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AN EVALUATION OF GEOTHERMAL RESOURCES FOR THE STATE OF HAWAII

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ABSTRACT

The Hawaii Geothermal Resources Assessment Program has completed field surveys in fifteen Potential Geothermal Resource Areas located on four of the major islands making up the Hawaiian archipelago. The results of these surveys have indicated that four of the prospects surveyed had a significant probability for the presence of a moderate to high temperature (125 degrees C. to 350 degrees C.) resource and three others showed indications of having at least a low to moderate temperature (50 degrees C. to 125 degrees C.) resource. One of the survey areas, the Kilauea East Rift Zone, presently has a deep exploratory well under extended production and hence is considered to be a Known Geothermal Resource Area.

Introduction

The Hawaii Geothermal Resources Assessment Program was initiated in 1978. The preliminary phase of this effort identified twenty Potential Geothermal Resource Areas using available geological, geochemical and geophysical data. The second phase of the Assessment Program undertook a series of field studies, utilizing a variety of geothermal exploration techniques, in an effort to confirm the presence of thermal anomalies in the identified PGRA's and, if confirmed, to more completely characterize them. A total of fifteen PGRA's on four of the five major islands in the Hawaiian Chain were subject to at least a preliminary field analysis; the remaining five were not considered to have sufficient resource potential to warrant study under the personnel and budget constraints of the program.

Kauai

The island of Kauai was not studied during the current phase of investigation; geothermal field studies were not considered to be merited due to the absence of significant geochemical or geophysical indications of a resource. The great age of volcanism on this island would further suggest that, should a thermal resource be present, it would be of extremely low temperature.

Oahu

Geothermal field studies conducted on Oahu focused on the caldera complexes of the two volcanic systems which form the island: Waianae Volcano and Koolau Volcano (Figure 1). The results of these studies and the interpreted probability for a resource in each is as follows:

Lualualei Valley: Geologic mapping located the focus of the late stage eruptive activity near the back of Lualualei Valley and tentatively identified the Waianae caldera boundaries within the Valley. Soil geochemistry studies defined anomalous zones of mercury concentrations and radon emanation that appeared to be coincident with the caldera boundary faults. Groundwater chemistry and temperature measurements identified a distinctly anomalous well, having both an elevated temperature and a thermally altered water chemistry, near the back of the valley and several others with slightly anomalous conditions on the caldera boundary fault. Geophysical soundings indicated low subsurface resistivities within the valley that were interpreted to correspond to warm, fresh to saline water-saturated basalt. On the basis of the available data, the probability for a low to moderate temperature resource (50 degrees C. to 125 degrees C.) within 3 kilometers of the surface is assessed at 10% to 20%. The probability for a higher temperature resource is less than 5%.

Mokapu Peninsula and Koolau Caldera: Geologic mapping identified three post-erosional volcanic vents on Mokapu Peninsula; the inferred ages were on the order of 300,000 years. Geochemical studies on Mokapu were unable to identify a self-consistent pattern of soil geochemical anomalies or significant groundwater chemical anomalies that would suggest a geothermal resource. Resistivity soundings determined subsurface resistivities that were consistent with cold sea water saturated sediment. The probability for even a low temperature geothermal source at depths of 3 km. or less beneath Mokapu is considered to be less than 5%.

Results of preliminary soil geochemical studies and interpretation of available groundwater data to the south of Mokapu, within the

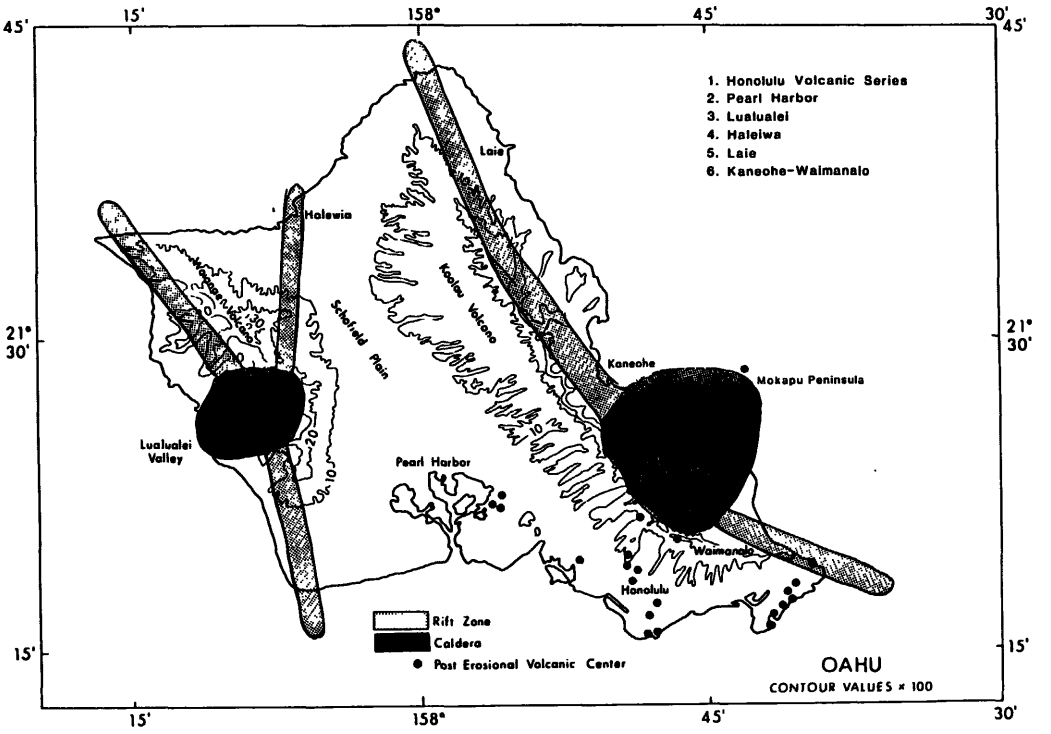

Figure 1. Map of the Island of Oahu showing principal rift zones and calderas of Waianae and Koolau Volcanoes. Potential Geothermal Resource areas identified during preliminary phase of Geothermal Resources Assessment Program are also noted.

Koolau Caldera, suggest that some thermally induced alterations may be present within the shallow groundwater supplies and surface soil layers. However, interpretation of magnetic data indicates that the temperatures within the ancient Koolau magma chamber are certainly less than 540 degrees C. (the Curie temperature) and that the shallow subsurface resistivities show little evidence of thermal effects. On the basis of the rather sparse data currently available, the probability for a low to moderate temperature resource associated with the Koolau magma chamber is considered to be 10% or less.

Molokai

Due to the anticipated small demand for geothermal power on the island of Moloaki in the foreseeable future, only preliminary efforts were made to assess the potential for a resource on this island. An abandoned well, reported to have produced warm water when it was first drilled in 1930 was located but temperature measurements were unable to detect anomalies within the open portion of the hole; collapse of the lower third of the hole did not, however, permit access to the water table. Soil geochemical analysis indicated neither significant mercury concentrations nor unusual alteration minerals in the vicinity of the well. In the absence of detectable anomalies from the preliminary investigation, further studies were not considered to be warranted. The probability for a resource on West Molokai is not considered to be high; however, insufficient data are available to offer an estimated probability for a resource.

Maui

Geothermal assessment activities on Maui included an evaluation of the major rift zones and post-erosional volcanic vents on both West Maui Volcano and Haleakala Volcano (Figure 2). Field Surveys conducted on West Maui yielded the following results:

Olowalu and Ukumehame Canyon: Extensive geologic mapping characterized the Southwest and Southeast Rift Zones of West Maui Volcano and interpreted the observed structures to suggest a migration of the rift zone activity late in the formation of West Maui. Numerous late stage alkalic and trachitic dikes and plugs were also identified in the survey area. Groundwater geochemical and temperature measurements identified distincly anomalous water chemistry and temperatures. Resistivity sounding data for the area was interpreted to indicate a thick layer of warm fresh-to-saline water beneath the Olowalu and Ukumehame Canyons. The probability of a thermal resource having a temperature greater than or equal to 50 degrees C. is estimated to be 50% to 60% whereas a temperature greater than or equal to 125 degrees C. has an estimated probability of 10% or less.

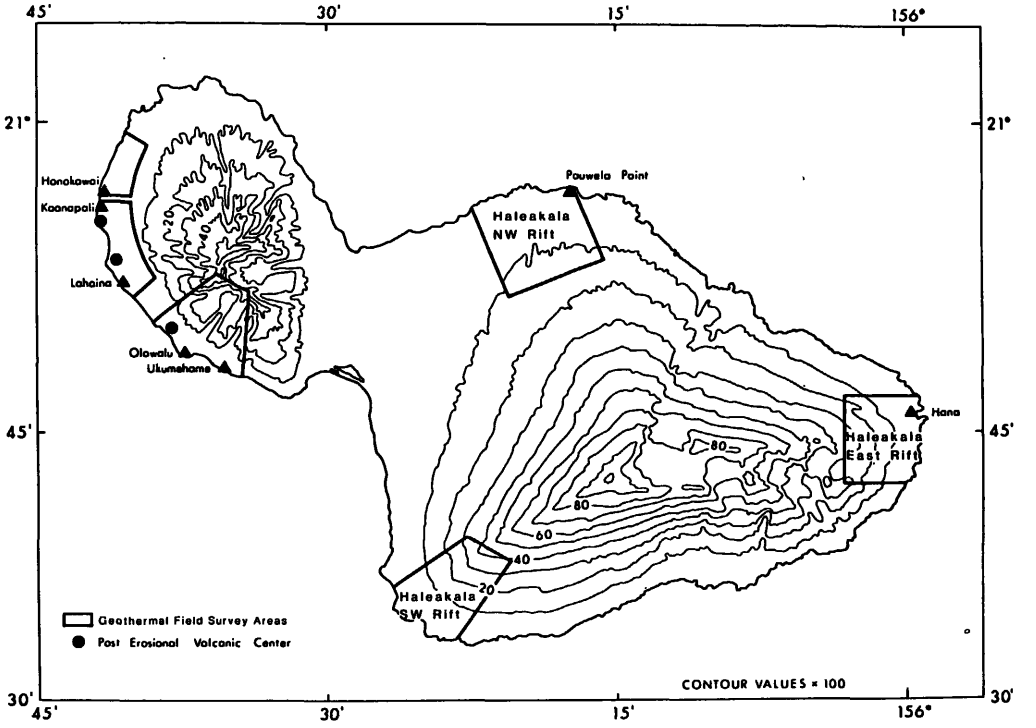

Figure 2. Map of the Island of Maui showing identified potential Geothermal Resource Areas and locations of subsequent field survey areas.

Lahaina-Kaanapali: Soil geochemical surveys were unable to identify a self-consistent pattern of soil mercury concentrations or radon emanation rates that would suggest a thermal resource; groundwater temperature measurements and chemical analyses were similarly unable to detect significant thermal alterations. Geophysical soundings detected subsurface resistivities consistent with cold water saturated alluvium and basalt. Thus, the probability of a thermal resource existing in this area is considered to be less than 5%.

Honokowai: Groundwater chemistry and temperature data for this area were unable to confirm the existence of any thermal effects and geophysical soundings indicated normal subsurface resistivities. Hence the probability for a resource in this location is believed to be less than 5%.

Field surveys on Haleakala were confined to the lower portions of the three major rift zones and yielded the following results:

Haleakala Northest Rift: Soil geochemical and groundwater chemical studies in this area both indicate potential anomalies; the interpretation of the anomalies with regard to thermal alterations was not, however, unequivocal. Geophysical surveys across the rift zone were unable to identify significantly anomalous subsurface resistivities or self-potential variations. The probability of a low to moderate temperature resource is placed at 10% to 20%, whereas that for a high temperature resource is less than 5%.

Haleakala Southwest Rift: Geologic mapping has determined that several flows on this rift are less than 10,000 years of age and that a few are less than 1,000 years old. Preliminary geochemical studies were unable to identify unequivocal evidence of thermal effects on the lower rift zone area whereas geophysical soundings indicated that thermal groundwaters may be present at depths of less than 3 km. The probability for a low to moderate temperature resource is estimated to be 30% to 40% whereas that for a high temperature resource is placed at 15% to 25%.

Haleakala East Rift Zone: Only preliminary geochemical and geophysical surveys were performed in this area due to its inaccessability and difficulty of field conditions. The results of these efforts did not identify significant anomalies; however, interpretational ambiguities and the small amount of data available do not allow an assessment of geothermal potential to be made.

Hawaii

The island of Hawaii, being the youngest and most volcanically active island in the Hawaiian Chain, was found to have the largest number of PGRA's. The current assessment program performed field surveys in five PGRA's and in one known geothermal resource area -- the Kilauea East Rift

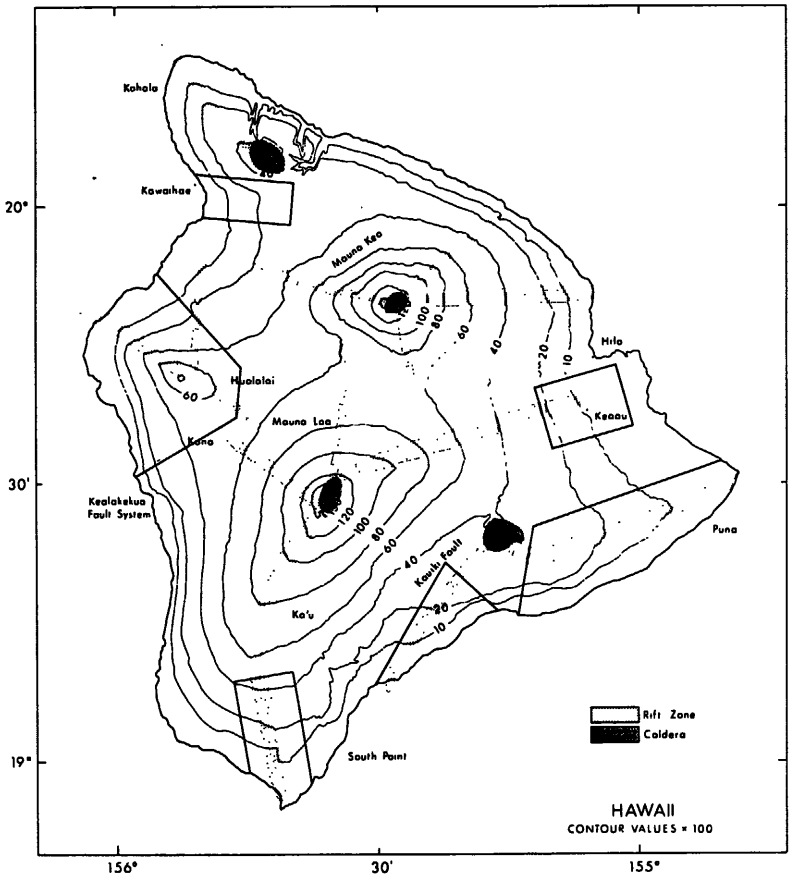

Figure 3. Map of the Island of Hawaii showing major rift zones and calderas of each volcano. Locations of Potential Geothermal Resource Areas and field surveys are noted.

(Figure 3). The results of these studies yielded the following interpretations:

Kawaihae: Geophysical surveys performed over this area defined a set of magnetic and resistivity anomalies that suggest that an intrusive body, associated with the Puu Loa cinder cone may be heating shallow groundwaters. Groundwater chemistry and temperature anomalies confirm the existence of a heat source in the vicinity however the temperatures are not indicated to be very high. The probability of a low to moderate temperature resource in the survey area is indicated to be 35% to 45% and a moderate to high temperature resource to be 15% or less.

Hualalai: Geologic mapping on the western flank of Hualalai suggests that frequent eruptive activity has occurred during the last 5,000 years. Geophysical surveys have identified distinct magnetic, resistivity and self-potential anomalies near the summit of Hualalai whereas the lower western flank has not shown significant thermal effects. Geochemical data on the lower flanks were similarly unable to identify any obvious thermally induced anomalies. These data suggest that there is a 35% to 45% probability of a low to moderate temperature thermal resource near the summit of Hualalai Volcano and a 20% to 30% probability of a high temperature resource in this area. Probabilities for comparable resources existing on the lower flanks are estimated at 15% to 25% and 5% or less, respectively.

Mauna Loa Southwest Rift: Limited geophysical surveys performed on the lower Southwest Rift were unable to detect significant resistivity anomalies to depths equivalent to the local water table and a self-potential traverse detected only one anomalous gradient that was interpreted to be the result of a downgoing streaming potential. No strong geothermal anomalies were identified; however, the limitations of the available data set do not allow a probability estimate to be made of the resource potential in this area.

Mauna Loa Northeast Rift: Geophysical and geochemical field studies performed in this PGRA were unable to detect any evidence of a geothermal anomaly in this location. The probability for even a low temperature resource is estimated to be less than 5%.

Kilauea Southwest Rift: Geologic mapping has indicated several areas of steaming ground and warm coastal springs adjacent to the rift system. A reanalysis of available geophysical data for this area concluded that warm groundwater was present within the rift zone. Magnetic anomalies observed over the rift indicate that subsurface temperatures may exceed the Curie temperature. The probability for a low to moderate temperature resource on this rift is considered to be 100% whereas that for a high temperature resource on the upper rift is estimated at 70% to 80%.

Kilauea East Rift Zone: An extensive body of geological, geophysical and geochemical data concerning the East Rift Zone is available and virtually all of this data indicates that a high temperature thermal system is associated with the entire rift. Deep exploratory geothermal wells drilled into the lower portion of rift zone have identified temperatures in excess of 350 degrees C. and continuous production from one of these wells for a period of more than two years indicates that sufficient recharge is available for production of geothermal electrical power. The probability for both a low and high temperature resource on this rift zone is 100%.

Summary

The Hawaii Geothermal Resources Assessment Program conducted field surveys in fifteen of the most promising Potential Geothermal Resource Areas in the State of Hawaii. Sufficient data was acquired in twelve of the prospects studied to allow an estimate to be made of the probability for a low to moderate temperature (50 degrees C. to 125 degrees C.) and a moderate to high temperature (125 degrees C. to 350 degrees C.) geothermal resource in each prospect (Table 1). The currently available data indicate that there is a significant probability (greater than 30%) for a moderate to high temperature resource in four of the prospects studied and three others are considered good prospects for low to moderate temperature resources. One of the survey areas, the Kilauea East Rift Zone, is currently undergoing extensive geothermal exploratory drilling and production and is currently considered to be a Known Geothermal Resource Area.

(AUTHOR'S NOTE: A map -- Geothermal Resources of Hawaii-- and a report -- An Assessment of Geothermal Resources in the State of Hawaii- or Hawaii's geothermal resources is available from:

Hawaii Institute of Geophysics
Geothermal Program
2525 Correa Road
Honolulu, Hawaii 96822.)

References

Cox, M.E., J.M. Sinton, D.M. Thomas, M.D. Mattice, J.P. Kauahikaua, D.M. Helstern, and P.F. Fan, 1979, Investigation of geothermal potential in the Waianae Caldera Area, western Oahu, Hawaii. Hawaii Institute of Geophysics Technical Report HIG-79-8, 76 p.

Cox, M.E., K.E. Cuff, B.R. Lienert, J.M. Sinton, and D.M. Thomas, 1982, A preliminary evaluation of the Mokapu Peninsula on the Island of Oahu, Hawaii. Hawaii Institute of Geophysics Technical Report HIG-82-2, 45 p.

Godson, R.H., C.J. Zablocki, H.A. Pierce, J.B. Frayser, C.M. Mitchell, and R.A. Sneddon, 1981, Aeromagnetic map of the Island of Hawaii, U.S. Geological Survey Geophysical Investigations Map, GP-946, 1 p.

Kauahikaua, J.P. and MD. Mattice, 1981, Geophysical reconnaissance of prospective geothermal areas on the Island of Hawaii using electrical methods. Hawaii Institute of geophysics Technical Report HIG-81-4, 50 p.

Keller, G.C., C.K. Skokan, J.J. Skokan, J. Daniels, J.P. Kauahikaua, D.P. Klein, and C.J. Zablocki, Geoelectric studies on the East Rift, Kilauea Volcano, Hawaii Island, Hawaii Institute of Geophysics Technical Report HIG-77-51, 195 p.

Klein, D.P. and J.P. Kauahikaua, 1975, Geoelectric geothermal exploration on Hawaii Island: Preliminary results, Hawaii Institute of Geophysics Technical Report HIG-75-6, 75 p.

Macdonald, G.A. and A.T. Abbott, 1970, Volcanoes in the sea; the geology of Hawaii. The University Press of Hawaii, Honolulu, HI, 491 p.

Suyenaga, W., M. Broyles, A.S. Furumoto, R. Norris, and M.D. Mattice, 1978, Seismic studies on Kilauea Volcano, Hawaii Island, Hawaii Institute of Geophysics Report HIG-78-8, 137 p.

Thomas, D.M., M.E. Cox, D. Erlandson, and L. Kajiwara, 1979, Potential geothermal resources in Hawaii: A preliminary regional survey, Hawaii Institute of Geophysics Technical Report HIG-79-4, 166 p.

Table 1. Estimated Probabilities for Geothermal Resources

Location	Probability for Low to Moderate Temp. Resource	Probability for Moderate to High Temp. Resource
Kauai:		
Post-erosional Volcanic Series Vents	N	N
Oahu:		
Lualualei Valley	10%-20%	<5%
Kaneohe-Waimanalo	≤10%	<5%
(Mokapu Peninsula)	(<5%)	(<5%)
Haleiwa	N	N
Laie	N	N
Pearl Harbor	N	N
Molokai:		
West Molokai	I	I
Maui:		
Olowalu-Ukumehame	50%-60%	≤10%
Lahaina-Kaanapali	<5%	<5%
Honokowai	<5%	<5%
Haleakala Northwest Rift (Pauwela)	10%-20%	<5%
Haleakala Southwest Rift	30%-40%	15%-25%
Haleakala East Rift	I	I
Hawaii:		
Kohala	N	N
Kawaihae	35%-45%	≤15%
Hualalai		
Summit	35%-45%	20%-30%
Lower Northwest Rift	≤15%	<5%
Mauna Loa		
Lower Southwest Rift (South Point)	I	I
Lower Northeast Rift (Keaau)	<5%	<5%
Kilauea		
Upper Southwest Rift	100%	70%-80%
Lower Southwest Rift	100%	50%-60%
East Rift Zone	100%	100%

I = insufficient data available to determine resource probability.
N = not studied during current field survey program.
Note that some of the survey areas have been subdivided (e.g. Hualalai) when the resource probabilities have been found to vary markedly within a given prospect.

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