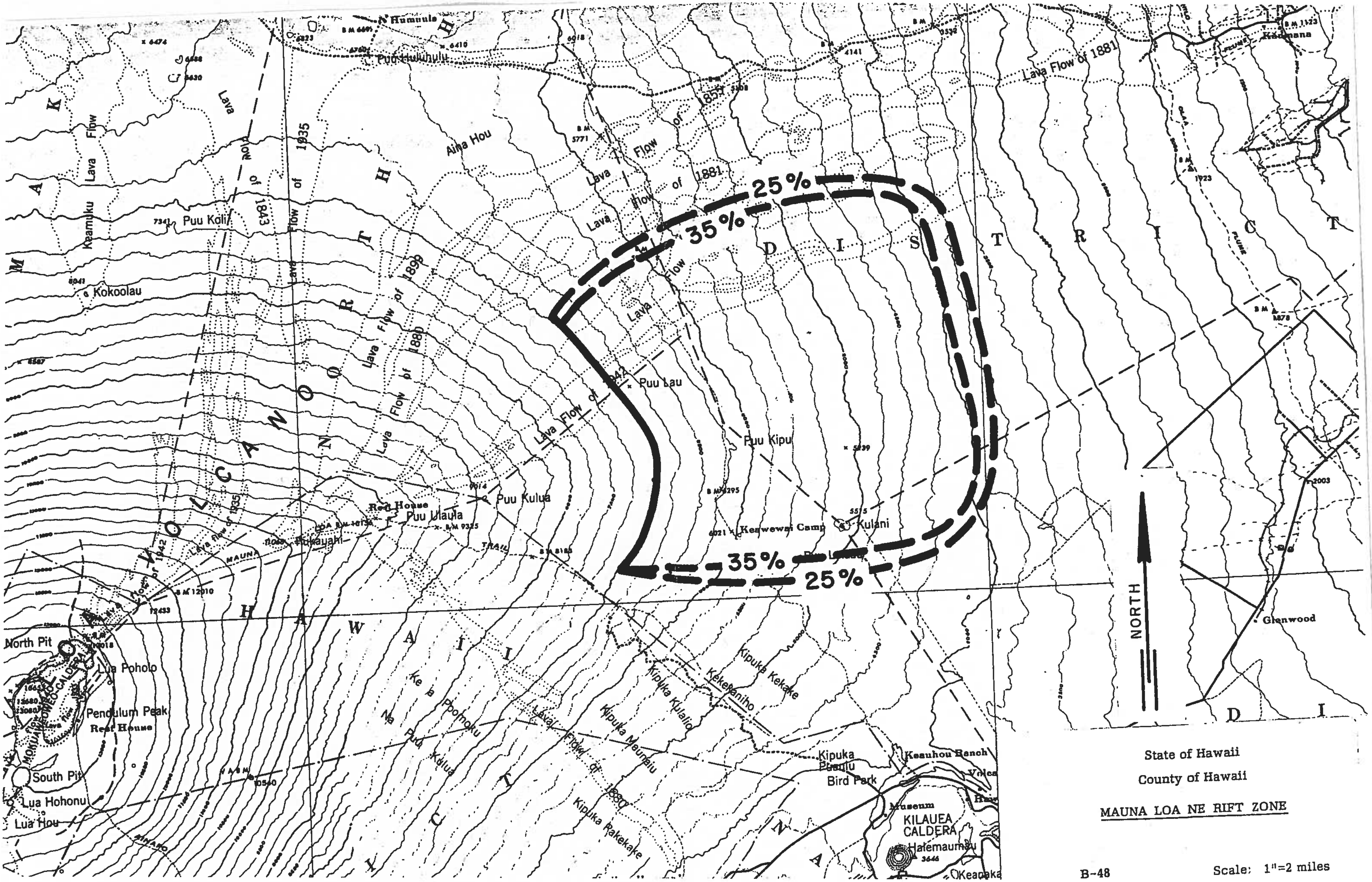
State of Hawaii
County of Hawaii

HUALALAI NW FLANK

Scale: 1"=2 miles



State of Hawaii
County of Hawaii
MAUNA LOA SW RIFT ZONE
Scale: 1"=2 miles



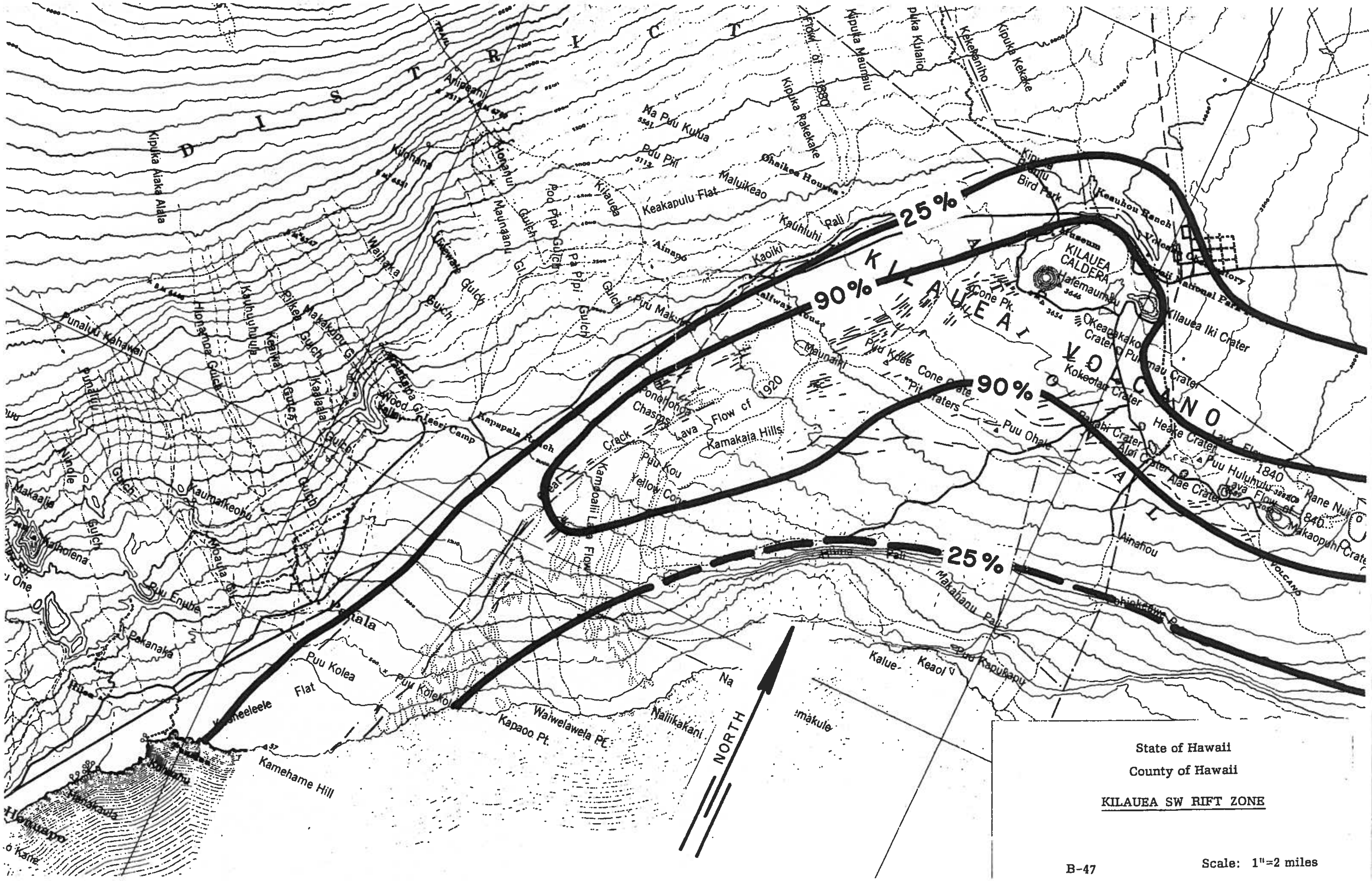
State of Hawaii

County of Hawaii

MAUNA LOA NE RIFT ZONE

B-48

Scale: 1"=2 miles

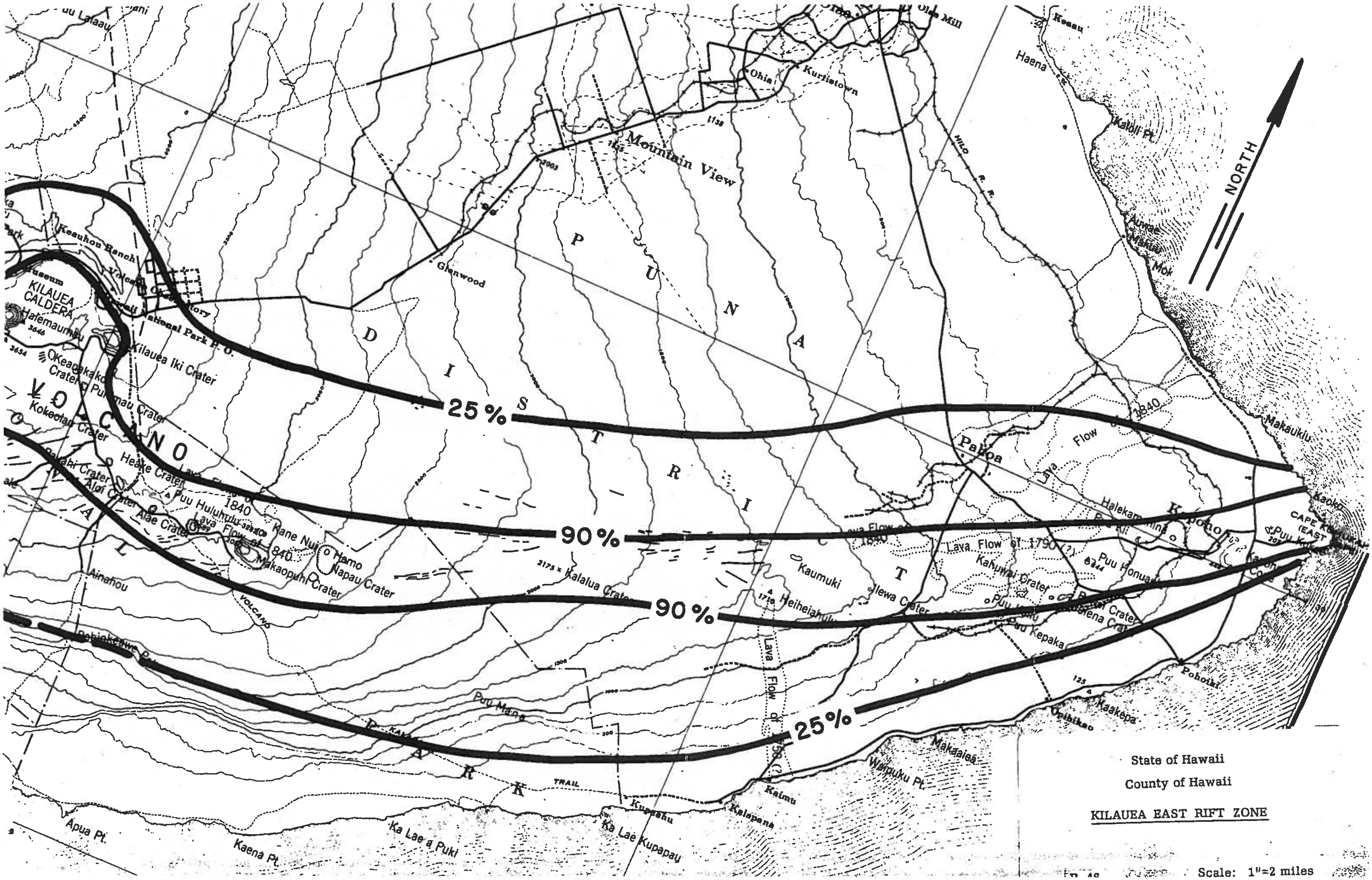


State of Hawaii

County of Hawaii

KILAUEA SW RIFT ZONE

Scale: 1"=2 miles


NORTH
KILAUEA CALDERA
Kilauea Iki Crater
Keauhou Ranch
Puu Puai
Kokoolau Crater
Heake Crater
Puu Huluhulu
Lava Flow of 1840
Alae Crater
Aloi Crater
Pauahi Crater
Ainahou
Kane Nui o Hamo
Napau Crater
Makaopuhi Crater
Kalalua Crater
Heiheiahulu
Kaumuki
Puu Kepaka
Puu Honuaula
Kahuwai Crater
Lava Flow of 1790 (?)
Lava Flow of 1750 (?)
Lava Flow
Halekamahina
Pahoa
Glenwood
Mountain View
Ohia
Kurtistown
Ola Mill
HILO R. R.
Haena
Keaau
Kaloli Pt.
Auwae
Mok
Makaukiu
Kaoko
CAPE KUMUKAHI (EAST)
Pohoiki
Kaakepa
Opihikao
Makaaiea
Waipuku Pt.
Kaimu
Kalapana
Kupahu
Ka Lae Kupapau
Ka Lae a Puki
Kaena Pt.
Apua Pt.
Puu Mana
TRAIL
VOLCANO
P U N A   D I S T R I C T
P A R K
25%
90%
90%
25%
State of Hawaii
County of Hawaii
KILAUEA EAST RIFT ZONE
Scale: 1"=2 miles

AGENDA

Geothermal Resources Technical Committee
Meeting No. 7

May 11, 1984
Hawaii Institute of Geophysics (Conference Room)
University of Hawaii
Honolulu, Hawaii

9:00 am Call to Order (Manabu Tagomori)

- Approval of Minutes
- Review of Potential Geothermal Resource Areas
  - High Temperature Areas (maps)
  - Low Temperature Areas (listing)
- Review of Public Information Meetings

12:00 Noon - Lunch

1:00 pm Continue Morning Session

- Discussion on Geologic Hazards
- Discussion of Other Impacts

3:00 pm Adjournment

MINUTES

Geothermal Resources Technical Committee
Meeting No. 7

Date: May 11, 1984

Time: 9:00 am - 10:00 Noon; 1:00 pm - 4:00 pm

Place: Division of Water & Land Development Conference Room

Participants: Manabu Tagomori, Chairman, DOWALD
Donald Thomas, HIG
Richard Moore, USGS
James Kauahikaua, USGS
John Sinton, HIG
Joe Kubacki, DOWALD
Dean Nakano, DOWALD

Agenda is attached.

Morning

Manabu Tagomori called the meeting to order at 9:10 am. The Committee was asked to comment on the minutes of the previous meetings and review the lines drawn for the potential geothermal resource area maps.

Mr. Tagomori discussed the recent public participation and information meetings held at Hilo, Hawaii on May 8, 1984 and at Kahului, Maui on May 9, 1984. Dr. Thomas stated that public comments were received regarding direct heat use (e.g. food processing), and for the identification of areas capable of this type of heat application.

The next public informational meetings are scheduled for May 29 and 30, 1984 on Hawaii and Maui, respectively. Mr. Tagomori stated that additional informal meetings are tentatively planned for both islands sometime in mid-June. These meetings are to be scheduled in conjunction with the local community association meetings held in each respective area. It was further noted that public hearings on the Administrative Rules on the Designation and Regulation of Geothermal Resource Subzones are to be held on all islands on May 22, 1984.

Copies of the "Reconnaissance Geological Investigations of Geothermal Energy Potential of Kohala, Lanai, and West Molokai Volcanoes, Hawaii" report by L. T. Grose, submitted to the Department of Land and Natural Resources by Mr. Ed Craddick were distributed to members of the Committee. It was recommended that Committee members review this additional data prior to continuation of the Technical Committee meeting at 1:00 pm today.

Afternoon

The meeting was reconvened by Manabu Tagomori and the technical group began its review of the report by L. T. Grose, dated January 24, 1978. The Committee concluded that the report did not contain any significant new data regarding Kohala, Lanai and Molokai and that the Committee's earlier conclusions would not have to be changed.

Upon evaluation of the complete list of percentages, the Committee selected seven High Temperature and five Low Temperature Potential Geothermal Resource Areas. The selection of a low temperature resource area was based on the area having an assessed probability of at least 15% chance of finding low temperature (less than 125°C) resource at depths less than 3 km. These low temperature resource areas were not mapped but are included in a list of the Committee's selections for potential geothermal resource areas that is attached.

The technical members began their review of the High Temperature Potential Geothermal Resource area maps based on the Committee's earlier conclusions. After some discussion by the Committee, it was noted that only those areas having an assessed probability of at least 25% chance of finding high temperature (greater than 125°C) resource at depths less than 3 km should be mapped. These revisions to the earlier maps would be made on the basis that any probability lower than that value would be so small that there would be little justification to accurately draw a probability boundary line. These revised maps are to be attached to the amended minutes for meeting No. 6.

Dr. Thomas was asked to define the use of hashed lines versus solid lines in the mapping of certain potential geothermal resource areas. It was stated that due to the limited data available, there was less justification to clearly draw a solid boundary line locating the resource area.

The Technical Committee reviewed a complete tabulation of the percent probabilities for the State of Hawaii. This county-by-county assessment based on the potential for high and low temperature resource is attached.

Mr. Tagomori asked the Technical Committee to discuss the impacts of geologic hazards, specifically earthquakes and lava flows, on the selected potential geothermal resource areas.

It was noted that earthquakes having a magnitude 6.0 or greater should be taken into consideration. Since 1951, four significant earthquakes have occurred, ranging in magnitude from 6.2 to 7.2 on the Richter scale. The Committee agreed that while earthquakes are a definite hazard, it would be extremely difficult to accurately predict their occurrence or potential damage.

Historic lava flows were discussed with regard to their duration and areal extent. It was noted that while elevated ground should be considered for power plant locations, evidence indicates that selection of high ground is not entirely safe from inundation by lava flows. The pattern of eruptions along the Kilauea East Rift Zone suggests a migration of eruptive vents, but the actual location of future vents cannot be accurately predicted.

Dr. Thomas suggested that while inundation by lava flows is a definite concern, more consideration should be given to the potential loss of electrical power from damage to the power plant. It was noted that the assessment of geologic hazards could be based on a power loss criteria, where a predetermined concentration of power production (e.g. 50 MW within a 1000-acre parcel), should not exceed the replaceable amount of electricity that the utility company could restore through alternate means during a power plant shut-down.

The Committee agreed that since all surface lava flows have occurred within the last 1000 years and strictly on the basis of geologic time, the Kilauea rift zone should be considered active. Although past history of events could give some idea of what could occur, it would be difficult to accurately predict the future occurrence of geologic hazards with any degree of scientific certainty.

Mr. Tagomori thanked the Committee for their continued assistance in this assessment phase, and suggested that a future meeting be held sometime in June after the May 29 and 30 public participation and information meetings. A tentative date was set for June 8, 1984 in Honolulu.

The meeting was adjourned at 4:00 pm.

DEAN NAKANO

APPROVED:

MANABU TAGOMORI

POTENTIAL GEOTHERMAL RESOURCE AREAS

HIGH TEMPERATURE RESOURCE AREAS (greater than 125°C at depths less than 3 km)

	Percent Probability
Maui:	
Haleakala S.W. Rift Zone	25% or less
Haleakala East Rift Zone	25% or less
Hawaii:	
Hualalai	35% or less
Mauna Loa S.W. Rift Zone	35% or less
Mauna Loa N.E. Rift Zone	35% or less
Kilauea East Rift Zone	Greater than 90%
Kilauea S.W. Rift Zone	Greater than 90%

LOW TEMPERATURE RESOURCE AREAS (less than 125°C at depths less than 3 km)

Statewide	Percent Probability
Waianae, Oahu	15% or less
Olowalu-Ukumehame, Maui	75% or less
Kawaihae, Hawaii	45% or less
Mauna Kea N.W. Rift Zone, Hawaii	Less than 50%
Mauna Kea East Rift Zone, Hawaii	Less than 30%

PERCENT PROBABILITIES

(County-by-County)

Island/Area	High Temperature (greater than 125°C at depths less than 3 km)	Low Temperature (less than 125°C at depths less than 3 km)
KAUAI	Less than 5%	Less than 5%
OAHU		
Waianae	Less than 5%	15% or less
Koolau	Less than 5%	Less than 10%
MOLOKAI	Less than 5%	Less than 5%
LANAI	Less than 5%	Less than 5%
MAUI		
Olowalu-Ukumehame	Less than 15%	75% or less
Lahaina-Kaanapali	Less than 5%	Less than 5%
Honolua	Less than 5%	Less than 5%
Haleakala S.W. Rift	25% or less	35% or less
Haleakala N.W. Rift	Less than 5%	Less than 10%
Haleakala East Rift	25% or less	35% or less
HAWAII		
Kawaihae	Less than 10%	45% or less
Hualalai	35% or less	70% or less
Mauna Loa S.W. Rift	35% or less	60% or less
Mauna Loa N.E. Rift	35% or less	60% or less
Kohala	Less than 5%	Less than 10%
Mauna Kea N.W. Rift	Less than 20%	Less than 50%
Mauna Kea East Rift	Less than 10%	Less than 30%
Kilauea S.W. Rift	Greater than 90%	Greater than 90%
Kilauea East Rift	Greater than 90%	Greater than 90%

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

SUSUMU ONO, CHAIRMAN
BOARD OF LAND & NATURAL RESOURCES

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STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF WATER AND LAND DEVELOPMENT
P. O. BOX 373
HONOLULU, HAWAII 96809

AGENDA

Geothermal Resources Technical Committee
Meeting No. 8

June 8, 1984
Hawaii Institute of Geophysics (Conference Room)
University of Hawaii
Honolulu, Hawaii

9:00 am Call to Order

- Approval of Minutes
- Review of Draft Committee Report

10:00 pm Adjournment

MINUTES

Geothermal Resources Technical Committee
Meeting No. 8

Date: June 8, 1984
Time: 9:00 am - 12:00 Noon
Place: HIG Conference Room, University of Hawaii

Participants:
Manabu Tagomori, Chairman, DOWALD
Donald Thomas, HIG
Daniel Lum, DOWALD
John Sinton, HIG
Richard Moore, HVO
Bill Chen, UH-Hilo
Joe Kubacki, DOWALD
Dean Nakano, DOWALD

Manabu Tagomori called the meeting to order and briefly reviewed the Departmental activities underway for the Committee's general information.

* S.B. 2184-84 was signed into law on May 23, 1984 and is now Act 151. The new law contains a "grandfather clause" which automatically subzones an existing BLNR geothermal mining lease area having a county special use permit.

* Public hearings on the Administrative Rules held in each county on May 22, 1984 and public information and participation meetings held on Hawaii and Maui on May 29 and 30 respectively. Additional meetings have been scheduled for July 10 and 11 with the Pahoa and Volcano Community Associations.

* Briefing of the Board of Land and Natural Resources will be held on June 21 and preliminary subzone designations and site specific public hearings are tentatively scheduled for sometime in August.

The first draft of the Statewide Geothermal Resource Assessment report mailed prior to the meeting was briefly discussed. Dean Nakano highlighted the draft report for discussion purposes. Don Thomas noted that for consistency, we should standardize the probability percentages by using "% or less" rather than just a sole "%" figure. The committee agreed to revise the table on percent probabilities as a result of these changes.

It was also recommended that wherever possible geothermal resource area maps should depict two boundary lines of percent probablity. This additional information would be valuable during the impact analysis and preliminary subzone designation by the Board of Land and Natural Resources.

A final draft will be mailed to each member and at that time signatures will be sought from the committee members.

Mr. Tagomori thanked the committee for their valuable time and asked for continued assistance during the entire assessment study. He advised the members that any future meetings would be on an on-call basis.

The meeting was adjourned at 12:00 noon.

DEAN NAKANO

APPROVED:

MANABU TAGOMORI

APPENDIX C

BIOGRAPHIES OF TECHNICAL COMMITTEE MEMBERS

MANABU TAGOMORI
3035 Hiehie Street
Honolulu, Hawaii 96822

- Born and raised in Kahului, Maui.
- Educated at Kahului School and Baldwin High School on Maui and graduated from the University of Hawaii at Manoa in 1957 with a Bachelor of Science degree in Civil Engineering.
- Registered Professional Engineer in Hawaii.
- 1957-1959, employed as design engineer with the Hawaii Water Authority.
- 1959-1972, served as design and project planning engineer with the Division of Water and Land Development, Department of Land and Natural Resources.
- 1973-1976, appointed the Study Manager of the Hawaii Water Resources Regional Study by the U. S. Water Resources Council.
- 1977-1978, appointed the Executive Secretary of the State Water Commission.
- In January 1979, appointed to present position as Chief Water Resources and Flood Control Engineer with the Division of Water and Land Development, Department of Land and Natural Resources.
- Member of the American Society of Civil Engineers
  Member of the National Society of Professional Engineers
  Member of the American Water Works Association
  Member of the American Public Works Association

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CURRICULUM VITAE

Donald Mattson Thomas

Personal

Born: 18 May 1948, Bethesda, Maryland

Education

1966–1970 Dickinson College: B.S., Chemistry, Physics (Graduated Cum Laude)

1970–1972 Oregon Graduate Center: M.S., Electrochemistry
Thesis: The Pressure Dependence of Hydrogen Absorption on a Platinum Electrode

1973–1977 University of Hawaii: Ph.D., Chemistry
Thesis: An isotopic Profile of Gases From the Summit and Flank of Kilauea Volcano

Active Research Specialization

Volcanic gas geochemistry: determination of isotopic and elemental compositions of fumarolic and eruptive gases as a means of identifying the ultimate sources of volcanic volatiles (e.g., meteoric waters, mantle outgassing, etc.), as well as a means of monitoring quiescent and eruptive processes in the volcanic pile. Also of interest are the effects of volcanic outgassing on global atmospheric budgets of natural and anthropogenic pollutants.

Geothermal exploration geochemistry: determination of chemical and isotopic composition of groundwaters and soil gases as tracers of leakage from geothermal reservoirs. The application of elemental and isotopic ratios of dissolved rare gases in the characterization of geothermal reservoirs.

Geothermal production geochemistry: interpretation of the chemical and isotopic composition of geothermal production fluids in terms of reservoir production characteristics, production aquifers/fluid sources, scaling/corrosion characteristics and potential environmental impacts.

Current Research

Western States Cooperative, Direct Heat Resource Assessment Program, Year IV, Department of Energy, Principal Investigator/Project Manager.

HGP-A Wellhead Generator Proof of Feasibility Project, Department of Energy, Principal Investigator: Geochemistry, Environmental Monitoring.

RESUME

NAME	Bill H. Chen
PRESENT POSITION	Associate Professor and Chair Computer Science and Engineering College of Arts and Sciences University of Hawaii at Hilo
EDUCATION	Ph.D., University of Rochester, 1970 M.S., University of Rochester, 1968 B.S., National Taiwan University, 1963

EMPLOYMENT EXPERIENCE

1979-present	Associate Professor and Chair, Engineering and Computer Science, University of Hawaii at Hilo
1977-1979	Geothermal Energy Project Manager, Center for Science Policy and Technical Assessment, Department of Planning and Economic Development, State of Hawaii
1977-1982	Acting Project Manager, Assistant Project Manager and Project Manager, HGP-A Geothermal Wellhead Generator Project (Total project cost - $10 million)
1975-1977	Associate Professor, Engineering and Computer Science, University of Hawaii at Hilo
1971-1975	Assistant Professor, Engineering and Computer Science, University of Hawaii at Hilo
1969-1971	Assistant Professor of Mathematics, Greater Hartford Community College
1968-1969	Research Assistant, University of Rochester
1966-1968	Teaching Assistant, University of Rochester
1964-1966	Teaching Assistant, National Taiwan University

VITAE-SUPPLEMENT

NAME: Bill H. Chen AGE: 41

MARITAL STATUS: Married DEPENDENT : 1 Son

HOME ADDRESS: 137 South Wilder Road, Hilo, Hawaii 96720

HOME TELEPHONE: (808) 935-7897

OFFICE: University of Hawaii at Hilo
1400 Kapiolani Street
Hilo, Hawaii 96720

OFFICE TELEPHONE: (808) 961-9388

OTHER EDUCATIONAL EXPERIENCES:

1. Completed a two-week course in Applied Reservoir Engineering offered by Applied Reservoir Engineering School, Oile and Gas Consultants International Inc., Newport Beach, California, May, 1974.

2. Completed a four-day course in Project Management offered by University of Hawaii College of Continuing Education and Community Service, Honolulu, Hawaii, March, 1979.

3. Completed a three-day technical training course in basic Geothermal Drilling and Completion Technology offered by Geothermal Resources Council, Albuquerque, New Mexico, March, 1980.

GEOTHERMAL EXPERIENCE IN SUMMARY:

1. Reservoir Engineer with Hawaii Geothermal Project, University of Hawaii, 1973-1977. Primary responsibility in well test equipment procurement and construction, wel tests and reservoir engineering analysis. Also participated in well drilling discussions.

2. Geothermal Energy Project Manager, State of Hawaii Department of Planning and Economic Development, 1977-1979. Primary responsibility in assisting procurement of Federal funding for (a) HGP-A Wellhead Generator Project ($10 million); (b) Statewide Geothermal Assesment ($600,000); (c) State of Hawaii Geothermal Commercialization Plan ($100,000).

3. Acting Project Manager, HGP-A Wellhead Generator Project, Jan.-June, 1978. Primary responsibility in procuring governmental permits, preparing environmental impact statement, negotiating contracts with U. S. Department of Energy, selecting engineering design

services and selecting environmental monitoring services.

4. Assistant Project Manager, HGP-A Wellhead Generator Project, 1978-1981. Primary responsibility in technical assistance on reservoir and wellhead equipment design and procurement, environmental monitoring, well workover and plant operations.

5. Project Manager, HGP-A Wellhead Generator Project, Aug. 1981-Oct., 1982. Overall responsibility in start-up operation and maintainance of the power plant.

6. Consultant to Feasibility Study on Utilizing Geothermal Energy in Sugar Processing, Amfac Corporation, Puna Sugar Company, 1979. Primary responsibility in providing well fluid estimation.

7. Consultant to Feasibility Study on Geothermal Industrial Park at Puna, Dillingham Corporation, 1980. Primary responsibility on geothermal reservoir and production estimation, geothermal heat pricing structure, and geothermal heat in papaya processing, wood-kiln processing and coffee processing.

8. Visiting Lecturer to University of Auckland Geothermal Institute, June, 1981 and Visiting Scientist to Department of Scientific and Industrial Research, Taupo, New Zealand, June-July, 1981.

9. Co-principal investigator on "Utilization of Geothermal Energy in Tropical Fruit Processing," with L. P Lopez, funded by State of Hawaii Department of Planning and Economic Development, 1982.

10. Principal investigator on "Interference and Well Test Analysis of Kapoho Geothermal Reservoir," funded by Hawaii Natural Energy Institute, 1981-1983.

11. Principal Investigator on "Scaling and Corrosion Study of Heat Exchangers using Geothermal Waste Water," funded by Hawaii Natural Energy Institute, 1983-1984.

12. Member of State of Hawaii Geothermal Advisory Committee since 1978.

13. Member of the State of Hawaii Department of Land and Natural Resources Technical Committee to designate geothermal subzones for the state, 1984.

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U.S. Department of the Interior
Geological Survey
Geologic Division

PROFESSIONAL/TECHNICAL PERSONNEL RECORD

NAME (last)	(first)	(initial)	2. Duty station	3. Date prep
Jackson	Dallas	B.	Hawaiian Volcano Observ.	Feb. 1984

Birth date	(month)	(day)	(year)	5. Classification title	Series	Grade
	January	19	1933	Geophysicist	1313	13

List first and second scientific or technical specialties

a. Geophysical Exploration

b. Volcanology

Other scientific, technical, or special skills (regardless of relation to present position)

8. Education (include secondary schools)

School	Dates attended	Major and minor specializations	Degree, year or anticipated y
Univ. of Colorado	1951-53, 1956-58	Geology	B.A., 1958
Univ. of Colorado	1959-1960	Geology-Geophys.	
Colo. School of Mines	1963	Geophysics	

9 Specialized training (including postgraduate and Government courses)

10. Civil Service grades and dates

Check if career employee [x]

Grade*	5	7	9	11	12	13				
Date	11/58	7/61	12/62	1/67	12/69	8/75				

*Use asterisk for any grade obtained in a management or other nonresearch capacity above GS-12

11 List or describe any information and (or) experience not covered on form that might affect career assignment

12a. Memberships in professional societies. List, give dates, and include significant offices held.

Sigma Gamma Epsilon - 1960 to present
Society of Professfonal Well Log Analysts - 1968 to 1974
American Geophysical Union - 1974 to present
Geothermal Resources Council - 1979 to 1982

12b. Lectureships, symposia, invited conference participation. Give dates, nature of entry (were you sought out or did you apply to partic and level of participation.

Symposium on electrical geophysical techniques applied to geothermal exploration. Snowbird, Utah, 1977. Invited attendance; gave poster session on Coso Hot Springs, California.

12c. Committees to render scientific judgment. Include scientific review panels, editorial boards, editorships, with dates. Include the cap which you served (chairman, subcommittee chairperson, member, observer, expert consultant, etc.).

12d. Other committees, special assignments, significant consultant roles (government and (or) industry). Name organization, group, dat nature of contribution.

Visiting professor, University of Clermont II, Clermont-Ferrand, France. April to October 1982.

Consultant and advisor from June to September, 1982, on volcanic surveillance techniques at the French Observatoire Volcanologique de la Reunion, Indian Ocean.

List inventions, patents held, techniques or methods developed or improved. Include dates.

1969-1971. Developed the technique for "dry tilt" measurements used for ground deforamtion studies at the Hawaiian Volcano Observatory. The technique is now used routinely in various volcanic areas throughout the world.

1982. Developed a new type of portable break-down tilt rod system for use at Piton de la Fournaise where all equipment must be backpacked to remote "dry tilt" sites. Because of the assymetric nature of a rod set a technique for temperature corrections to compensate for varying coefficients of expansion of individual rods was also developed.

Honors, awards, recognition, elected membership. List and give dates.

Best presentation award for mining session, 38th annual International SEC meeting.

1968, Denver, CO., paper by Zohdy, A.A.R., Jackson, D.B., Mattick, R.E., and Peterson, D.L., Resistivity, seismic refraction, and gravity investigations for ground water near White Sands, New Mexico.

US Geological Survey, 1959, Special Achievement Award

US Geological Survey, 1974, Special Achievement Award

Career experience: (Use separate sheet, follow form below. List chronologically starting as early as necessary to include pertinent informat Include significant committee and administrative assignments.)

Dates: From	Dates: To	Brief description of work or position (if USGS, give name of supervisor and organization.)

See attached

Bibliography: Use separate sheet and list all report references chronologically in USGS bibliographic style. Number each entry followed the proper publication code: (P) published report; (M) published map; (O) open-file; (A) published abstract; (Ad) administrative report. manuscripts "in press" give number of manuscript pages and intended publication medium. Progress reports, Work Plans and Accomp ments, and similar reports should not be included. See attached

Significant contributions: On single separate sheet, list your 3 most important publications in normal bibliographic style and describe scientific significance of your contrubution to the publication; do not repeat an abstract. Do not use results of a scientific investigation will not be published in the future. In describing each of these, include the following: a) statement of results (conclusions); b) signific of results (your feeling of worthiness); c) impact on field; d) for multiauthored papers, discuss what your actual contribution consiste Significant contributions which are not part of normal project work may be listed in place of a publication. Items included should be your last promotion or within the last 5 years (whichever is shorter). This item is increasing in importance in Office and Division level mee It is to your own advantage to write it up as carefully and accurately as possible. See attached

Statement of career goals (optional)
If you wish to provide information on types of assignments, geologic specializations, additional education, geographic, or organiza locations you would like to, or plan to, have in the future or any other information having to do with your career, please write not than 2 pages on it. See attached

Dallas B. Jackson

13. Career Experience continued:

From	To	Nature of Work
11/58	7/61	Geologic Field Assistant, Geophysics Branch. Attended graduate school part time. Reduced data for professional geophysicists in the branch. Conducted field geophysical surveys under the guidance of a professional. Shared the responsibility for data collection, reduction, during 5 months of IGYC (International Geophysical Year Continued) on Ice Island T-3. Responsible for navigation of Ice Island T-3.
7/61	7/65	Geologist, Branch of Theoretical Geophysics and later Crustal Studies. Louis Pakiser, Branch Chief. Persons supervised -0 to 2. Well log studies of overburden to bedrock in western Nebraska, Colorado, and eastern Utah. The well log studies served as background for very deep DC resistivity studies in the western and mid-western US. Under the supervision of G.V. Keller I was responsible for geophysical survey, interpretation, and publication of the data from the western US. These data, plus other deep soundings funded by the BPA and using Arizona, Nevada, and California power grids for current sources were the first DC soundings to demonstrate the presence of a deep crustal conductor in the US.
7/65	6/67	Geologist, Branch of Regional Geophysics. Don Mabey, Branch Chief. Team member and part time principle investigator for numerous DC resistivity surveys to solve various structural and lithologic problems related to ground water distribution. Many surveys defined deep, fresh-water bodies over saline water in the Basin and Range Province. Surveys were made in numerous lithologic environments throughout the mainland US and in Hawaii. As well as studying water resources problems (all funding for these surveys was WRD) research and development on the improvement of DC resistivity sounding techniques. Schlumberger and dipole arrays, was an integral part of the electrical profiling and mapping surveys. Supervised 0-5 people. Work directed by project chief Adel Zohdy.

13. Career Experience continued:

From	To	Nature of Work
6/67	6/68	Geologist, Branch of Regional Geophysics. Branch Chief Don Mabey. Principle investigator for electrical surveys in Grass Valley California area to evaluate usefullness of DC techniques to map lateral boundaries and depth of gold bearing paleochannels. This was part of a multidiscipline survey to compare the usefulness of aeromag., IP, EM resistivity, DC resistivity, gravity, and reflection seismology. DC resistivity defined lateral boundaries marginally well but defined paleo-channel depth to about + 15% (as well or better than any other technique except refraction profiling). Project Chief Howard Oliver. Participated in the first electrical measurements over shallow geothermal targets in Yellowstone and in 2 more ground water related surveys: one in Alaska and one in Utah.
6/68	8/71	Geophysicist, Branch of Field Geochemistry and Petrology. Transferred to staff of Hawaiian Volcano Observatory. Scientist-in-charge, Howard A. Powers and later Don L. Peterson. Shared responsibility for ground deformation measurements and their inter-pretations for 3 rift eruptions and 1 summit eruption. Developed a spirit level tilt technique that allowed field tilt measurements to be made in the daytime or at night. Expanded the tilt network to cover Kilauea more thoroughly and improved the existing water-tube tilt system so measurements could be made in overcast weather. Initiated electrical studies at Kilauea by mapping thermal features with VLF EM techniques and was the principal investigator for a EM sounding survey of Kilauea's summit area that delineated a broad shallow conductor (> 1 km depth) that may be a geothermal system above a shallow magma reservoir. 0-1 person supervised.
8/71	3/73	Geophysicist, Branch of Reigonal Geophysics. Branch Chief Don Mabey. Transferred to Regional Geophysics Branch, Denver. Interpretation for publication of eruption and intrusion data collected at HVO. Modeled summit deformation data for magma reservoir depth, to map its location and depth, and studied migration patters of the reservoir. Evaluated all available deformation models for the summit (spherical source, vertical line source, tabular body, etc.) and concluded that the Mogi spherical source best explained observed deformation changes. Two satellitic magmatic chambers on the upper east rift zone were also identified. Part time work on field resistivity surveys for the ground water project; project chief Adel Zohdy. No people supervised.

13. Career Experience continued:

From	To	Nature of Work
3/73	1/78	Geophysicist, Branch of Regional Geophysics. Branch Chief Martin Kane. Principle investigator on ground water resistivity surveys in southern New Mexico to delineate areas of saline water; in eastern Washington to map basement configuration of the moscow-Pullman Basin; and unsuccessfully in western Washington to trace shallow aquifers in a complex sequence of thin, discontinuous sand and clay layers. --Shared responsibility for EM and DC resistivity surveys to target low resistivity regions related to geothermal areas in the Geysers geothermal field, California, and Long Valley, California and Raft River, Idaho. --Principal investigator for bipole-dipole and Schlumberg surveys to locate geothermal targets near Marysville, Montana and in the Bruno-Grandview area, Idaho. Principal investigator and project chief for AMT, telluric current, and DC resistivity studies at Cose Hot Springs, California to delineate the known geothermal resource and to investigate the surrounding region for new geothermal prospects. AMT proved to be the best tool in the Coso area for reconnaissance work although DC soundings best defined true resistivity values. 0-5 persons supervised.
1/78	1/82	Transferred to Hawaiian Volcano Observatory at Kilauea Volcano as a research geophysicist. Scientist-in-Charge: Gordon Eaton. Project supervisor for electromagnetic and galvanic geoelectrical studies on the island of Hawaii. --Mapped SW rift zone of Kilauea Volcano to Puu Koae delineating numerous self-potential anomalies related to geothermal phenomena. --Established and maintain numerous lines for self-potential monitoring on Kilauea Volcano. --Mapped with D.C. soundings the summit and upper rift zones of Kilauea to delineate areas of dike impounded groundwater. --Completed preliminary self-potential survey of Hualalai Volcano delineating a possible zone along the NW rift zone of geothermal potential. --Team member in an ELF (extra low freq.) loop-loop electromagnetic sounding survey of the summit and upper rift zones of Kilauea and to define the geoelectrical structure of Kilauea. --Established an electromagnetic vertical-field monitor at the summit of Kilauea to study direct sensing of magma movement and possible eruption-related precursors. --In cooperation with Hawaii Institute of Geophysics participated in a mise-a-la-masse survey to define the lateral extent of the HGP-a geothermal steam field in the Puna District.

Dallas B. Jackson

13. Career Experience continued:

From	To	Nature of Work
1/82	Present	Research Geophysicist. Branch of Igneous and Geothermal Processes. Branch Chief. Patrick Muffler. Scientist-in Charge since 1979. Robert Decker.

A portable dry-tilt system for use in highly inaccessable areas was designed and built in early 1982. The remainder of 1982 was spent in France and on Piton de la Fournaise in the Indian Ocean. A dry-tilt (spirit level) network was installed on Fournaise as the first step to setting up a ground deformation measurement program. At Kilauea ground tilt measurements are the most valuable tool to define centers of vertical displacement that may be precursive to eruptions. This has also proved to be true on Fournaise where ground displacements are negligable most of the time. The December 1983 eruption of Fournaise was preceeded by vertical uplift in the vicinity of the new eruptive fissures; precursive uplift was documented by tilt vectors before eruption began.

Principle investigator for geoelectrical studies at HVO. Research on self-potential (SP) source mechanisms at Kilauea. mapping of SP on Kilauea. Hualalai. and Mauna Loa volcanoes. Monitoring of SP changes on permanent arrays located over zones of high heat flux and continuation of a monitoring program for vertical magnetic field changes at 4 sensors located in and near the summit area. The measured magnetic fields are generated by a large horizontal source loop 1 km NW of the caldera and for convenience is called a controlled source electromagnetic monitor (CSEM).

The CSEM began in 1979 is ongoing and will be automated to an analog telemetry system in 1984. The monitor system. nearing completion. was designed and is being built at the Geophysics Branch electronics laboratory. Large CSEM anomalies have been identified related to intrusions in August 1980 and January 1981. The CSEM event in 1981 was precursive to the intrusion. Modelling experiments in December 1983 show that orthoginal horizontal coils added to the existing vertical coils at the monitor sites will increase the sensitivity of the monitors to emplacement of conductors (dikes) and may also add the capability of defining the direction to an intrusion relative to the monitor sensors.

Dallas B. Jackson

13. Career Experience continued:

From	To	Nature of Work
1/83	present-cont.	SP mapping of Hualalai volcanoe, ongoing since 1980 and to be compete in 1984, reveals high amplitude anomalies associated with the rift zone at the summit and down the NW rift zone to about the 1500 m elevation. Confirmatior of the existance of a conductor coincident with the SP high at the 1800 m elevation by EM techniques and anolog to SP relations at Kilauea suggests this may be an important, exploitable geothermal resource for west Hawaii.

PROFESSIONAL/TECHNICAL PERSONNEL RECORD

1. Name (last)	(first)	(initial)	2. Duty Station	3. Date Prepared
Kaushikaua	James	P.	Honolulu, HI	February 1984

4. Birth date (month)	(day)	(year)	5. Classification Title	Series	Grade
August	1	1951	Geophysicist	1313	12/4

6. List first and second scientific or technical specialities

a. (303) Electrical geophysics b. (603) Numerical methods for computation

7. Other scientific, technical, or special skills (regardless of relation to present position)

Proficiency in computer languages - APL, FORTRAN, BASIC, PASCAL, PL/1, HP-41C language
Photography
Auto mechanics
Scuba diver
Voice, guitar, piano trained
Reading knowledge of French and German

8. Education: (include secondary schools)

School	Dates attended	Major and minor specializations	Degree year or anticipated year
Kamehameha School	to 1969		H.S. Diploma
Univ. of So. California	1969-1971	Physics	
Pomona College	1971-1973	Geology	B.A. 1973
Univ. of Hawaii	1973-1976	Geophysics	M.S. 1976
Univ. of Hawaii	1978-1982	Geophysics	Ph.D. 1982

9. Specialized training (include post-graduate and government courses)

None

10. Civil Service Grades and dates — Check if career employee X

Grade	GS-9	GS-11	GS12
Date	12/76	11/78	10/80

11. List or describe any information and/or experience not covered on form that might affect career assignment.

Memberships in professional societies. List, give dates, and include significant offices held.

American Geophysical Union 1979-present
Society of Exploration Geophysicists 1978-present
Geothermal Resources Council 1979-1981
Assoc. for Computing Machinery 1972-1978
Hawaii Association of Professional Geologists 1982-present

2b. Lectureships, symposia, invited conference participation. Give dates, nature of entry (were you sought out or did you apply to participate?), and level of participation.

Invited symposium speaker on "Electromagnetic exploration methods for geothermal resources", Hawaii Natural Energy Institute, April 1980.

Invited speaker on "Use of Electrical-resistivity techniques for groundwater exploration", Hawaii Water Works Assoc., May 1983.

2c. Committees to render scientific judgement. Include scientific review panels, editorial boards, editorships, with dates. Include the capacity in which you served (chairman, subcommittee chairperson, member, observer, expert consultant, etc.).

Served on U.S. Geological Survey committee reviewing the non-seismic geophysics program at Hawaii Volcano Observatory, May,. 1982.

Served as a judge for Hawaii State High School Sience Fairs, 1982-1984.

2d. Other committees, special assignments, significant consultant roles (government and/or industry). Name organization, group, dates, and nature of contribution.

None

2e. List inventions, patents held, techniques or methods developed or improved. Include dates.

1977- developed a numerically stable technique for computing the coupling between two, very closely-spaced, finite length wires on a layered halfspace.

1980- developed a fast algorithm to compute EM fields about a polygonal-shaped, horizontal loop on a layered halfspace.

2f. Honors, awards, recognition, elected membership. List and give dates

Graduated cum laude, Pomona College, 1973
Awarded research assistantship, University of Hawaii, 1973-1976
Awarded USGS internship, 1977-1982

Career Experience

From	To	Nature of work
971	1973	(exd. summers) teaching assistant for various introductory geology courses at Pomona College.
973	1976	Research assistant, Hawaii Geothermal Project, University of Hawaii; Doug Klein, supervisor. Application of electrical geophysical methods to geothermal exploration in Hawaii. Involved planning small surveys, field work, gathering data using the following techniques: loop-loop frequency sounding, time-domain electromagnetic sounding, Schlumberger sounding, and direct-current bipole mapping. Master's thesis reported on a newly developed method to interpret the time-domain data. These results integrated with those from other disciplines were used to locate a successful geothermal well.
1/76	12/77	Geophysicist, Branch of Electromagnetism and Geomagnetism, Branch Chief: Frank Frischknecht. Research involving numerical modelling of electromagnetic techniques used as geophysical tools. Derived formulas and developed computer algorithms to compute the electromagnetic fields (both time and frequency domains) about a finite-length wire, the electric field very close to a wire (in a Schlumberger array, for example), and the electric field of a grounded wire on an earth model with complex (frequency-dependent) conductivities. Applied these programs to the interpretation of electromagnetic data obtained at Randsburg KGRA in California.
1/77	12/81	Geophysicist, Branch of Electromagnetism and Geomagnetism, and Hawaii Geothermal Resource Assessment Program, University of Hawaii. Proposed, planned and supervised completion of three joint projects of (USGS and UH): 1) geothermal assessment of five selected areas on Hawaii island using a combination of time-domain electromagnetic and Schlumberger sounding techniques; 2) mise-a-la-masse experiment using a geothermal well casing as the prominent electrode; 3) investigation of the use of VLF and EM loop-loop profiling for fast regional reconnaissance of volcanic terrain.
6/78	Present	Geophysicist, Branch of Electromagnetism and Geomagnetism; Branch Chief: Frank Frischknecht, Adel Zohdy; Project: Hawaii Geothermal Investigations, Project Chief: Charlie Zablocki. Completed two- and three-component magnetic field measurements at 45 locations about a large, controlled-source loop located in the summit region of Kilauea volcano, Hawaii. The original purpose was to map subsurface magma concentrations with this technique because of its sensitivity to magma's inherently low resistivity. Compilation of layered-earth interpretations for most of these soundings together with physical scale model results, show that the entire summit region is underlain by a thin, very conductive layer less than 2 km below the surface. Magma bodies below this layer are difficult or impossible to detect with this technique. The results of this experiment were reported in a PhD dissertation, June 82.

Partly on the basis of the above resuslts, an experiment to continuously monitor the summit region resistivity was begun i March, 1979 and has continued to present. Experiment could be an important tool with which to predict volcanic eruptions because it relies on entirely different properties than conventional monitors like surface tilt and seismicity, therefore can be independent. Results have been promising enough to warrant further sophistication. A computer-controlled data acquisition system coupled with telemetry has been built and is being tested for installation in FY 84. The new system will allow more accurate data to be obtained more often with less manpower.

6/82 Present Geophysicist, Branch of Geophysics, Groundwater exploration project, Branch and Project Chief: Adel Zohdy. Overall aim was to evaluate electrical geophysics techniques for groundwater exploration in the three environments normally encountered in Pacific islands. A combination of Schlumberger and electromagnetic techniques were used to estimate groundwater reserves and the results were compared to preexisting wells to determine success of application.
Field studies to date include:
Recent volcanic terrains in the State of Hawaii, Waimea and Kona, Hawaii, Kalaupapa, Molokai, and Schofield, Oahu were studied. Several islands in Truk and the Marshalls were studied representing low-lying atolls. Finally, Guam and Saipan were host to several studies of marine limestone capped volcanic islands, known as "high" islands.
Research into appropriate interpretation methods for these environments centers around computer methods and models suited for the differing geologic conditions.

March 1984

DANIEL LUM
272 Kalalau Street
Honolulu, Hawaii 96825

EDUCATION

1956: Rice University, Houston, Texas. B.A. degree in Geology.

1957: University of Utah, Salt Lake City. M.S. degree in Geophysics.

WORK EXPERIENCE

1957-1960: Geophysicist, South Dakota Geological Survey, Vermillion. In charge of all geophysical activities of the Survey, including regional gravity studies for oil and gas and structural geology, electrical resistivity investigations for ground water development, and geophysical well logging.

1960-1984: Geologist, Head of Geology-Hydrology Section, Water Resources and Flood Control Branch.

- Project geologist and supervisor for more than 50 ground water exploration and development wells.
- Project geologist on major dam and reservoir projects.
- Responsible for numerous investigations in water resources planning and development, hydrology and mineral resources.
- Principal author and coordinator in the adoption of Hawaii State's geothermal leasing and drilling regulations in 1978.

PUBLICATIONS

Author of numerous published reports and papers, unpublished administrative reports, and technical presentations.

PROFESSIONAL MEMBERSHIPS

Geological Society of America
American Geophysical Union
Society of Exploratory Geophysicists

(:.62)

U.S. Department of the Interior
Geological Survey
Geologic Division

PROFESSIONAL/TECHNICAL PERSONNEL RECORD

NAME (last)	(first)	(initial)	2. Duty station	3. Date r
Moore	Richard	B	Hawaiian Volcano Observ.	Feb. 1

Birth date (month)	(day)	(year)	5. Classification title	Series	Grade
July	10	1945	Geologist	GS-1350	13

List first and second scientific or technical specialties

Geologic mapping and interpretation of petro-chemical data

b. Operation of electron microprobe

Other scientific, technical, or special skills (regardless of relation to present position)

Familiarity with volcano monitoring equipment.
Operation of mass spectrometers.

Education (include secondary schools)

School	Dates attended	Major and minor specializations	Degree, y or anticipate
Lexington MA High School	1960-63		Diploma
Tufts Univ., Medford MA	1963-67	Geology, Classics	B.S. 196
U of North Dakota, Grand Forks	1967-69	Igneous Petrology	M.S., 19
U of New Mexico, Albuquerque	1970-73	Igneous Petrology	Ph.D., 1

Specialized training (including postgraduate and Government courses)

Graduate courses in geology and physical chemistry.

0. Civil Service grades and dates

Check if career employee x☐

Grade*	5	5	6	5	5	9	9	12	13	
Date	1968	1969	1970	1971	1972	1973	1974	1974	1982	

Use asterisk for any grade obtained in a management or other nonresearch capacity above GS–12

1. List or describe any information and (or) experience not covered on form that might affect career assignment

See attached

Moore, Richard B.

11. List or describe any information and/or experience not covered on form that might affect career assignment.

A. U.S.G.S. field experience includes: (1) examining ore deposits in San Juan Mts., Colo.; (2) mapping a diabase intrusion and examining uranium deposits in McKinley and Valencia counties, New Mexico; (3) mapping the late Cenozoic San Francisco volcanic field, Az., and studying its petrology; (4) assignment to Hawaiian Volcano Observatory (8/77 to 9/80), and consequent observation of eruptive activity, handling of monitoring equipment, and field geologic mapping on Kilauea Volcano; (5) mapping and petrologic studies on Hualalai Volcano (project chief); (6) mapping and petrologic studies on Sao Miguel Island, Azores (agreement with USAID).

B. Laboratory experience includes: (1) operating electron microprobe to analyze returned lunar samples and San Francisco volcanic field rocks; (2) operating mass spectrometer.

12a. Memberships in professional societies. List, give dates, and include significant offices held.

Geological Society of America	1968-present
Sigma Xi	1968-present
Sigma Gamma Epsilon	1968-present
American Geophysical Union	1971-present

12b. Lectureships, symposia, invited conference participation. Give dates, nature of entry (were you sought out or did you apply to part, and level of participation.

1. Invited guiding of field trips-GSA Rocky mt. Section Meeting, 1974 (San Francisco Volcanic Field)
2. Invited guiding of field trips-Circum-Pacific Energy Meeting, 1978 (Island of Hawai
3. Invited guiding of field trips-IAVCEI Symposium on Volcanism, 1979 (Island of Hawai
4. Invited to present paper on Hawaiian volcanism, IUGG meeting in Canberra, 1979 (abstract is listed in bibliography, but I did not receive approval for foreign travel--Bob Decker presented my paper)
5. Chaired section on volcanism, GSA Cordilleran Section, 1978, Tempe

12c. Committees to render scientific judgment. Include scientific review panels, editorial boards, editorships, with dates. Include the cc which you served (chairman, subcommittee chairperson, member, observer, expert consultant, etc.).

None

12d. Other committees, special assignments, significant consultant roles (government and (or) industry). Name organization, group, d nature of contribution.

Geologist in USGS team assisting the government of the Azores in the assessment of Azorean geothermal resources, 1980-1983.

Assisted Apollo 17 crew in geologic traverses, San Francisco volcanic field, 1972.

Moore, Richard B.

13. Career experience:

From	To	
7/68	9/68	U.S.G.S. Field Assistant, supervisor Calvin S. Bromfield, Denver. Mapping of volcanic rocks in the western San Juan Mts., Colorado; collection of ore samples and stream sediments.
6/69	10/69	U.S.G.S. Field Assistant, supervisor Charles T. Pierson, Denver. Mapping and petrography of a diabase intrusion; examination of uranium deposits.
10/69	10/70	U.S.G.S. Physical Science Technician, supervisor E. W. Wolfe, Flagstaff. Mapping, petrology, and geochemistry of San Francisco volcanic field.
5/71	9/71	U.S.G.S. Field Assistant, supervisor E. W. Wolfe, Flagstaff. Mapping, petrology, and geochemistry of San Francisco volcanic field.
5/72	9/72	U.S.G.S. Field Assistant, supervisor E. W. Wolfe, Flagstaff. Mapping, petrology, and geochemistry of San Francisco volcanic field.
1967	1969	Graduate Assistant, University of North Dakota. Teaching of optical mineralogy and petrology laboratory classes.
1970	1971	Graduate Assistant, University of New Mexico. Teaching of physical geology laboratory classes.
1971	1973	Research Assistant, University of New Mexico. Analyzed lunar samples in electron microprobe for Klaus Keil and Martin Prinz.
10/73	8/77	Geologist, U.S.G.S., Flagstaff, Arizona. Project Chief: E. W. Wolfe. Mapping, petrology (including electron microprobe work), and geochemistry of San Francisco volcanic field.
8/77	9/80	Geologist, U.S.G.S., Hawaiian Volcano Observatory. Supervisors: G. P. Eaton and R. W. Decker. Surveillance of activity of Kilauea and Mauna Loa volcanoes. Field geologic mapping of part of Kilauea volcano. Petrology and geochemistry of Kilauea rocks.

Moore, Richard B.

13. Career experience (Continued):

From	To	
10/80	Present	Geologist, U.S.G.S., Hawaii. Chief of "Geology and Petrology of Hualalai Volcano" project. Supervisor--Field G & P Branch Chief. Includes 8 months studying geology and petrology of the Agua de Pau, Sete Cidades, and Furnas Volcanoes, Sao Miguel Island, Azores. I have supervised two employees. The Hualalai project will result in reports that identify volcanic hazards and potential geothermal targets on a possibly dangerous, heavily populated volcano. Ditto for the Azorean project--I am the geologist in a 6-member USGS team.

(02/10/84)

CURRICULUM VITAE

John M. Sinton

PRESENT POSITION: Associate Professor of Geology and Geophysics
Hawaii Institute of Geophysics
University of Hawaii
Honolulu, Hawaii 96822
(808) 948-7751

PERSONAL INFORMATION:

Date of Birth: April 12, 1946
Place of Birth: Bozeman, Montana
Social Security No.: 563-62-0212

EDUCATION:

A.B.	Geology, University of California at Santa Barbara, June 1969
M.S.	Geology, University of Oregon, Eugene, Oregon, September 1971
Ph.D.	Geology, University of Otago, Dunedin, New Zealand, May 1976

Theses:

M.S.	A Study of Granitization in Northern Saskatchewan
Ph.D.	Structure, Petrology and Metamorphism of the Red Mountain Ophiolite Complex, New Zealand

PROFESSIONAL EXPERIENCE:

June, 1969-Sept. 1969	Summer Field Geologist, Standard Oil Co. of California, 6/69-9/69
Sept. 1969-June 1970	Teaching Fellow, University of Oregon, Geology Dept.
June, 1970-Sept. 1970	NSF Summer Traineeship
Sept. 1970-June 1971	Head Teaching Fellow, University of Oregon, Geology Dept.
June 1971-Sept. 1971	Senior Assistant, Saskatchewan Dept. of Mineral Resources, Precambrian Division
Sept. 1971-Dec. 1975	Teaching Fellow, University of Otago, Geology Department
Jan. 1976-March 1977	Post-doctoral Fellow, Smithsonian Institution, Dept. of Mineral Sciences

PROFESSIONAL EXPERIENCE: (Contd.)

Nov. 1976-Jan. 1977	Shipboard Scientist with Deep Sea Drilling Project aboard GLOMAR CHALLENGER Leg 51
1977-Present	Research Associate, Smithsonian Institution
May 1977-July 1981	Assistant Professor, Geology and Geophysics Dept. and Hawaii Institute of Geophysics, University of Hawaii,
May 1979-June 1979	Co-chief Scientist: R/V KANA KEOKI, Cruise KK78-12, Leg 05, Galapagos Ridge
July 1980	Chief Scientist: R/V KANA KEOKI, Cruise KK80-07, Musicians Seamounts,
July 1981-Present	Associate Professor, Geology and Geophysics Dept. and Hawaii Institute of Geophysics, University of Hawaii
April 1982	Shipboard Scientist, R/V KANA KEOKI, Cruise KK82-03, Melanesian Borderland
April 1983	Scientific Observer, Research Submersible MAKALII, Dives 83-157 and 83-159.

SOCIETIES:

American Geophysical Union

APPENDIX D

PUBLIC REQUEST FOR INFORMATION

LEGAL NOTICE

PUBLIC NOTICE

REQUEST FOR GEOTHERMAL RESOURCE INFORMATION

The Department of Land and Natural Resources is in the process of assessing geothermal resource development areas in the State of Hawaii as mandated by Act 296, SLH 1983. In order to maximize the base of available information, the Department invites any person or organization to submit any pertinent information to assist in the assessment.

Information may include, but need not be limited to:

(1) Areas with geothermal resource development potential to develop electrical energy.
(2) Geologic hazards that may be encountered in geothermal resource development.
(3) Social or community impacts that may arise from geothermal resource development.
(4) Economic impacts that may result from geothermal resource development.
(5) Environmental impacts that may be encountered from geothermal resource development.
(6) Any other related information that may be considered in the subzoning of geothermal resource development areas.

The information should be sent to the Division of Water and Land Development, Department of Land and Natural Resources, P.O. Box 373, Honolulu, Hawaii 96809, or delivered to the Division of Water and Land Development office at 1151 Punchbowl Street, Room 227, Kalanimoku Building, Honolulu, Hawaii, by May 21, 1984.

BOARD OF LAND &
NATURAL RESOURCES
SUSUMU ONO
Chairperson of the Board

Dated: April 10, 1984
(S.B.: Apr. 16, 18, 1984) (SB-5279)