Seismicity Study - Hawaii Geothermal

The proposed work will allow us to:

1. Determine baseline background seismicity (intensity, directionality and waveform characteristics) for comparison to seismicity during injection procedure.

2. Characterize the upflow zones geophysically so other, potentially profitable upflow zones can be identified elsewhere based on the geophysical characteristics.

3. Monitor in-hole noise and conduct zero-offset vertical seismic profile in a suitable (standard seismic downhole instrumentation is not designed to withstand temperatures more than 100°C) hole.

Proposed work (budget requests funding for this work):

1. Analysis of P-wave traveltimes to USGS permanent stations.

Determine regions of obvious lateral velocity variation on Kilauea's East Rift Zone; site stations for the microearthquake study (or compartmentalize target region) to avoid significant lateral variations in velocity.

2. Construct initial velocity model.

Use zero-offset vertical seismic profile data from nearby well to estimate shallow P- and S-wave velocity stucture (one-dimensional inversion ok); ≤15-m vertical spacing. Published velocity models will be used for deeper velocity structure.

3. Microearthquake array study.

Deploy a small seismic array with 4-7-km aperture for a 10-day period. Do a progressive inversion for hypocenters and P-wave and S-wave velocity structure. The theory and software exist; this type of analysis has been done in The Geysers. Two areas on the East Rift Zone of Kilauea are targeted for instrumentation using the seismic array instrumentation available through the PASSCAL facility operated by IRIS. One array of 14 sites will be roughly centered on the HGP-A well: two 3-component, short period instruments will be located at each site, each with different gain settings; site spacing is approximately 2 km; array aperture is about 7 km. The second array will be sited to the southwest of HA-4,5 &6, north of Kalapana: two 3-component, short period instruments will be located at each of 14 sites, each with different gain settings; site spacing is approximately 2 km; array dimensions are 4 x 7 km.

(Recording of 3 components is required because S-wave traveltimes estimated from vertical seismometers are unreliable. An estimate of S-wave velocity structure is needed in addition to P-wave velocities in order to make inferences about physical properties such as fracture density and fluid saturation in the target region.)

4. Calculate P- and S-wave slowness gradients and velocity-depth functions.

Note: zones with few or no earthquakes will be poorly resolved. The Vp/Vs-depth structure can be related to variations in degree of fluid saturation; the saturated condensation zone (max Vp/Vs) that lies above the primary production zone (min Vp/Vs) at The Geysers is resolvable with this type of data.

5. Earthquake locations and source parameters.

Seismicity may be confined to regions directly associated with fluid transport in the main reservoir(s). Source parameters reflect the state of stress in near the event location.

Suggestions for further exploration efforts (budget does not request funding for this work):

1. High-resolution seismic refraction and gravity survey.

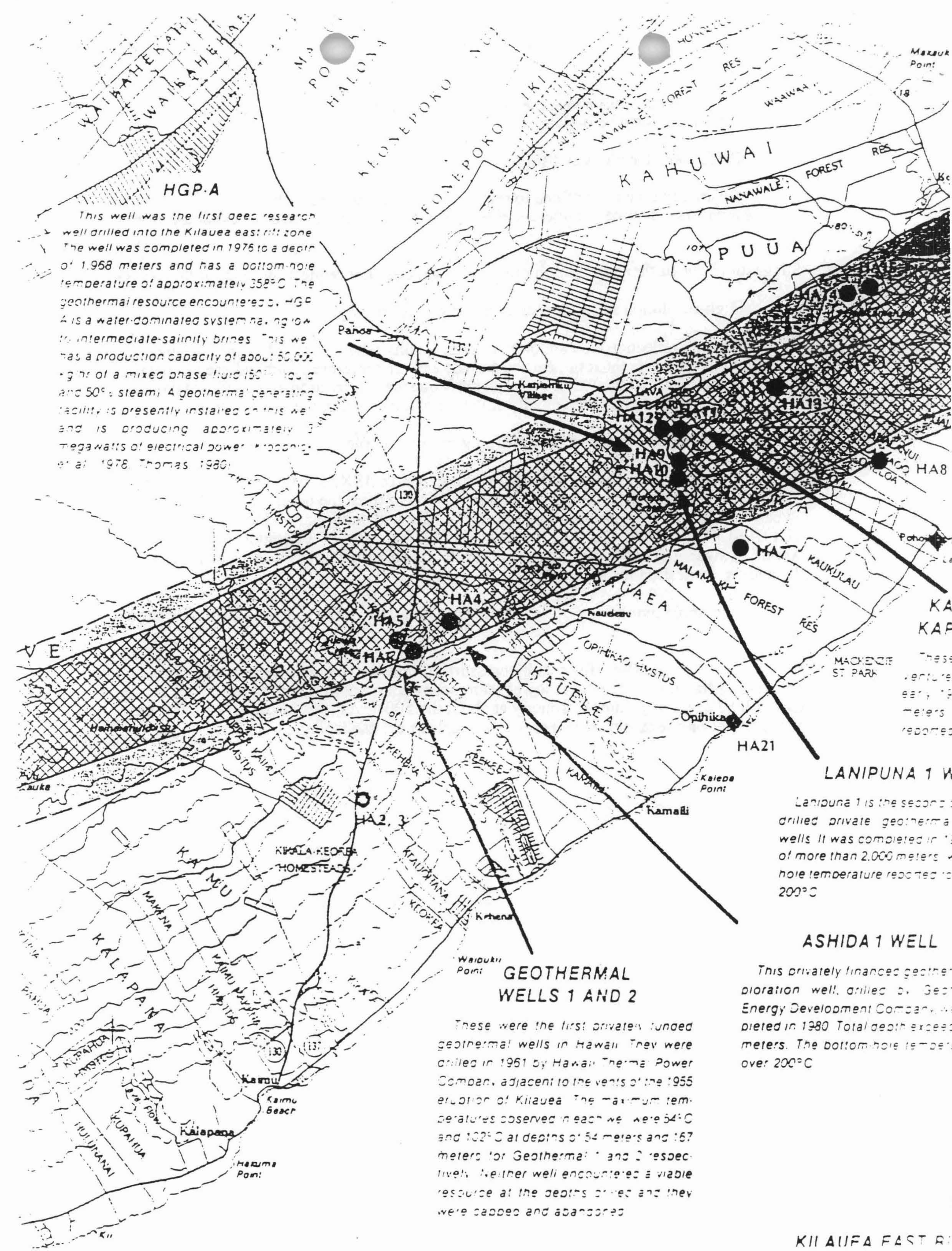
Seismic reflection data are often of poor quality when recorded in areas where volcanic rocks are present at or near the surface and are therefore of limited use in imaging exploration targets that lie within the volcanic sequence. Refraction and gravity data may be useful if constrained by the velocity structure obtained using the seismic array.

2. Multi-offset vertical seismic profiling in several holes.

This requires a VSP vibrator source (e.g. Mertz BSX; $70,000 for a typical survey) operated in the P-wave mode and offset less than 60 m from the hole; vibrator sweep=nonlinear, 15-s upsweep beginning at 10 Hz and ending at 60 Hz. OR OTHER SUITABLE SOURCE. Downhole receiver should be series of 3-component geophones. About 10 sweeps at each recording depth level; recording levels at intervals of 10-15 m, depending on desired resolution.

3. Downhole monitoring of seismicity on a long-term basis, tied into a suitable surface array.

Underground fluid disposal by pressurized injection can induce seismicity on preexisting fractures at pressures lower than those necessary to fracture rock. Well seismic tool will be used to monitor seismicity at about the 500' level; this instrument would serve ar the center of a semi-permanent array with real-time data display.



HGP-A

This well was the first deep research well drilled into the Kilauea east rift zone. The well was completed in 1976 to a depth of 1,968 meters and has a bottom-hole temperature of approximately 358°C. The geothermal resource encountered by HGP-A is a water-dominated system having low to intermediate-salinity brines. This well has a production capacity of about 50,000 kg/hr of a mixed phase fluid (50% liquid and 50% steam). A geothermal generating facility is presently installed on this well and is producing approximately 3 megawatts of electrical power (Kroopnick et al., 1978; Thomas, 1980).

GEOTHERMAL WELLS 1 AND 2

These were the first privately funded geothermal wells in Hawaii. They were drilled in 1961 by Hawaii Thermal Power Company, adjacent to the vents of the 1955 eruption of Kilauea. The maximum temperatures observed in each well were 54°C and 102°C at depths of 54 meters and 167 meters for Geothermal 1 and 2 respectively. Neither well encountered a viable resource at the depths drilled and they were capped and abandoned.

KA… KAP…

These … venture … early 19… meters … reported …

LANIPUNA 1 W…

Lanipuna 1 is the second … drilled private geotherma… wells. It was completed in 19… of more than 2,000 meters … hole temperature reported to … 200°C.

ASHIDA 1 WELL

This privately financed geothe… ploration well, drilled by Geot… Energy Development Company, was com… pleted in 1980. Total depth exceed… meters. The bottom-hole tempera… over 200°C.

KILAUEA EAST RI…

SEISMICITY STUDY - HAWAII GEOTHERMAL

Year I

A.	SENIOR PERSONNEL		
	1. Patricia Cooper	6	31,188
	2. Greg Moore	1	7,694
B.	OTHER PERSONNEL		
	1. Undergraduate Student Help 1000 hours @ $6.50 per hour		6,500
		Sub-Total	$45,382
C.	FRINGE BENEFITS		
	26% for Cooper and Moore		10,109
	1% for Student Help		65
	TOTAL WAGES AND FRINGE BENEFITS		$55,556
D.	PERMANENT EQUIPMENT		
	none		-0-
E.	TRAVEL		
	1. Domestic Training on PASSCAL instruments at Lamont-Doherty Geological Observatory Round trip airfare to Kennedy APT, NY and return. Per diem for 14 days @ $130; car rental for 2 wks @ $120 per week		3,060
	Array deployment, maintenance; data retrieval 30 RT Hawaii-Oahu @ $80		2,400
	TOTAL TRAVEL		$5,460
F.	PARTICIPANT SUPPORT COST		-0-

G.	OTHER COSTS		
	1.	Materials and Supplies 28 automobile batteries	200 2,800
	2.	Publication costs/page charges/graphics	3,000
	3.	Shipping costs (roundtrip LDGO to Honolulu)	6,500
	4.	Computer SOEST Alliant @ $60/hr for 100 hours Sun™ yearly maintenance fees	6,000 2,000
	5.	Engineering Support Facility	17,000
	6.	Other Communications	1,000
	TOTAL OTHER COSTS		$38,500
H.	TOTAL DIRECT COSTS (A THROUGH G)		$99,516
I.	INDIRECT COSTS		
J.	TOTAL DIRECT AND INDIRECT COSTS		$
K.	RESIDUAL FUNDS		-0-
L.	AMOUNT OF THIS REQUEST		$