Hawai‘i Play Fairway: Final Report

Project Title: Comprehensive analysis of Hawai‘i’s geothermal potential through Play Fairway integration of geophysical, geochemical, and geological data

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Principal Investigator: Nicole C. Lautze

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UH Project Team Members: Donald Thomas, Garrett Ito, Neil Frazer, Stephen Martel, Nicholas Hinz, Robert Whittier, Philip Wannamaker

A panorama of the drill site in Pālāwai Basin, Lāna‘i Island. The highest ridge on the island looms in the background.

ACKNOWLEDGEMENT AND DISCLAIMER

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ACRONYMS LIST

'	Feet (unit of measurement)
BP	Budget Period
DHHL	Department of Hawaiian Home Lands, State of Hawai‘i
DOE	U.S. Department of Energy
EA	Environmental Assessment
GIS	Geographic Information Systems
GW	Groundwater
HECo	Hawaiian Electric Company
HSDP	Hawaiian Scientific Drilling Program
KERZ	Kīlauea East Rift Zone
km	Kilometer(s)
m	Meter(s)
MT	Magnetotelluric
MW	Megawatt
NL	National Laboratory
NREL	National Renewable Energy Laboratory
PFA	Play Fairway Analysis
PGV	Puna Geothermal Venture, the only commercial geothermal power plant in Hawai‘i
Pr_F	Probability of Fluid
Pr_H	Probability of Heat
Pr_P	Probability of Permeability
Pr_R	Probability of Resource
RFP	Request for Proposals
SOPO	Statement of Project Objectives
UH	University of Hawai‘i

Executive Summary

Most of Hawai‘i’s geothermal resources are blind—their manifestations, such as hot springs and steam vents, do not appear on the ground surface because the heated water flows far below. With the exception of Kīlauea East Rift Zone, in most areas of Hawai‘i, high lateral permeability in the first kilometer below ground surface prevents surface thermal features from developing. As a methodology for discovering these blind resources, Play Fairway Analysis (PFA) involves finding potential locations of blind hydrothermal systems and describing potential geothermal sources in rift-zone settings. Using the PFA to find Hawai‘i’s geothermal resources, the University of Hawai‘i (UH) conducted the Hawai‘i Play Fairway Project, Hawai‘i’s first statewide geothermal resource assessment since 1985. Sponsored by the U.S. Department of Energy, the Hawai‘i Play Fairway Project provided an updated resource assessment, a roadmap for additional exploration activities, and the identification of areas for further exploration. Benefitting from UH’s core competency in earth sciences and experienced geothermal researchers, the project comprised three phases.

During the first phase, the team identified, compiled, and ranked existing geologic, groundwater, and geophysical datasets relevant to subsurface heat, fluid and permeability. Using a Bayesian statistical approach, the team developed a statistical methodology to integrate these data into a resource probability map. The team evaluated the confidence in the probability value and considered development viability of areas with geothermal resources. With these analyses, the team identified 10 locations in the Hawaiian Islands for exploration activities.

For the second phase, the team collected new groundwater data in 10 locations across the state and new geophysical data on Lāna‘i, Maui, and central Hawai‘i Island and modeled topographically induced stress to better characterize subsurface permeability. Analyzing the subsurface stresses, the team evaluated the potential for fracture-induced permeability. The team inverted the MT and gravity data to produce 3D models of resistivity and density, respectively, on Lāna‘i, across Haleakalā’s SW rift (Maui), and surrounding Mauna Kea (Hawai‘i Island). The team developed and applied a new method for incorporating depth information about resistivity, density, and potential for fracture-induced permeability into the statistical method for computing resource probability in these three focus areas. The team incorporated the new groundwater results with the new geophysical results and the calculations of potential for fracture-induced permeability to produce updated maps of resource probability and confidence.

Through combining data from the first and second phases, the team determined locations for further exploration during the third phase. For MT and gravity surveys, the team recommended Kaua‘i’s Līhu‘e Basin, the east rift of Maui’s Haleakalā volcano, and the southwest rift of Hawai‘i Island’s Mauna Loa volcano. The MT and gravity surveys aimed to enable improved confidence in the resource potential in these locations. For drilling deep groundwater well(s), the team recommended Southeast Mauna Kea and Lāna‘i’s Pālāwai Basin.

During the third phase, further exploration involved drilling a groundwater well in Lāna‘i’s Pālāwai Basin and performing more geophysical surveys. We deepened an existing water well proximal to our target area on Lāna‘i due to funding constraints that precluded us from spudding a new well that would exceed 1km depth. Drilling was preceded by a number of substantial elements including: writing an Environmental Assessment and the subsequent legal process, performance of deviation logging, lowering a camera down the well, coordinating site preparation with Pūlama Lāna‘i, shipping the UH-owned rig interisland, procuring supplies, and leading 3 community meetings on Lāna‘i. Drilling occurred 24/7 the entire month of June 2019

over which time Lāna‘i Well 10 was deepened from 427 m to 1057 m, with continuous core collected. We measured a roughly linear temperature gradient averaging 42°C/km and a maximum bottom hole temperature of 66°C. This gradient is more than twice the background for Hawai‘i and within a range of gradients measured in this depth range for some exploration wells within KERZ. We consider these results encouraging for Lāna‘i’s resource potential and recommend following with a slim hole within Lāna‘i’s caldera (our target zone) to ~ 2 km. Further, the positive implications such results have for the island of O‘ahu are substantial - the shield stage of O‘ahu’s volcanoes ended 1-2 My earlier. However, O‘ahu uses more electricity than the rest of the islands combined, and the utility recently called for 500-700MW of firm, dispatchable renewable electricity on O‘ahu by 2033.

In Phase 3, we also collected limited new encouraging groundwater data, and updated our thoughts on the probabilities of fluid and permeability at resource depths (Pr_F = 1; Pr_P = mostly unconstrained). Ultimately, we advocate for using our final probability of heat, and confidence in this probability, to drive the next phase of exploration. We contend further development of geothermal in Hawai‘i will enable the state to achieve its 100% renewable policy objective and Hawai‘i to transition off of fossil fuels through geothermal discovery and development.

The project not only produced a large amount of data and expanded the existing knowledge of Hawai‘i’s geothermal resources, but also produced publications, theses, presentations, core photos, datasets, media reports, television interviews, community events, and a blog. Students and new professionals benefitted from the project’s hands-on research experiences and educational opportunities and earned awards and recognition.

Introduction

Historically, Hawai‘i has had the highest electricity price in the nation (EIA, 2018). This price currently more than doubles the national average and adds to Hawai‘i’s high cost of living (EIA 2018). Furthermore, the state legislature mandated that 100% of Hawaii’s electricity come from renewable sources by 2045 (State of Hawai‘i, 2015). Hence, the state has aggressively pursued renewable sources. The percentage of renewable power in the state has more than doubled (to 22%) over the past half-dozen years–primarily through expansion of intermittent renewable energy sources including solar and wind. With Hawai‘i’s active volcanism, limited landmass, and fragile natural resources, geothermal can serve as Hawai‘i’s only cost-effective, base-load renewable energy source and can help the state to reach its 100% renewable source mandate by 2045.

Geothermal will also help the state of Hawai‘i reduce carbon emissions. Recently, the Hawaiian Electric Company announced that its climate action plan to cut carbon emissions (Hawaiian Electric Company, 2021). A key element of this plan is to expand geothermal resources.

Currently, the Kīlauea East Rift Zone (KERZ) on Hawai‘i Island is the only geothermal system in the Hawaiian archipelago from which geothermal electric power is being produced (Lautze et al., 2017). Operated by Ormat Technologies, Inc., the Puna Geothermal Venture (PGV) produced up to 38 MWe before the Kīlauea eruption and now produces 25 Mwe as of October 2021 (Shinno, 2021). To create electric power, PGV uses >300 ◦C fluids at depths of up to 2.5 km. In 2015, PGV provided ∼25% of Hawai‘i Island’s and ∼3% of the state’s energy needs (DBEDT 2015). Other than PGV and the Puna area, the major Hawaiian Islands have very few deep (∼2 km) wells. Therefore, from a geothermal perspective, the remainder of Hawaii is largely unexplored. Nonetheless, analyses of data collected from the few existing deep wells indicate that a high contrast exists between areas with recent magmatic intrusions and the background geothermal gradient of ∼18 ◦C/km (Büttner and Huenges 2003). Therefore, heat is one of the key elements to identify the Hawai‘i Play Fairway Project.

Hawaii’s geothermal resources are mostly blind—no signs of their geothermal activities can be seen at the surface, such as surface hot springs and steam vents—because the heated water flows far below (Lautze et al. 2017). Kīlauea’s lower east rift zone is the only area of Hawai‘i with known geothermal activity at the surface. These include warm springs along the Puna coast, which outflow from the rift zone likely fed, and sparse, very weak fumaroles in some deep pit craters (Thomas 1987, 1989; Conrad et al., 1997). In other locations, high lateral permeability in the first kilometer below ground surface (composed mainly of subaerial lava flows) prevents surface thermal features from developing (Lautze et al. 2017).

Since producing Hawai‘i’s first geothermal well (HGP-A) in the 1970s (Tilling et al. 2014), the University of Hawai‘i (UH) has served as a leader in Hawai‘i geothermal research. UH contributed to the last statewide geothermal resource assessment during the mid-1980s (Thomas 1985). In 2013, with funding from the U.S. Army, a UH team led a drilling effort in search of groundwater (Lautze et al. 2017). This effort found water at an elevated temperature (~140℃) in a location not previously recognized as a geothermal area of interest (Lautze et al. 2017). This discovery not only expanded our state’s resource potential but also demonstrated that our understanding of Hawai‘i’s geothermal resource potential is limited (Lautze et al. 2017).

For its most recent geothermal research effort, UH executed the Hawai‘i Play Fairway Project, a multi-year project with three phases. The project’s experienced research team

performed a Play Fairway Analysis to identify areas with geothermal resources on the main Hawaiian Islands. Originating in the oil and gas industry, Play Fairway Analysis (PFA) involves identifying the characteristics necessary for a resource to exist. The steps include identifying and ranking the data that inform such characteristics in a given geographic area, or Fairway; and then systematically combining the disparate datasets to yield an internally consistent probability map of resource regions (Plays) that have a greater or lesser probability for a resource. The resource probability map then serves as a tool to define an assessment program that can most cost-effectively identify the viable resources within the Fairway.

Applying to geothermal resources, Play Fairway Analysis serves as a methodology for finding potential locations of blind hydrothermal systems and describing potential geothermal sources in rift-zone settings (U.S. Department of Energy). According to the U.S. Department of Energy, a viable geothermal Play needs subsurface heat (H), permeability (P), and fluid (F). Heat is needed for the resource to exist, fluid to transport heat from the resource to the surface, and permeability so fluids can be extracted and replenished in the subsurface. Hence, the Hawai‘i Play Fairway project aimed to i) identify the datasets relevant to H, P, and F in Hawai‘i; ii) rank them in terms of their ability to inform each of H, P, and F in a way that is consistent with Hawai‘i’s specific geologic, hydrologic, and structural conditions; iii) compile the data; iv) develop a systematic method of incorporating the data into an internally consistent resource probability map for the Hawai‘i Fairway; and v) devise an exploration plan for Plays deserving of more site specific resource analysis.

As Hawai‘i’s first statewide geothermal resource assessment since 1985—thirty decades ago—the Hawai‘i Play Fairway Project is the first to produce a quantitative resource probability model (Ito et al., 2017), provided an updated resource assessment and a roadmap for additional exploration activities, and identified areas for further exploration. With UH as the lead institution, this project benefits from UH’s core competency in earth sciences including geothermal and groundwater research. As Hawai‘i is the only U.S. state without an official geological survey, UH historically contributed a huge bulk of what we know about Hawai‘i’s geology. The technical leader of Hawai‘i’s last statewide geothermal resource assessment, Dr. Donald Thomas contributed his decades of experience in Hawai‘i geothermal research to the Hawai‘i Play Fairway Project as a senior researcher. Building on UH’s strong research foundation, this modern effort in play fairway analysis and exploration expanded our knowledge of Hawaii’s geothermal resources—a key element for Hawai‘i’s success in achieving its 100% renewable goals.

This report describes the Hawai‘i Play Fairway Project’s activities for each of the three phases. The last section, “Products from the Hawai‘i Play Fairway Project,” lists work resulting from the project: 7 journal articles, 13 conference papers, 7 theses, 26 conference presentations, 11 University and community presentations, core photos from the Lanai drilling, 21 datasets, 18 media reports, 8 television interviews, 4 community events, a blog about the drilling effort on Lāna‘i, and awards and recognition.

Hawai‘i Play Fairway Project

Sponsored by the U.S. Department of Energy Geothermal Technologies Office, the Hawai‘i Play Fairway Project aimed to produce an updated statewide geothermal resource assessment, plan for additional exploration activities, and identify target sites for drilling. The project comprises three phases. During the first phase, the team developed a broadly applicable method for integrated data analysis, produced a ranked evaluation of geothermal resources for Hawai‘i--based on maps of calculated probability, confidence in those maps, and a formal assessment of the viability of development--and defined a roadmap for site-specific exploration activities. For the second phase, the team collected new groundwater data in 10 locations across the state and new geophysical data on Lāna‘i, Maui, and central Hawai‘i Island and modeled topographically induced stress to better characterize subsurface permeability. The team incorporated Phase 2 data into an updated resource probability map. During the third phase, the team coordinated the drilling of a geothermal well in the island of Lāna‘i and obtained scientific data. The following describes the project activities for each phase.

PHASE 1 (BUDGET PERIOD 1)

Phase 1 compiled and integrated existing data to produce a comprehensive assessment of geothermal resources statewide. Our main accomplishments for Phase 1 were 1) identifying, obtaining, and ranking all legacy and current geologic, geochemical, and geophysical data relevant to the geothermal qualities of heat, permeability, and fluid across the state; 2) compiling these data into a Geographic Information Systems (GIS) project; 3) developing a method for using diverse data types to produce probability maps of geothermal resources; 4) applying the method to Hawai‘i; and 5) identifying prospective targets with quantified risk to pursue exploration in Phase 2.

The technical strengths of the probability modeling include simplicity, coherence, adaptability, and robustness. The methodology combines established principles of generalized linear models with the conditional independence assumption with demonstrated robustness in Bayesian learning. Its utility lies in wide-area reconnaissance for any geologic setting, not just Hawaii, as well as for any resource, not just geothermal. The methodology can be used in the mode of “learning from proven resources,” expert elicitation, or a combination of the two. Unlike some methods, our approach estimates actual *probabilities*: the probability of heat, the probability of fluid, the probability of permeability, and, finally, the probability of a geothermal resource, Pr(resource). Risk is quantified as the probability of no resource, or 1-Pr(resource). The uncertainty in the results is quantified by a calculation of *confidence*, which depends on the number of data types available, and their relative weighting. The probability and confidence results were combined with the results of an analysis of *development viability*. Together, all three measures – probability, confidence, and development viability – were used to produce a prioritized ranking of areas targeted for Phase 2 exploration activities. Four project tasks were recommended for Phase 2: groundwater, stress modeling, geophysics, and 2-D and 3-D mapping.

Project activities closely followed those established in our Technical Volume, Statement of Project Objectives (SOPO), and Milestone Schedule (**Table 1**). In general, the project stayed on schedule and encountered no significant problems. All tasks were successfully completed in

advance of the project end date of October 31, 2015. Notably, original completion dates were planned for a 12- versus the actual 13-month project.

Hawaii Play Fairway Phase 1: Milestone Schedule

SOPO Task #	Milestone Description*	Original Planned Completion Date*	Actual Completion Date	% Complete	Progress Notes
1	Search of Available Data	12/31/14	12/31/14	100%	
2	Data Obtained and Compiled	3/31/15	3/31/15	100%	
3	Initial Modeling	6/30/15	5/15/15	100%	
4	Model/Data analysis and revision	7/1/15	9/20/15	100%	
5	Run Final Model	8/31/15	9/30/15	100%	
6	Identify and Rank Plays for Phase 2	10/1/15	10/10/15	100%	
	**follows Milestone Summary Table in SOPO*				

Table 1. Milestone Schedule from the Phase 1 Statement of Project Objectives.

A quarterly summary of our project activities follows. In Quarter 1 (Q1), we identified the Hawai‘i datasets relevant to geothermal resources and compiled them in a uniform and accessible format. We succeeded in having nearly all the data in a GIS digital data format by the end of Q2.

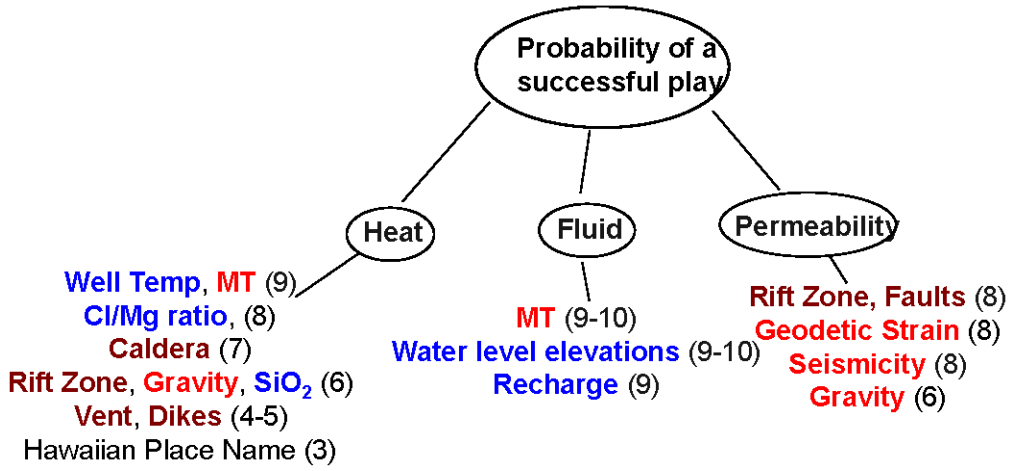


Table 2. Datasets used in the Hawai‘i Play Fairway Analysis (PFA). All data has been uploaded to the National Geothermal Data System (NGDS) through the Geothermal Data Repository (GDR) web application.

During Q2, we began the probability modeling by ranking each dataset in terms of its relevance to geothermal heat (H), permeability (P), and fluid (F) (**Fig. 1**), using expert elicitation. Q3 focused on modeling: we refined the relative rankings of the datasets, updated the specific mathematical functions used for each dataset, and applied the model to several Hawaiian Islands. In Q4, we refined the model, finalized the statewide probability map(s), developed a method to assess uncertainty (confidence) in the probabilities, and evaluated the commercial viability and/or plausibility of resource development in the areas of interest.

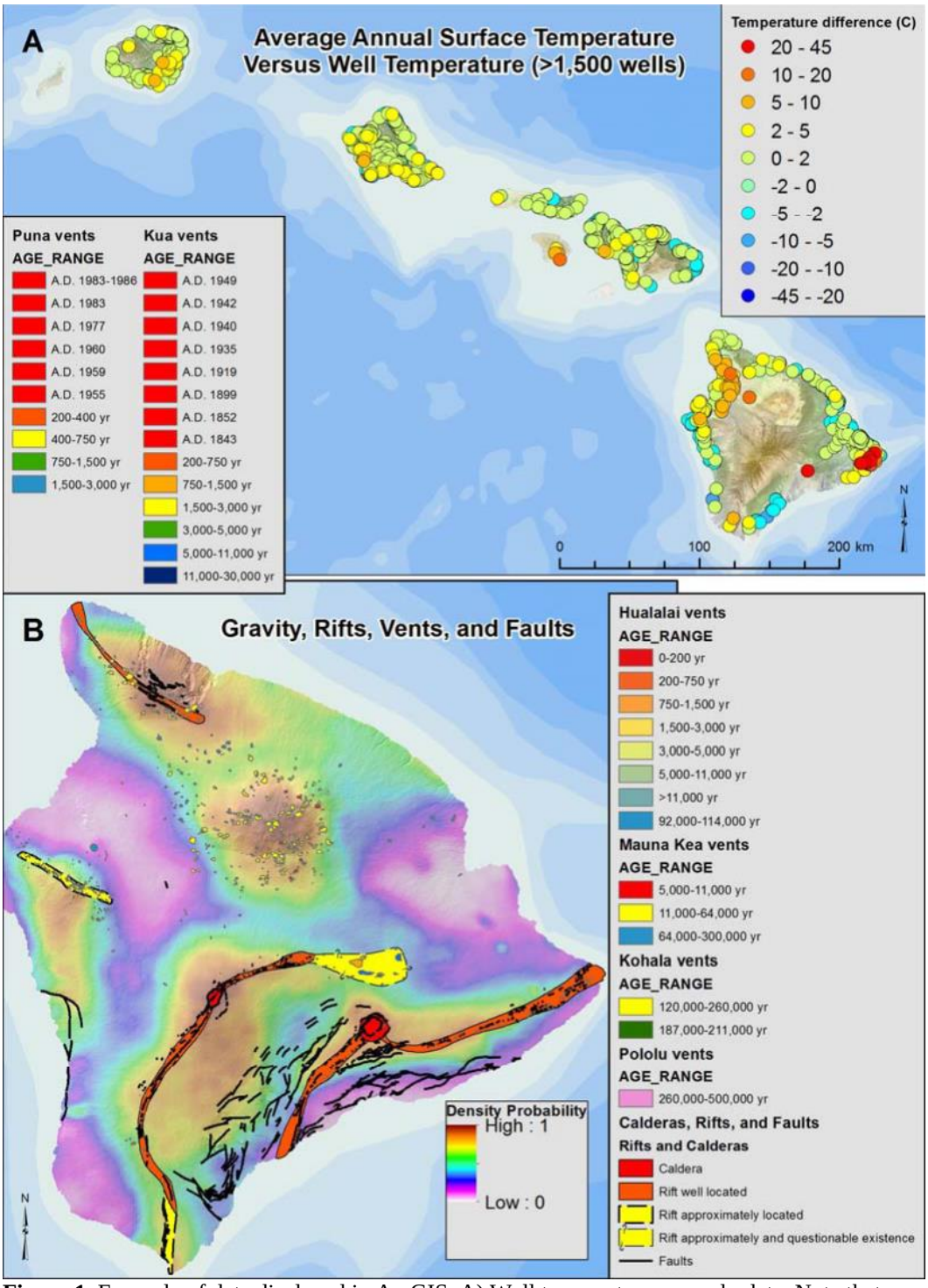


Figure 1. Example of data displayed in ArcGIS. A) Well temperature anomaly data. Note that anomalies (orange to red) exist on nearly all islands; B) Density probability derived from modeled gravity data overlain by mapped geologic structures: calderas, rift zones, vents (with ages), and faults.

PHASE 2 (BUDGET PERIOD 2)

For BP2, the team successfully executed four activities:

1) *Collected groundwater samples* in 10 areas of interest across the state and analyze for a) consistency with legacy data compiled in BP 1, b) geothermal indicators, and c) the improvement of groundwater flow direction. Generally, BP2 groundwater data reinforce the BP1 legacy data. BP2 data confirm the presence of multiple warm water wells on the east coast of Kaua‘i, in Wai‘anae’s caldera region (O‘ahu), in Lāna‘i, and along the Northwest and Southern coasts of Hawai‘i Island. Geochemical data lend further evidence for the presence of high crustal temperatures in some of these areas. Isotopic data was used to improve upon model groundwater flow models on Lāna‘i.

2) *Produced 3D models of crustal stress due to topography* to inform the probability of fracture- induced permeability. We developed a first-order method for computing topographic stresses using Green’s functions that is more than an order of magnitude faster than existing boundary element or finite element numerical methods. The new results as well as the team’s ongoing and prior research indicate that topography can induce appreciable crustal stresses, and, in places, can enhance permeability through fracturing.

3) *Performed MT and gravity surveys and geophysical inversions in three target areas: Lāna‘i Island, Mauna Kea, and Haleakalā Volcano’s SW Rift Zone (Maui).* The augmented gravity and new MT data sets were inverted to solve for subsurface structure of density and resistivity, respectively. The results provide a basis for evaluating potential drilling areas and for establishing conceptual models about hydrologic and geothermal processes.

4) *Produced updated resource probability maps and confidence in those maps.* We developed a method to incorporate depth information about resistivity, density, and topographic stresses into our voter-veto method of computing the relative probabilities of heat, fluid, permeability and a viable resource, as well as confidence in those probabilities. New maps of probability and confidence were made for the whole state, as well as for the three targeted geophysical survey areas.

Based on our augmented data set, four locations were considered for BP3 drilling. Scrutiny of the data, in parallel with our evaluation of the probability, confidence, as well as practical considerations (e.g. cost to haul water) led us to propose BP3 drilling in one of two locations: SSE of Mauna Kea on Department of Hawaiian Homelands property or on Lāna‘i, which is privately owned and managed by Pūlama Lāna‘i.

1. SUMMARY OF BP2 ACTIVITIES

Project activities closely followed our BP2 Statement of Project Objectives (SOPO). All SOPO tasks were successfully completed as was geophysical work beyond what were defined in the original SOPO as **Table 1** shows.

Table 1

BP2 SOPO TASK	OUTPUT	OUTCOME
8. Groundwater Sampling	• 62 samples collected in 10 areas • The samples were analyzed for T, major, trace elements and isotopes	• Validated BP1 legacy data • Anomalies identified on 3 islands. • Improved GW flow paths for Lāna‘i
9.Topographic Stress Modeling	• 3D models of stresses for all target islands	Added information to inform the probability of permeability and increased confidence.
10. Geophysical Surveys	• Collected new data from 44 MT sites Lāna‘i, 8 on Maui. • New inversions of 4 (pre-existing) MT transects around Mauna Kea • Collected new gravity data on Lāna‘i (140 pts) and east and SE of Mauna Kea (73 pts) • Acquired and inverted a dense gravity survey of Haleakalā’s SE Rift Zone done by ORMAT (parent company of PGV)	Models of depth-varying resistivity and density structure allow us to reject some areas and accept others for potential geothermal reservoirs.
11. New calculations of probability and confidence	• Updated maps of probability of heat, permeability, fluid, and geothermal resources across Hawai‘i and in the 3 geophysical survey areas	• Improved assessment of resource potential statewide. • New probability and confidence maps of geophysical survey areas inform where and where not to drill.
12. Rank Drilling Plays for BP3	• Qualitative and quantitative evaluations of all data in the 3 geophysical	• 1st priority: SE Mauna Kea on DHHL lands • 2nd priority: Lāna‘i’s Pālāwai caldera

2. EQUATIONS

1) $\sigma^{total} = \sigma^{ambient} + \Delta\sigma^{topography}$

2) $$\phi = \left| \frac{(\sigma_1 - \sigma_3)}{(\sigma_1 + \sigma_3)} \right|,$$

3) $$C(\mathbf{x}) = \left[1 + \exp\left(-w_0 - \sum_{i=1}^{m} w_i z_i^+ q_i(\mathbf{x}) \right) \right]^{-1}.$$

4) $\Pr R(\mathbf{x}) = \Pr H(\mathbf{x}) \Pr P(\mathbf{x}) \Pr F(\mathbf{x})$

5) $$C(\mathbf{x}) = \left[1 + \exp\left(-w_0 - \sum_{i=1}^{m} w_i z_i^+ q_i(\mathbf{x}) \right) \right]^{-1}.$$

6) $C_R(\mathbf{x}) = C_H(\mathbf{x})\, C_P(\mathbf{x})\, C_F(\mathbf{x})$.

7) $$\gamma(\mathbf{x},\rho) \equiv -\ln\left\{\frac{\int_0^D \left[\ln\rho(\mathbf{x},y) - \ln\bar{\rho}(y)\right]^2 k_\rho(y) k_y(y)\,dy}{\int_0^D k_y(y)\,dy}\right\}$$

3. GROUNDWATER CAMPAIGN

Groundwater samples were collected in the 10 locations defined as BP2 focus areas at the conclusion of BP1 (red boxes, **Figs. 2** & **3**). A total of 61 samples were collected from existing wells, and 1 spring was sampled at southeast of Mauna Kea, where no wells existed. Standard field methods were followed. Parameters included groundwater temperature, pH, dissolved oxygen, and specific conductivity and were measured in the field using a YSI Pro Plus Meter.

Groundwater samples collected in the field were distributed among three laboratories at the University of Hawai‘i at Mānoa: the Water Research and Resource Center (WRRC) Chemistry Laboratory analyzed for major ions using an ion chromatograph via the EPA method (Pfaff 1993; Hautman et al. 1997). The Inductively Coupled Plasma (ICP) Facility analyzed for trace metals and silica using a Varian Vista MPX ICP optical emission spectrometer following standard methods (Martin et al. 1993; 1997). The Biogeochemical Stable Isotope Facility analyzed for oxygen, deuterium, and carbon-13. The 13C isotopes were measured using an automated headspace sampling and continuous-flow mass spectrometry (Torres et al. 2005). The 18O and D isotopes were measured using a Picarro cavity ring down spectrometer (Godoy et al. 2012). Team member R. Whittier measured alkalinity.

We note general consistency between BP1 legacy and BP2 data. Anomalously warm wells were identified along the NW coast, S point and the Puna region of Hawai‘i Island, along the SW rift zone of Haleakalā (Maui), in multiple wells central to Lāna‘i, and in the Wai‘anae caldera region (SW O‘ahu). In general, geochemistry patterns are consistent with the thermal anomalies. The isotope data was used to improve groundwater flow paths, with a focus on Lāna‘i. Not enough wells (BP2 data points) exist to feasibly use this technique in many locations across the state.

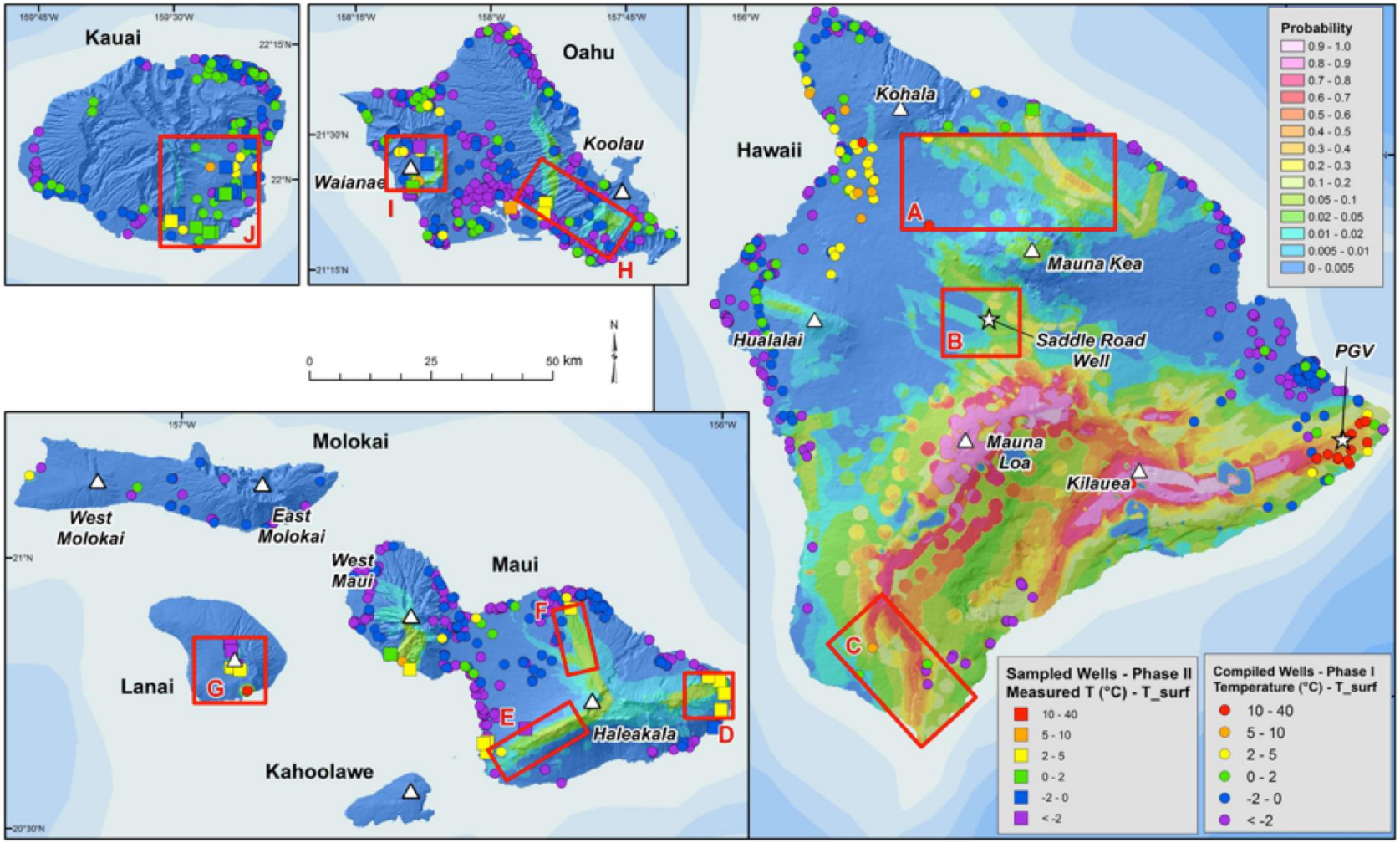


Figure 2. Groundwater temperatures in excess of mean annual surface temperature. Circles mark locations of where data was collected during BP1; squares mark locations of where data was collected during BP2. Data are overlain on our BP1 probability model.

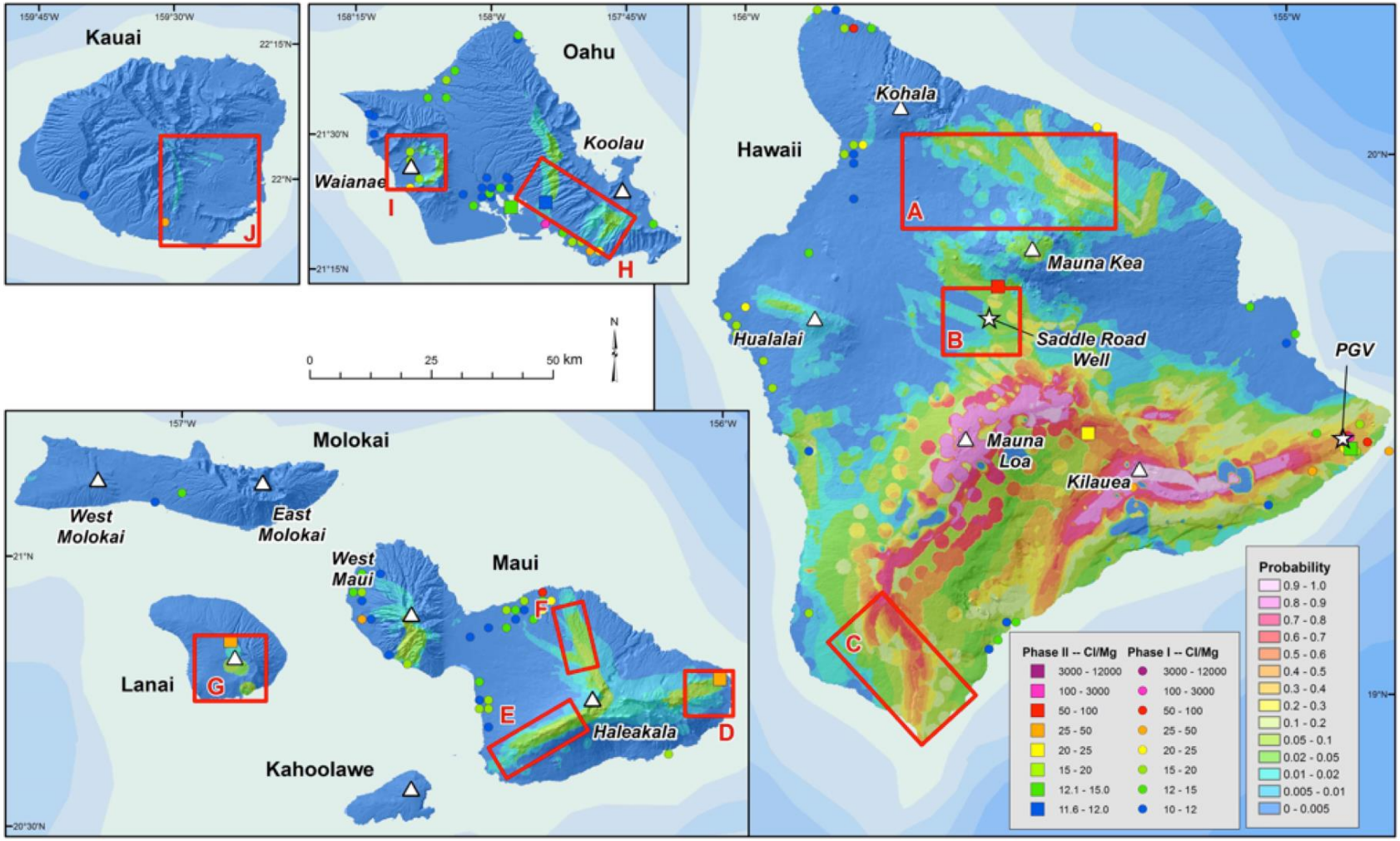


Figure 3. Map of only the Cl/Mg ratios that are considered anomalous (Lautze et al., 2017), with BP1 data shown as circles and BP2 as boxes. Data are superimposed on our BP1 probability model.

4. NEW PROBABILITY AND CONFIDENCE MAPS FOR A STATE-WIDE ASSESSMENT

Our updated statewide assessment incorporated the new data from the water sampling, gravity, MT surveys, as well as calculations of topographic stresses. The new water temperatures, Cl/Mg ratios, SiO2 data, and the new gravity data were used with geological data to compute the probability of heat using Eq. (3) as was done in BP1. Fits of the inverted (3D for Lānaʻi and 2D for Mauna Kea and Maui) resistivity structure to the ideal resistivity profiles (Eqs. (7)-(8), Table 2) were incorporated into calculations of the probability of heat and fluid (Eq. (2)) using the same weighting as in BP1. The fit of the computed failure potential to the ideal profiles provided new, additional information about permeability. The numerical values of probability and confidence should (again) be interpreted in a relative (not absolute) sense.

Figs. 4 and **5** show the results. The addition of topographic stresses led to island-wide changes relative to our BP1 maps. For probability, the changes were positive or negative and small-amplitude (±0.03 or less). For confidence, the changes were always positive ~ +0.05. Changes over localized areas of more variable amplitudes resulted from the new water and geophysical data. On Kauaʻi and Oʻahu, the small-amplitude changes in probability were due mostly to the effects of topographic stresses on the probability of permeability. On Lānaʻi, the probability of a resource has been elevated over localized zones due to the MT data (see below), new water temperature measurements, and the failure potential distribution. Confidence in the probability estimates on Lānaʻi increased substantially (> 0.15). At the lower elevations of Haleakalā's southwest rift zone (SWRZ), the resource probability was now slightly lower due to the new MT and gravity data (see below), whereas confidence in this area has been elevated to > 0.70.

Around Mauna Kea, probability was little changed along the MT survey lines northwest and east of the summit, whereas the confidence in these areas has increased by 0.05-0.25. South of the summit along Saddle Rd, probability has increased by 0.05-0.2, whereas confidence showed little reliable change (the light blue patches were due to revised water data and depended on the precise trajectories of modeled but poorly known groundwater flow). In the central part and southern half of Hawaiʻi Island, resource probabilities were maximal owing to the young ages of the active Mauna Loa and Kīlauea volcanoes. They elevated the probability of heat, as well as the ongoing seismic activity and deformation (GPS), which increased the probability of permeability. Probability values for these volcanoes were little changed, and confidence remained low over large areas (except near Puna Geothermal Venture).

Generally, the probability of heat and fluid can reach high values (>0.8) at coinciding locations on Lānaʻi, Maui, and Mauna Kea Volcano, so the probability of permeability has the dominant vetoing influence. At these locations, the maximal probabilities of permeability were only moderate (0.5-0.6) and thus so were the maximal values of the resource probabilities. This result reflected the few data types that informed us about permeability and was consistent with the fact that permeability can vary by several orders of magnitude over short length scales with little or no surface expression. Correspondingly, the probabilities of a viable geothermal resource at our proposed BP3 drilling targets on SE Mauna Kea and Lānaʻi were limited mostly by our knowledge of permeability. For reference, the probabilities at the two BP3 target areas were about 50% of the probability computed for the PGV geothermal power plant, owing mostly to a higher probability of permeability due to active seismicity and deformation around PGV.

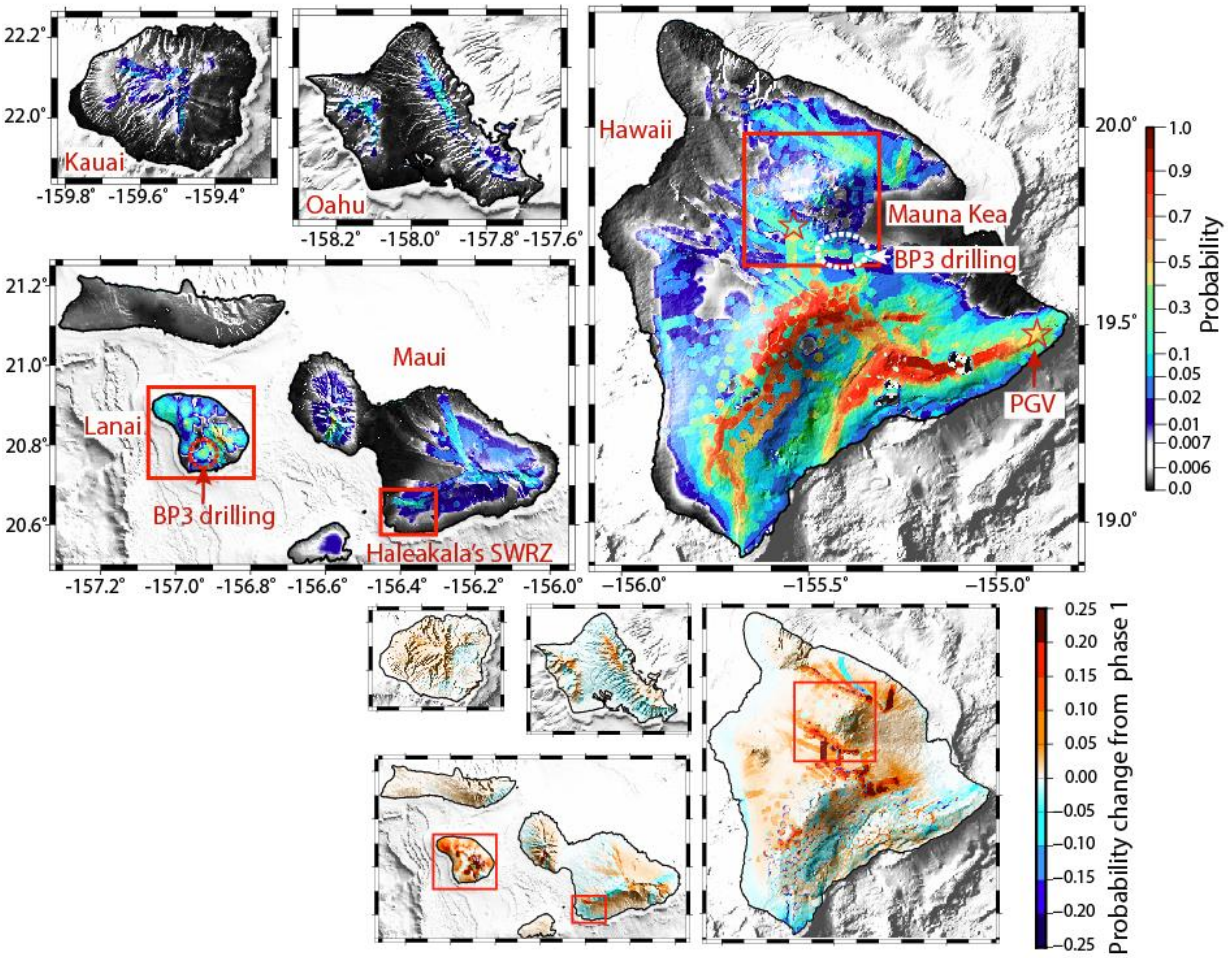


Figure 4. New resource probability maps. Red boxes outline areas of phase 2 focused geophysical surveying. Stars indicate the Saddle Drill site (north) where high temperatures were found, and Hawai‘i’s one geothermal production site, Puna Geothermal Ventures (PGV). Changes in probability relative to the BP1 assessment are shown below (warm colors show increased probability).

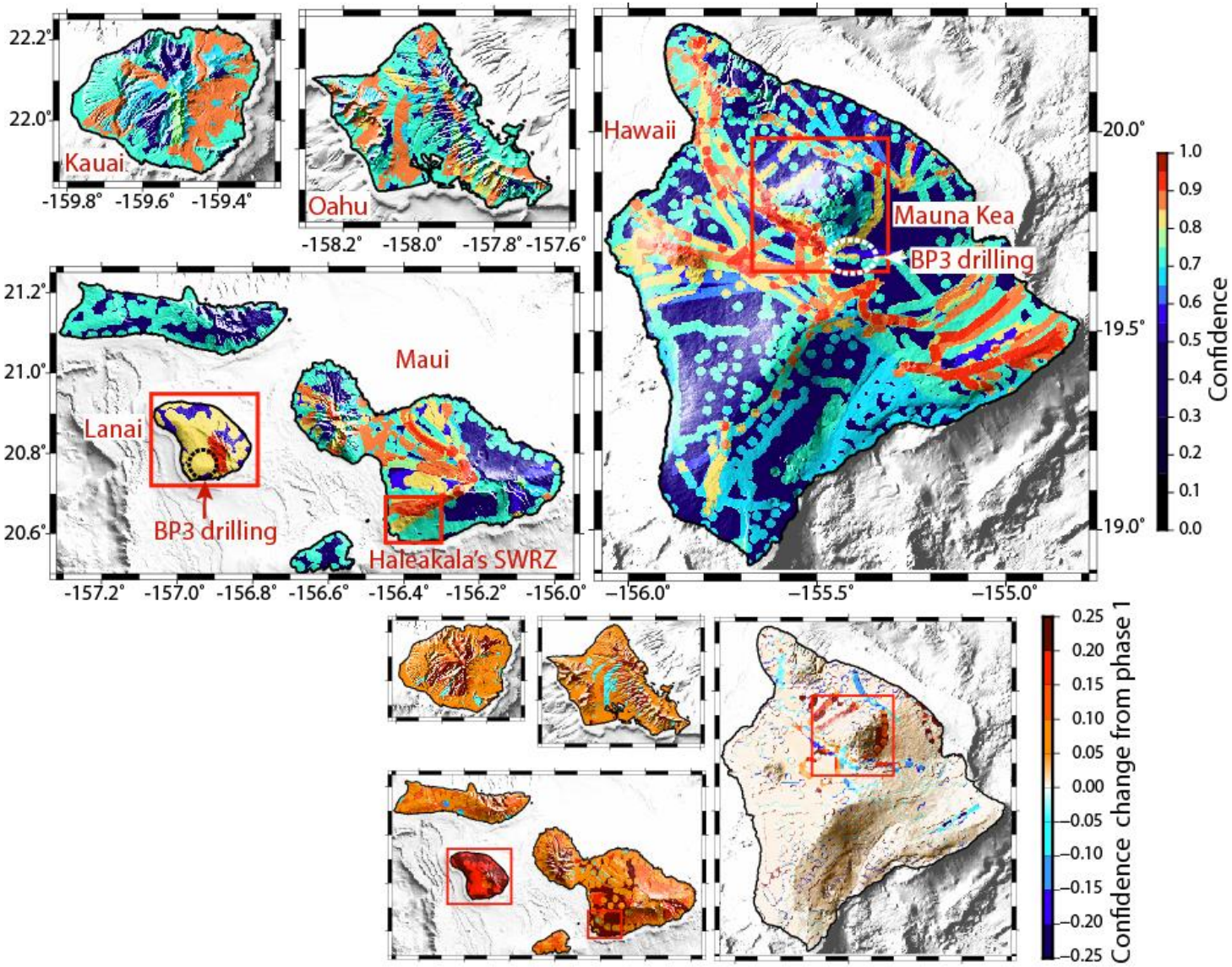


Figure 5. New maps of confidence in the probabilities. Changes in confidence relative to the BP1 assessment are shown below (warm colors show increased confidence).

5. RESULTS FOR PHASE 2 GEOPHYSICS SITES

The statewide assessment done in BP1 (and revised for BP2) enabled an evaluation of geothermal resource potential on a statewide scale. The results for BP1 motivated focused geophysical surveys in three areas: Lāna‘i, Mauna Kea, and Haleakalā’s southwest rift zone.

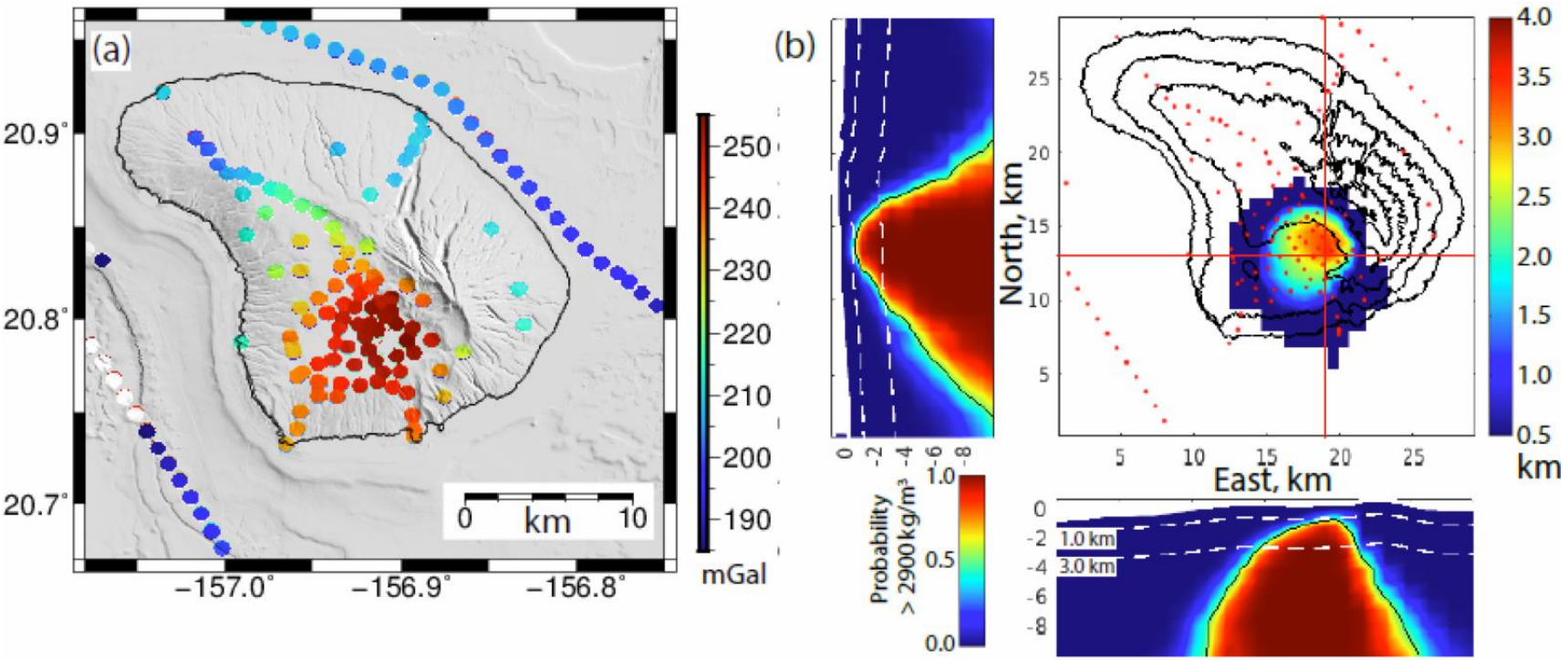


Figure 6. (a) Local complete Bouguer anomaly of Lāna‘i using ρ_0 = 2600 kg/m3 (colored patches at measurement locations). Topography is illuminated from the NE and the shoreline outlined. **(b)** Map of the depth below the surface to 90%-probability of densities ≥2900 kg/m3. Subaerial topography is contoured (100 m intervals) and gravity stations are marked with red dots. **(c)** East-west and **(d)** vertical cross sections along the lines in (b) showing probability of density >2900 kg/m3; black contour is for median density of 2900 kg/m3. The vertical axis is elevation relative to sea level.

5.1 LĀNA‘I

On Lāna‘i, the local complete Bouguer anomaly Δ*gBL* was found to be 50-60 mGal higher in the Pālāwai Caldera in the southern half of the island, compared to the coasts in the northern part of Lāna‘i (**Fig. 6a**). Gravity was also elevated in the southwest and southeast rift zones where dikes were exposed. The anomaly decreased rapidly to the north of the caldera and, surprisingly, was relatively low over most of the topographic ridge of the northwest rift zone.

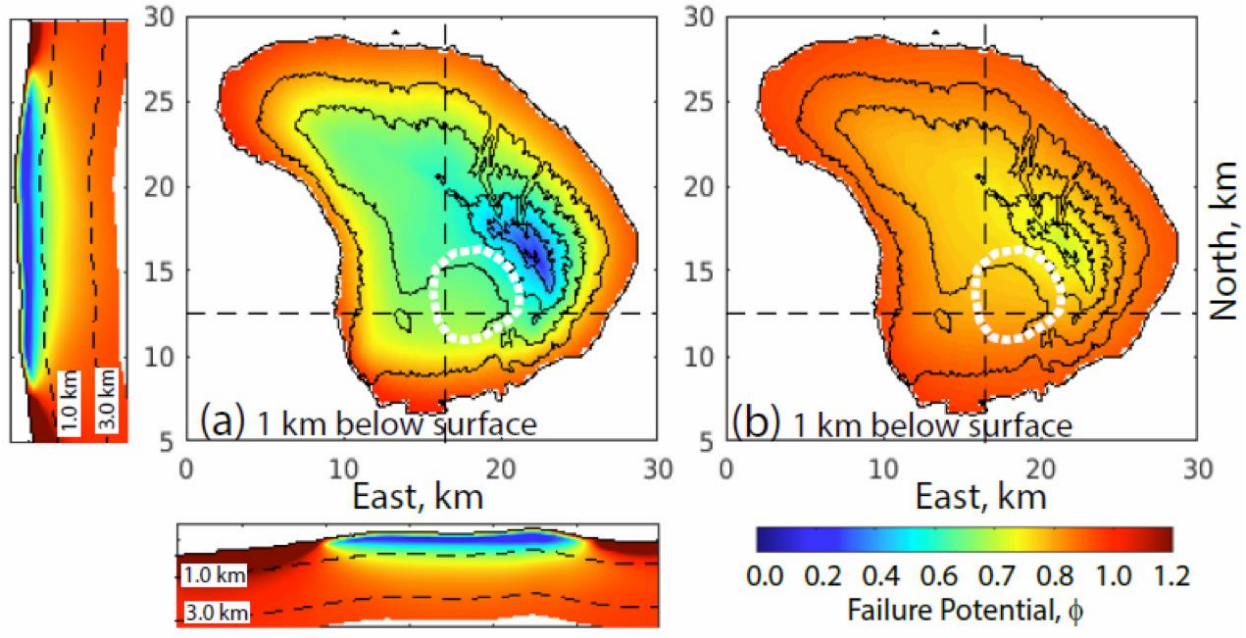


Figure 7. Failure potential, φ due to topographic stresses in the crust of Lana‘i shown at **(a)** 1 km and **(b)** 2 km below the surface topography. Vertical cross sections are taken along dashed lines. The white dashed oval outlines a median density of 2900 kg/m3 at 3

The inversions with Monte Carlo sampling predicted a large volume of high densities in a ~ 5-km-diameter area in the south central portion of the island (**Fig. 6b**). In the center of this volume, intrusive densities (≥2900 kg/m3) were > 90% probable from about 2 km below the surface all the way down to the base of the crust [*Watts and ten Brink* 1989; *Leahy et al.* 2010]. This body likely served as the remnant intrusive complex of the Pālāwai Caldera. Mean fits to the ideal density profiles (Eq. 7, Fig. C3) were best near the margins of this dense body; densities in the center of the volume were higher than ideal within 1-3 km of the surface. Failure potential (Eq. 2) computed from topographic stresses beneath Lāna‘i were lowest within 1 km of the surface and increased with depth reaching values of 0.7-0.9 at the resource depths of 1-3 km (**Fig. 7**). This structure produced moderately favorable fits to the ideal profile (Fig C4) and led to moderate probabilities for permeability (40-50%) in the area of the gravity high in the south central part of the island.

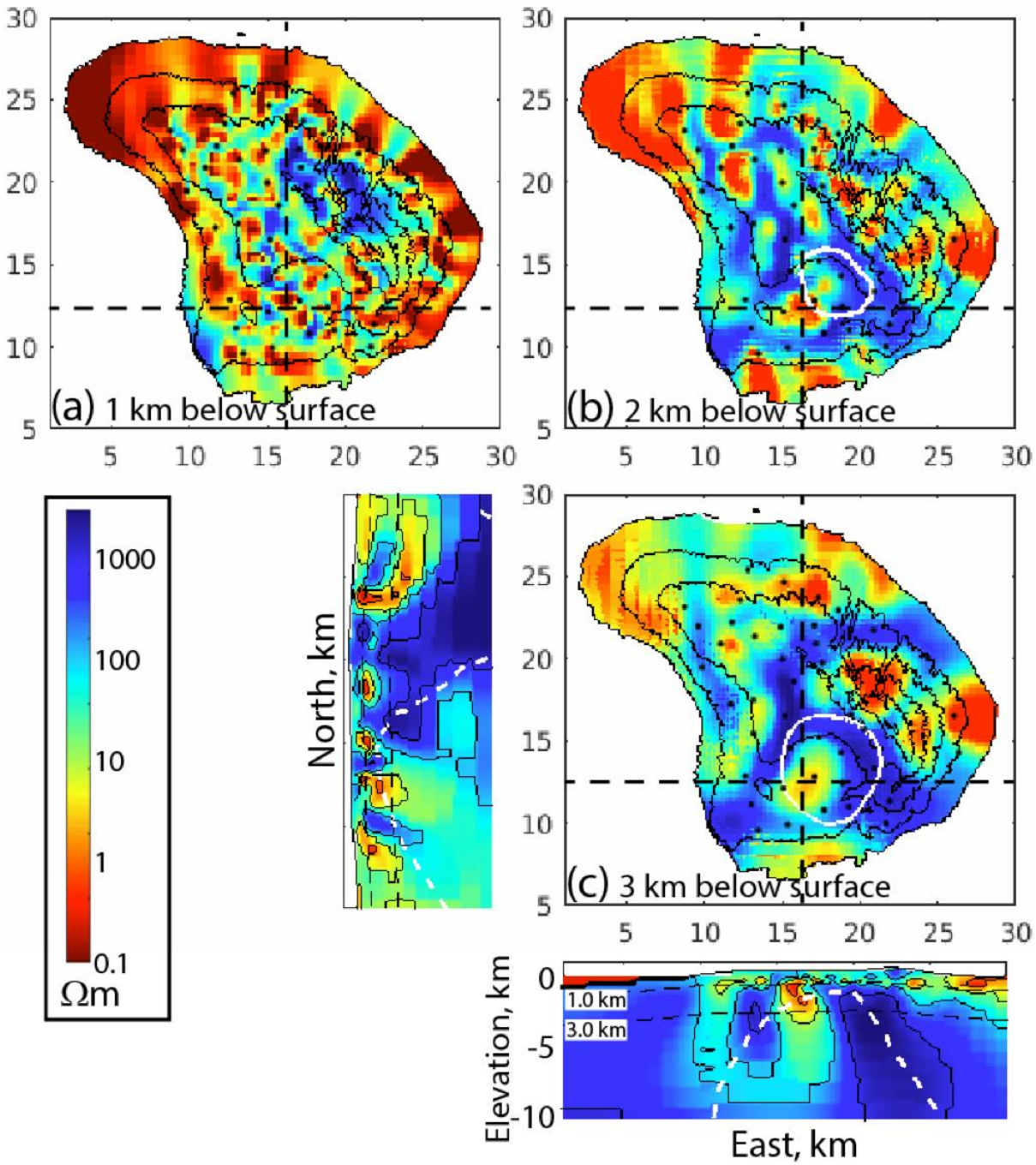


Figure 8. 3D resistivity structure from inversions of MT data shown at **(a)** 1 km, **(b)** 2 km, and **(c)** 3 km below the surface. Vertical sections along dashed lines are shown. White curves outline a median density of 2900 kg/m3 from the gravity inversions.

The 3D inversions of the MT data displayed a shallow layer (< 1 km below the surface) of moderate resistivities (~10 Ωm), which was punctuated with short (< 1 km) wavelength variations (**Fig. 8**). This layer probably encompassed a shallow groundwater reservoir. Below a 1 km-depth, the resistivity structure showed more variability, with some zones of low resistivities (0.1-10 Ωm) extending more than 1 km. In the south-central area, a broad (3-4 km wide) volume of low resistivity extended through the resource depths of 1-3 km down to ~6 km below the

surface. This body underlay much of the region of high gravity and overlapped substantially with the dense intrusive body of the Pālāwai Caldera. This spatial correlation was consistent with the presence of a broad, vertically extensive heat source.

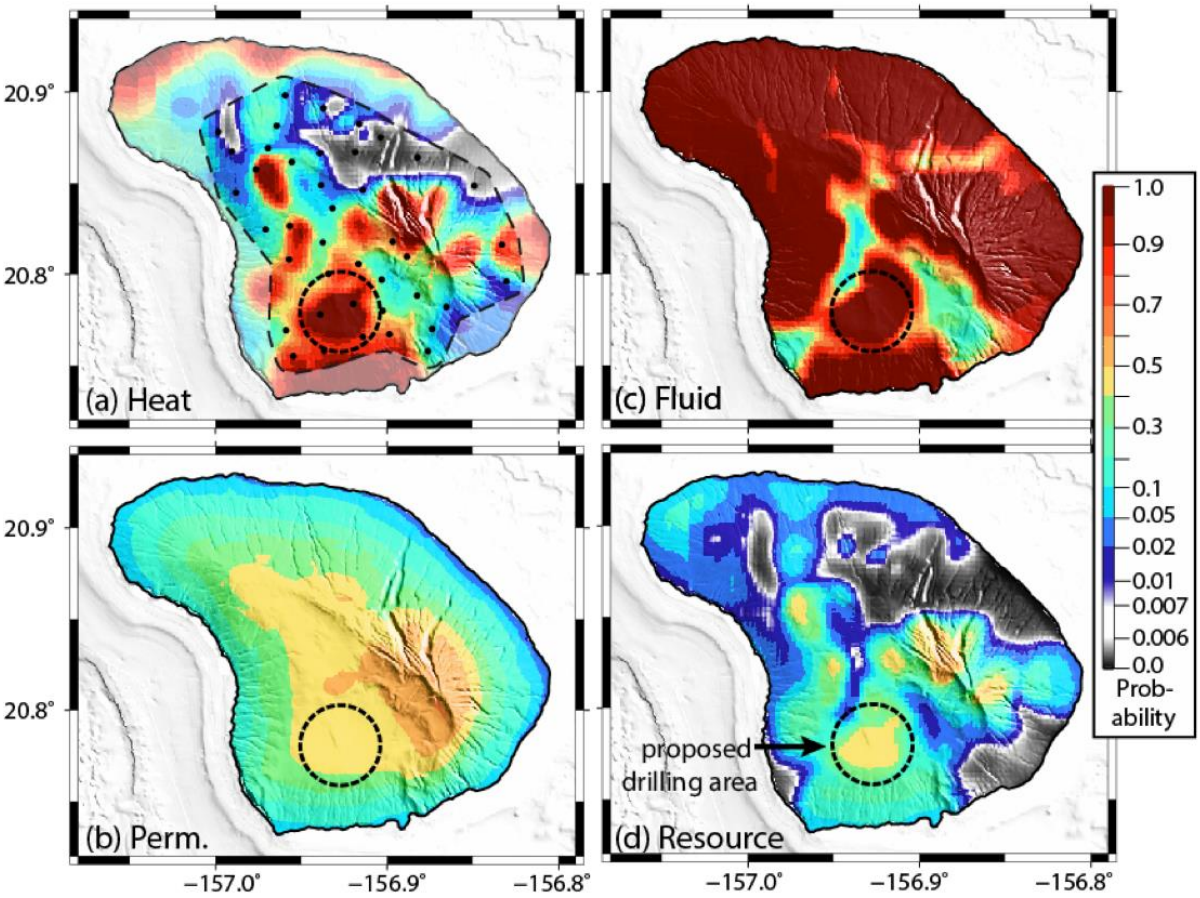


Figure 9. Local probabilities for Lāna‘i of (a) heat, (b) permeability, (c) fluid, and (d) a geothermal resource. The reliable area for the MT results is contained within the footprint (outlined by dashed lines) of the MT stations (marked by dots), both due to data coverage as well as the likelihood that salt water is highly conductive and probably intrudes the crust near the shorelines.

We modeled resource probabilities for Lāna‘i and the two other geophysical survey areas using a more select group of data types and information than was used for the statewide assessment (**Fig. 10**). The probabilities computed in geophysical survey site should therefore be read in a relative (not absolute) sense within each individual site (quantitative comparisons between sites or with the statewide assessment should be avoided). Probability of heat was computed based only on the fits of the 3D resistivity and density structure to the ideal profiles (Eq. (7)-(8)). The area of greatest interest for heat was the southeastern part of the Pālāwai Caldera. The information used to compute the probability of permeability included the proximity to faults and the caldera (as in BP1) and failure potential (**Fig. 4b**). As previously noted, the least information was available about permeability, so the probability of permeability was more uniformly low to moderate. The information used to evaluate the probability of fluid were the water table elevations, maps of groundwater recharge, and the 3D resistivity structure (**Fig. 10c**). The high prior probability (0.78) typically led to more uniformly high probabilities of fluid as was the case for Lāna‘i. The joint probability of heat, permeability, and fluid showed elevated

values in the eastern mountain range as well as in a 3-4 km wide annulus in the Pālāwai Caldera (**Fig. 10d**).

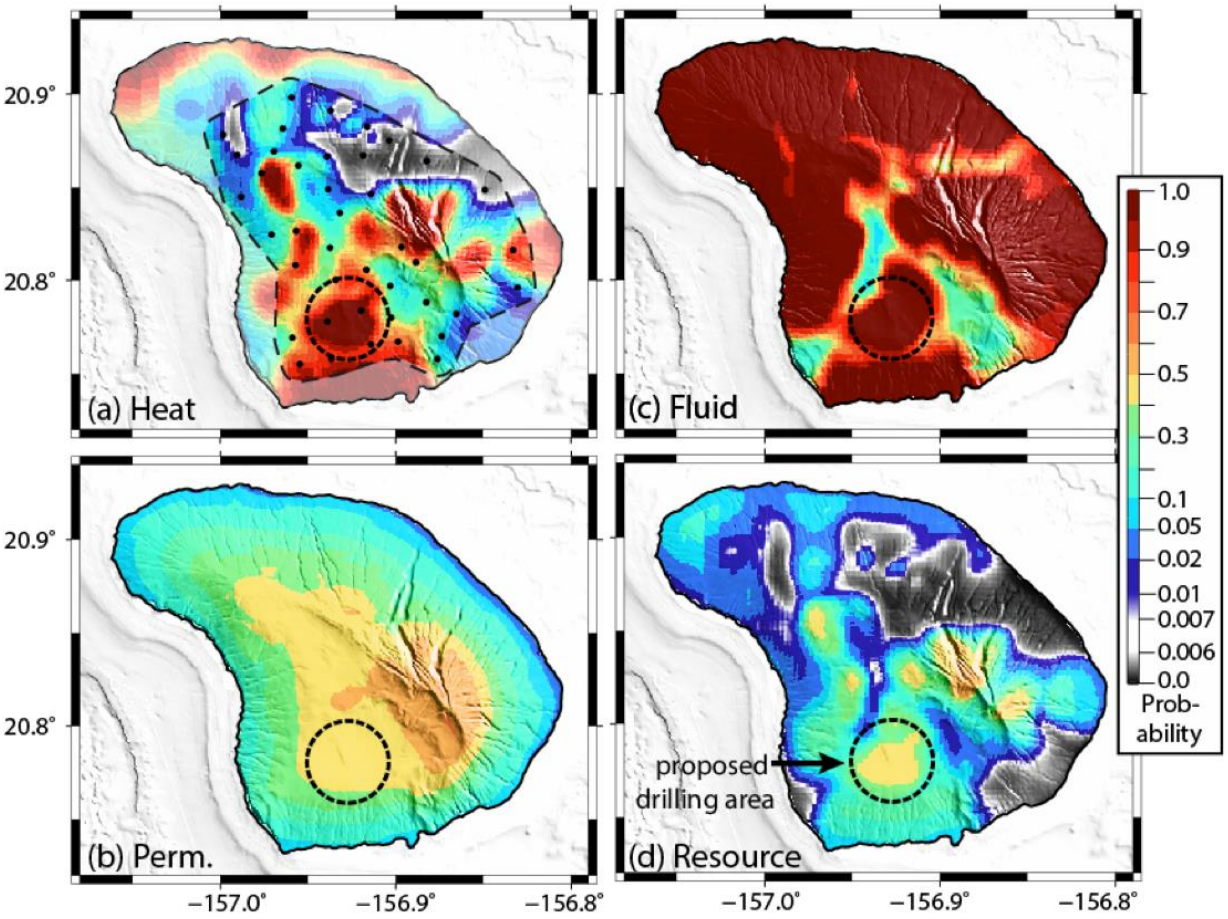


Figure 10. Local probabilities for Lāna‘i of (a) heat, (b) permeability, (c) fluid, and (d) a geothermal resource. The reliable area for the MT results is contained within the footprint (outlined by dashed lines) of the MT stations (dots), both due to data coverage as well as the likelihood that salt water is highly conductive and probably intrudes the crust near the shorelines.

5.2 MAUNA KEA VOLCANO, HAWAII ISLAND

The new gravity data from Mauna Kea focused on the east flank of the volcano along the Mana Rd MT survey line. These data were combined with those from BP1 as well as additional lines south of Saddle Rd and along the Parker Ranch (PR) MT lines A and B (**Fig. 11**). Together, these data yielded a local complete Bouguer anomaly having high values over the summit of Mauna Kea, its south flank and north of the summit near Kohala volcano. Low values occurred far west, far southwest, and far southeast of the summit. The gravity anomaly was moderate along the PR MT lines, low along the Mana Rd MT line, and high in the central portion of the Saddle Rd MT line.

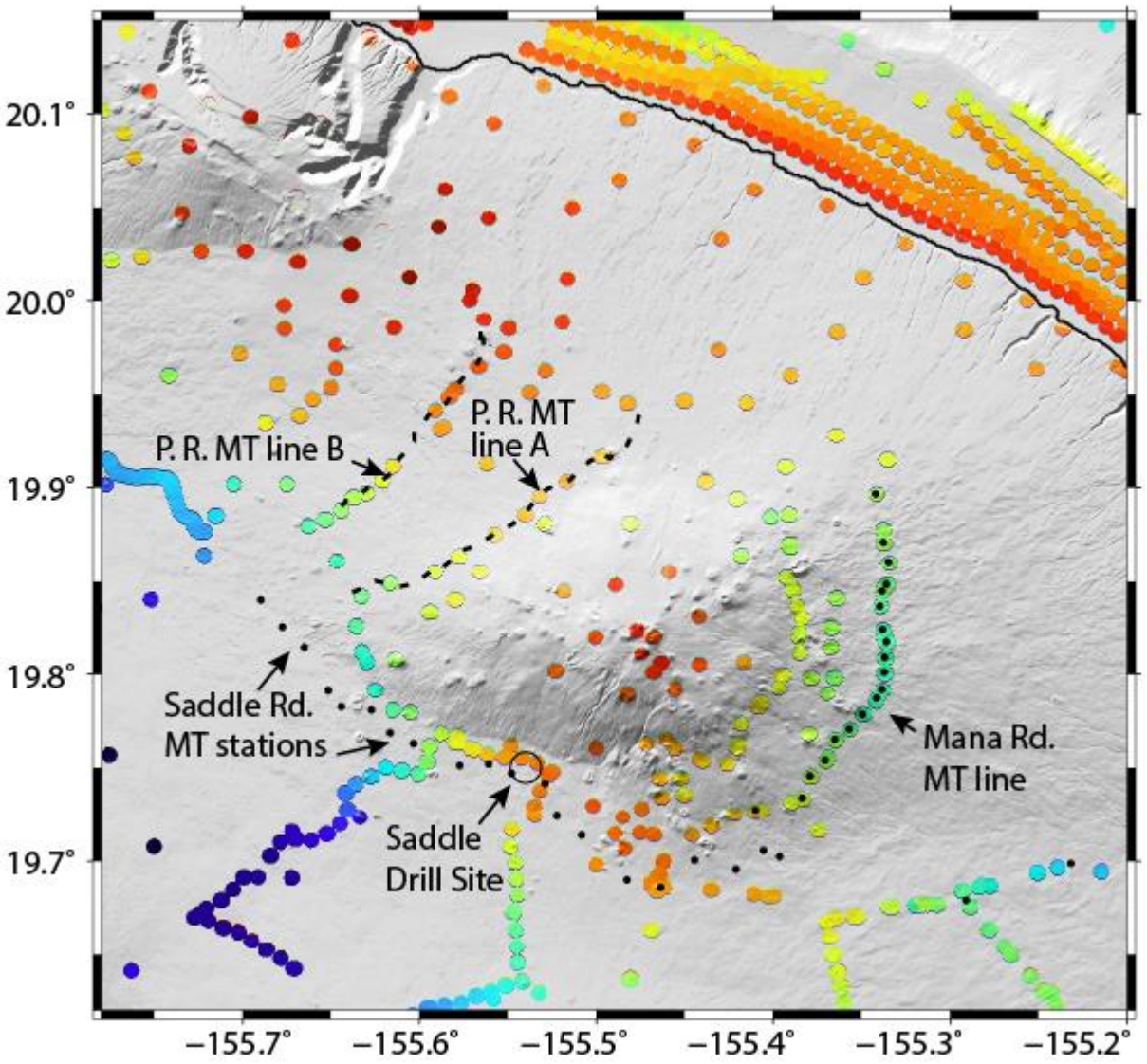


Figure 11. Local complete Bouguer anomaly around Mauna Kea volcano (using ρ_0 = 2700 kg/m3). Topography is illuminated from the NW. The shoreline is outlined in black dots and show the Saddle Rd. MT stations. The dotted line shows the Mana Rd. MT survey line, and the dashed line shows Parker Ranch MT line.

The 2D inversions of the four MT transects produced the resistivity structure shown in **Fig. 11**. The two PR models showed moderately high resistivities (500-1000 Ωm) at the 1-3km resource depths and lower values (<50 to 100 Ωm) at greater depths. Both resistivity models fit the ideal profile for heat poorly and thus yielded low probabilities (red curves, top row in Fig. GI8). For fluid, most of PR-B traverse showed high probability, whereas the PR-A traverse showed variable probabilities (blue curves, top row in Fig. GI8). The Mana Rd resistivity structure displayed a conspicuous layer ~2 km in thickness with low (50-100 Ωm) values, but it is centered below the ideal depth range of 1-3 km. Correspondingly, we found the probability of heat to be moderately low (0.1-0.3), but the probability of fluid to be very high (near 1.0). In all three cases, the median densities were low and did not fit the ideal density profile well.

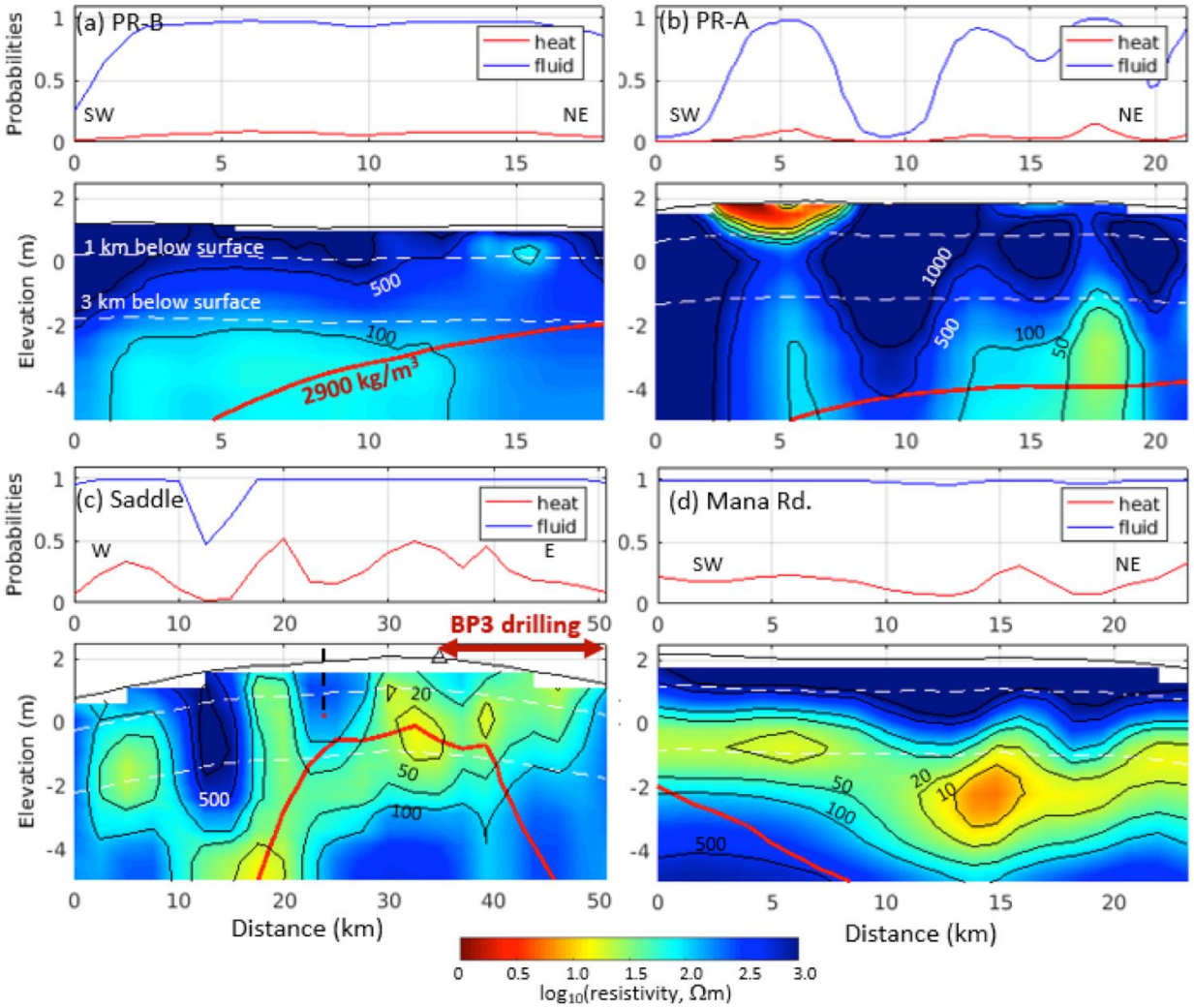


Figure 12. Colored panels show vertical slices of inverted resistivity structure along the four MT transects on Mauna Kea (contours labeled). Red curve is a contour for a median density of 2900 kg/m3 derived from the gravity inversions. The PTA Saddle Drill site (c) is marked by dashed line extending to the bottom of the hole. The profiles above show probability of heat (red) and fluid (blue) based on the mean misfit to the ideal profiles (see Eq. (7) and Table 2).

The Saddle Rd MT line, however, showed low values (<50 Ωm) at 1-3 km depth with minima centered on three areas (**Fig. 12**, lower left). One area was just west of the Saddle Rd Drill site, and two were further east. These zones also coincided with high densities, which were consistent with the presence high-temperature intrusive rocks near reservoir depths.

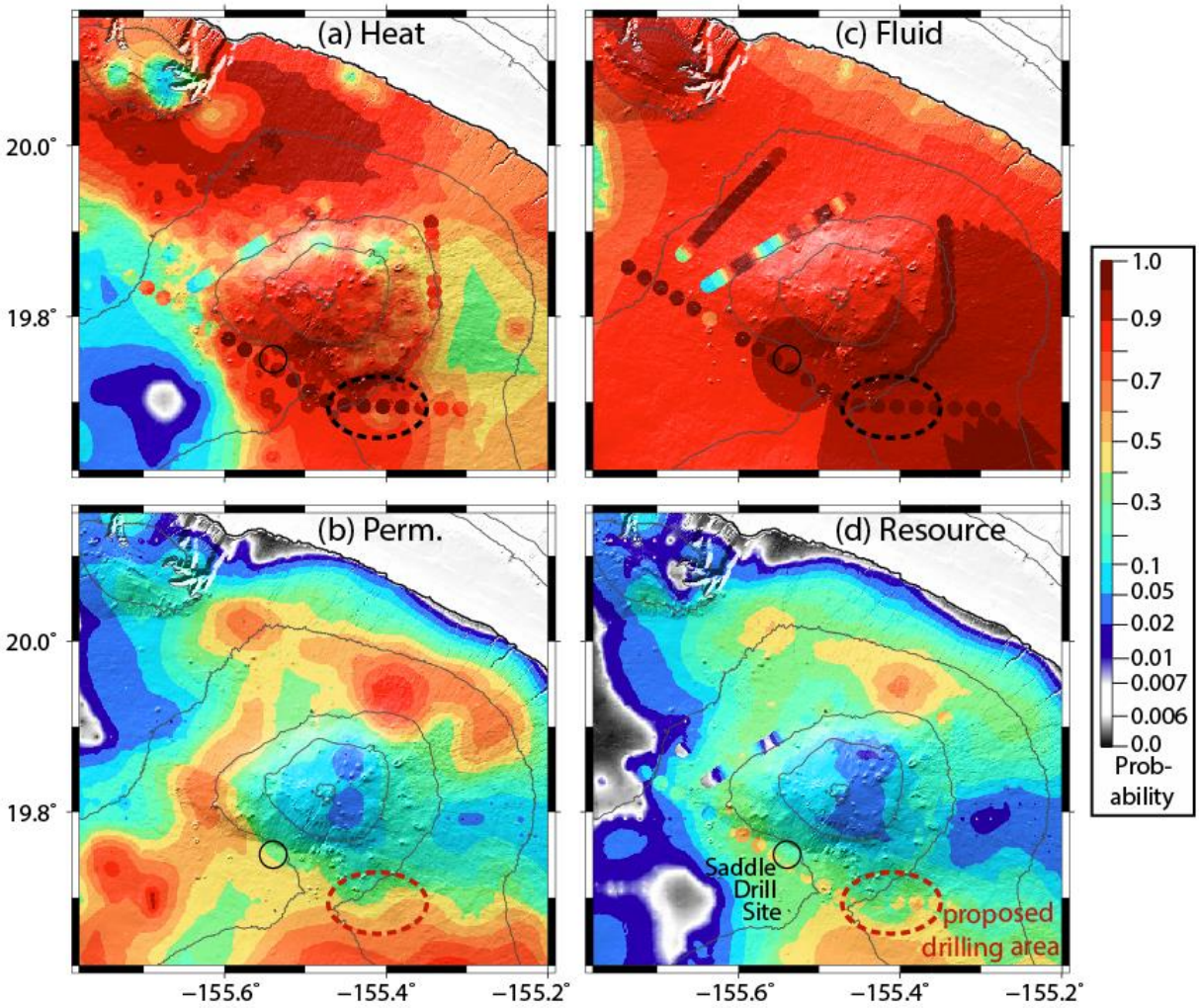


Figure 13. Local probabilities for Mauna Kea of (a) heat, (b) permeability, (c) fluid, and (d) a geothermal resource. For BP3, highest-priority drill site is marked by the dashed oval.

We produced maps of probabilities for Mauna Kea (**Fig. 13**) using the same data types and methods as described above for Lānaʻi. The one added data type used to inform the probability of permeability was seismicity (see *Ito et al.*, 2016). The probability of heat was found to be variable, with high values on and just south of the summit of Mauna Kea. Elevated heat probabilities occurred along the Saddle Rd MT profile, some of which were validated by the high-temperatures found at depth at the Saddle Rd drill site. Probability of permeability was low on and west of Mauna Kea's summit and moderate on the south, west, and north flanks. Probability of fluid was uniformly high and maximal along the MT profiles (except in a few locations along traverse PR-A). Together, the three marginal probabilities led to local resource probabilities that were highest (0.4-0.6) on Mauna Kea's northeast flank and southeast flank along and near the Saddle MT line.

4C. HALEAKALĀ's SOUTHWEST RIFT ZONE (SWRZ; MAUI)

Ormat's gravity survey showed a surprising pattern of low gravity anomalies along Haleakalā's SWRZ (**Fig. 14**). These findings combined with inversions of the MT profile led to a pattern of generally low probabilities of heat (**Fig. 15**). The resistivities in the depth interval of 1-3 km

were sufficiently low, however, to yield high probabilities of fluid (**Figs. 14-15**). Topographic stresses produced low probabilities of permeability near the southwestern tip of the rift zone and moderate values at higher elevations (**Fig. 15**). The probability of a resource was overall low with high confidence.

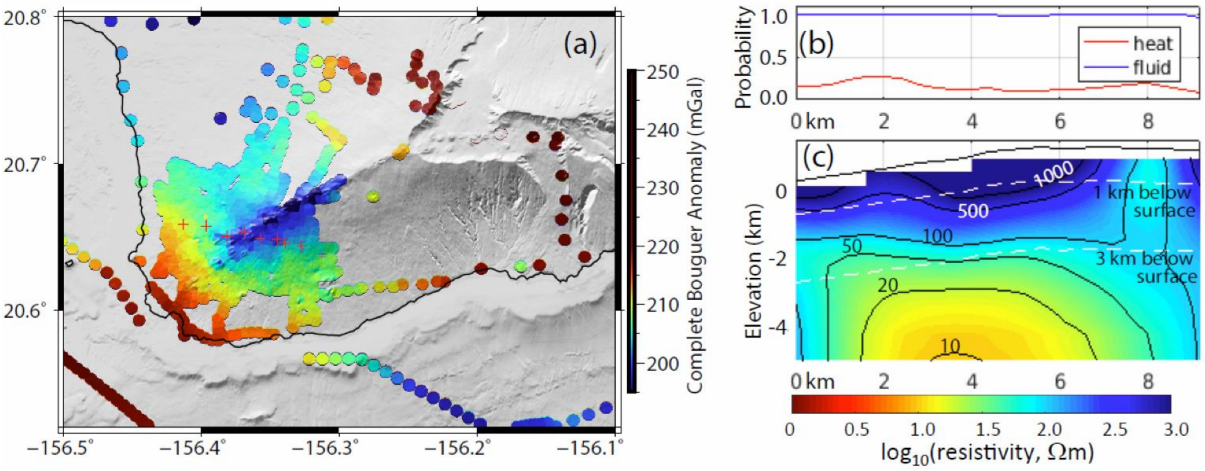


Figure 14. Geophysical results for Haleakalā's southwest rift zone: **(a)** local complete Bouguer anomaly (colors) and MT stations (crosses); **(b)** probabilities of heat and fluid from resistivity along the MT profile; and **(c)** resistivity structure beneath the MT profile from 2D inversion. Everywhere in this cross-section, the median density is < 2900 kg/m3.

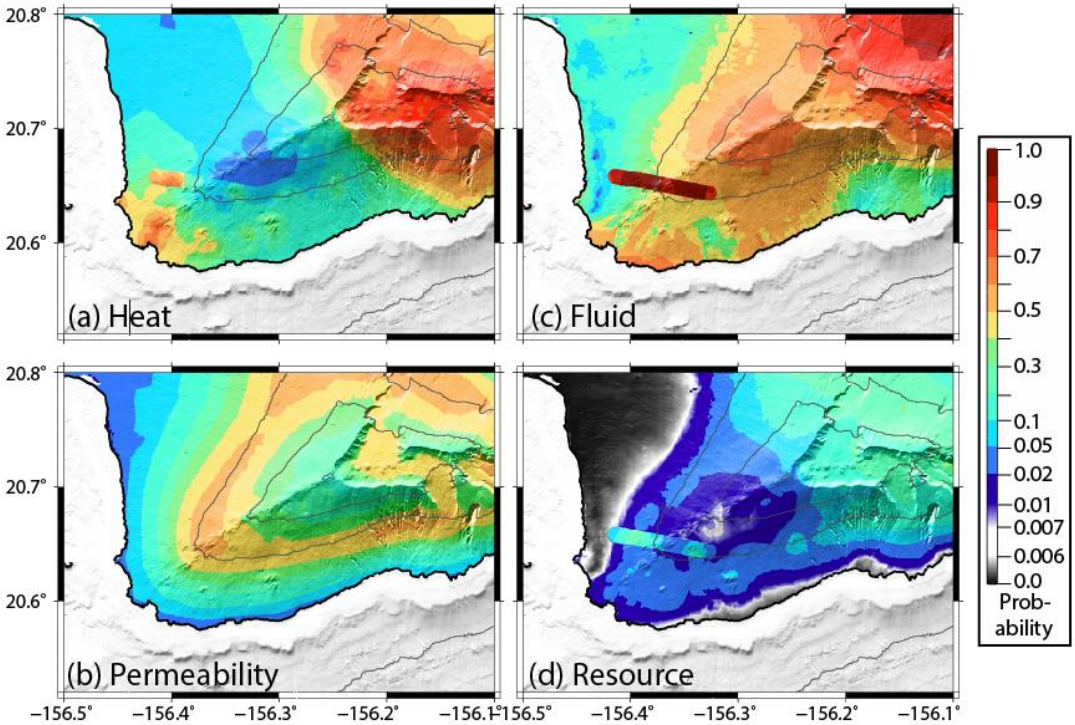


Figure 15. Probabilities for Haleakalā's southwest rift zone of (a) heat, (b) permeability, (c) fluid, and (d) a geothermal resource.

PHASE 3 (BUDGET PERIOD 3)

In Phase 3, the project aimed to validate the methodology established in the earlier two phases through drilling. Given funding limitations (drilling costs in Hawai‘i are much higher than the mainland, as noted by reviewers for the Phase 2 to 3 downselect, and in Dr. Lautze’s discussion with U.S. Senator Mazie Hirono’s energy staffer Joe McGarvey), the project team partnered with Pūlama Lāna‘i to deepen an existing water well not in use. In addition, Master of Science student Colin Ferguson collected additional groundwater chemistry (noble gas) data around the state.

The drilling aspect of the project was the most significant in terms of dollar amount as well as impact: drilling requires a large amount of capital and is the only way to confirm what is happening below the earth’s surface for blind resources. Additional challenges of drilling included, but were not limited to, supplies procurement, shipping/transportation, services agreements (e.g. with the drilling company), housing, NEPA/endangered species concerns, the monumental writing of the Environmental Assessment and response to public commentary, managing public/community perception, and timing and execution. Fortunately, the project team gained the support of the Lāna‘i community through hosting activities including two community meetings and a Drilling Open House.

1. LĀNA‘I DRILLING

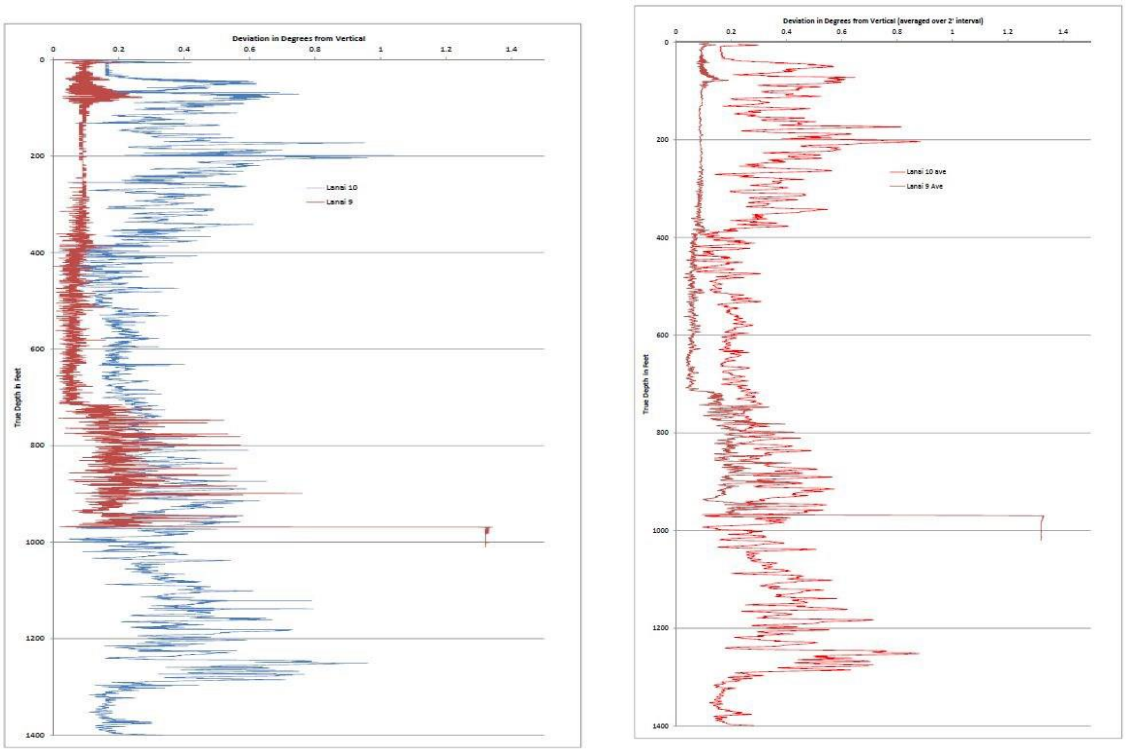
1.1 PRELIMINARY STEPS

1.1.1 Environmental Assessment

A major component of our Phase 3 work was the preparation of an Environmental Assessment (EA). Our 100+ page draft EA was submitted to the Hawai‘i Department of Health (HDOH) Office of Environmental Quality Control (OEQC) on September 19, 2018, with only one individual from the public commenting on the Draft EA who submitted 5 pages of questions at the end of the posting period. In accordance with Hawai’i environmental review requirements, we provided responses to all of the questions and comments submitted by the individual (Appendix A) and consulted with Pūlama Lāna‘i Conservation Directors and the Pacific Fish and Wildlife Office for biological survey information on rare or threatened species and for advice on creating a system of mitigation measures for the project, particularly focusing on Hoary Bats and Hawaiian Petrels. A Final EA and Finding of No Significant Impact (FONSI) was submitted to the HDOH-OEQC and published on December 23, 2018, with no challenges to the FONSI.

1.1.2 Downhole Camera and Deviation Logging

We conducted both video and deviation logging of Lāna‘i Wells 9 and 10 prior to the commencement of the drilling to determine the fitness of each well for the deepening. We



coordinated with the state’s Commission of Water Resources Management and Pūlama Lāna‘i to

Figure 16. Deviation logs averaged every two inches for Lāna‘i Wells 9 (left) and 10 (right).

log of Well 9 that Pūlama Lāna‘i had conducted a few years earlier. Both wells were found to be open enough to justify performance of a gyroscopic log. Because wireline core drilling is much more sensitive to sharp deviations in borehole direction (increasing the risk of twist-offs) we contracted with Frontier Logging Corporation to perform deviation logging on Wells 9 and 10, on December 2-9, 2018. Both wells were determined to be sufficiently free of any sharp directional deviations to allow us to deepen either one using the UH-owned truck-mounted coring rig. Reports of unconsolidated material at the bottom of Well 9, its proximity to residential areas of Lāna‘i City, and its location closer to the dominant source of cold rainfall recharge led us to select Lāna‘i Well 10 for our deepening effort.

1.2. ACTIVE DRILLING AND CORING

After ensuring the wells were open and straight, we proceeded to procure and ship supplies to Lāna‘i (including the drill rig) to prepare the site and to contract with a drilling company to provide licensed drillers and a few experienced drill hands. We contracted with Idea Drilling, from Virginia, Minnesota, which was purchased by Timberline Drilling, operated out of Hayden, ID, shortly after our contract was executed.

Drilling was executed on a 24/7 basis across the month of June 2019, with 2 crews working 12 hours daily. **Fig. 17** shows the daily rate of progress, and a daily drill log is included as Appendix B. At two stages throughout the drilling exercise – mid- and late-June 2019 – hole stability issues were encountered. In both instances, loose, unconsolidated material was

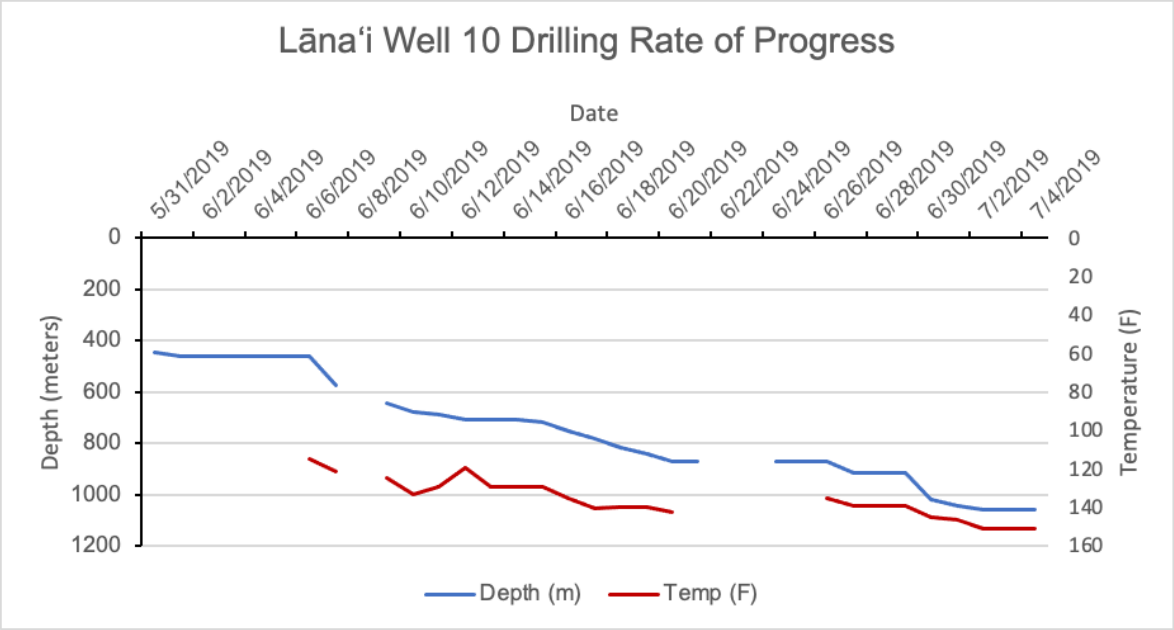


Figure 17. Plot showing rate of progress, or deepening per day (blue) and fluid temperatures measured during drilling (red) at Lānaʻi Well 10.

encountered by the drill bit and was unable to be cleared. These zones of unconsolidated material could have been sand or gravel formations, or, more plausibly, cave-in from the walls of the drill hole. We postulate that these unconsolidated sediments were in fact parts of friable formations of highly altered and relatively unstable material that was milled up between the drill string and the borehole walls into a fine sand (**Fig. 18**). To drill through these zones on both occasions, we cemented down the hole to stabilize the walls and solidify the formation at the depth of interest. Once the cement solidified, we were able to drill through these zones and continue to deepen the well. Dynamic temperature measurements were taken nearly daily, with a measured 28°C (50°F) increase to 66°C (151°F). The fluctuating temperatures with depth (**Fig. 17**) seemed to be a function of the temperature and volume of drilling fluid injected down the hole (fluid was recycled when possible) versus an indication of any near-equilibrium downhole temperature.

Figure 18. Cleaned, cut, and boxed rock core recovered from Lāna‘i Well 10. (Left) Example of solid, consolidated units within the borehole Evidence of a high-angle dike intrusion into the surrounding rock (left-most column in the core box). (Center, Right) Example of friable formations downhole. Most of this material came out of the core tube in a fairly competent form but clearly broke apart as they dried. This was milled up in between the drill string and the borehole walls into a fine sand.

Ultimately, Lāna‘i Well 10 was deepened from 427 m to ~1057 m, with nearly continuous rock core collected. An onsite core processing facility was established adjacent to Well 10 where the core was immediately cleaned, cut, and cataloged into core boxes. The core was palletized and shipped to Hilo, where via outside project funding, it has been nearly completely logged as of this writing. Preliminary core photos and a blog-style log of drilling activity from the core archiving crew are available.

The original objective of the drilling exercise was to double the original depth of Lāna‘i Well 10, drilling to a total depth of ~854 m. At the conclusion of June, this objective was completed and limited funding was remaining. The project proceeded to purge the hole of drilling fluid, take more detailed downhole temperature measurements, bring the well into compliance with CWRM standards in order to keep the well open for future activity and ship the rig and supplies back to Hawai‘i Island. The final downhole configuration of the Lāna‘i Well 10 is shown in **Fig. 19**.

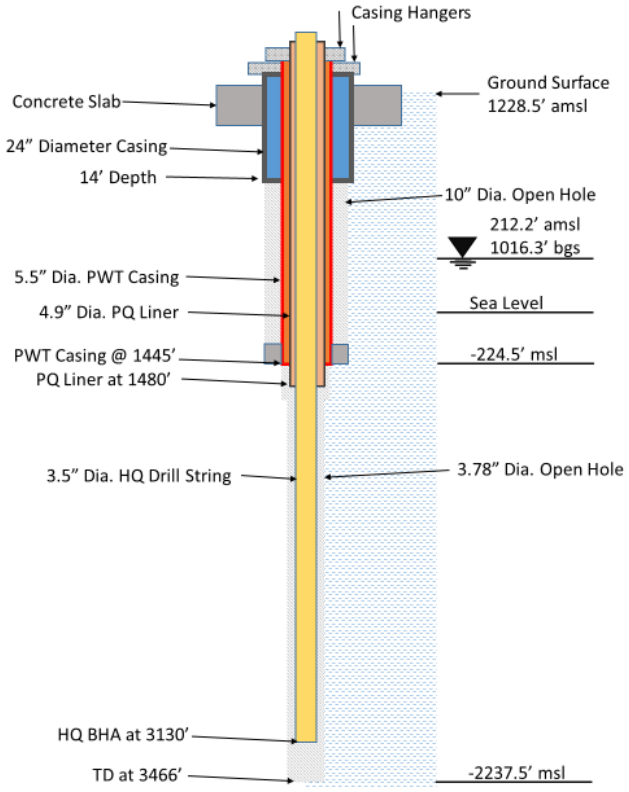


Figure 19. Final configuration of Lānaʻi Well 10.

1.3. DRILLING RESULTS

1.3.1 Temperature Profile

The temperature measurements taken downhole during active drilling are reported in **Fig. 17**. Downhole temperature surveys were also taken 2- 4- and 20- months after the completion of drilling, with no significant change in temperature between the first and last survey. In the post-drilling surveys, we used two downhole tools to validate the temperature measurements including during drilling (a HOBO logger and a Solonist tool); such validation was achieved. After drilling, a maximum depth of ~900 m (2955') was reached due to an obstruction that

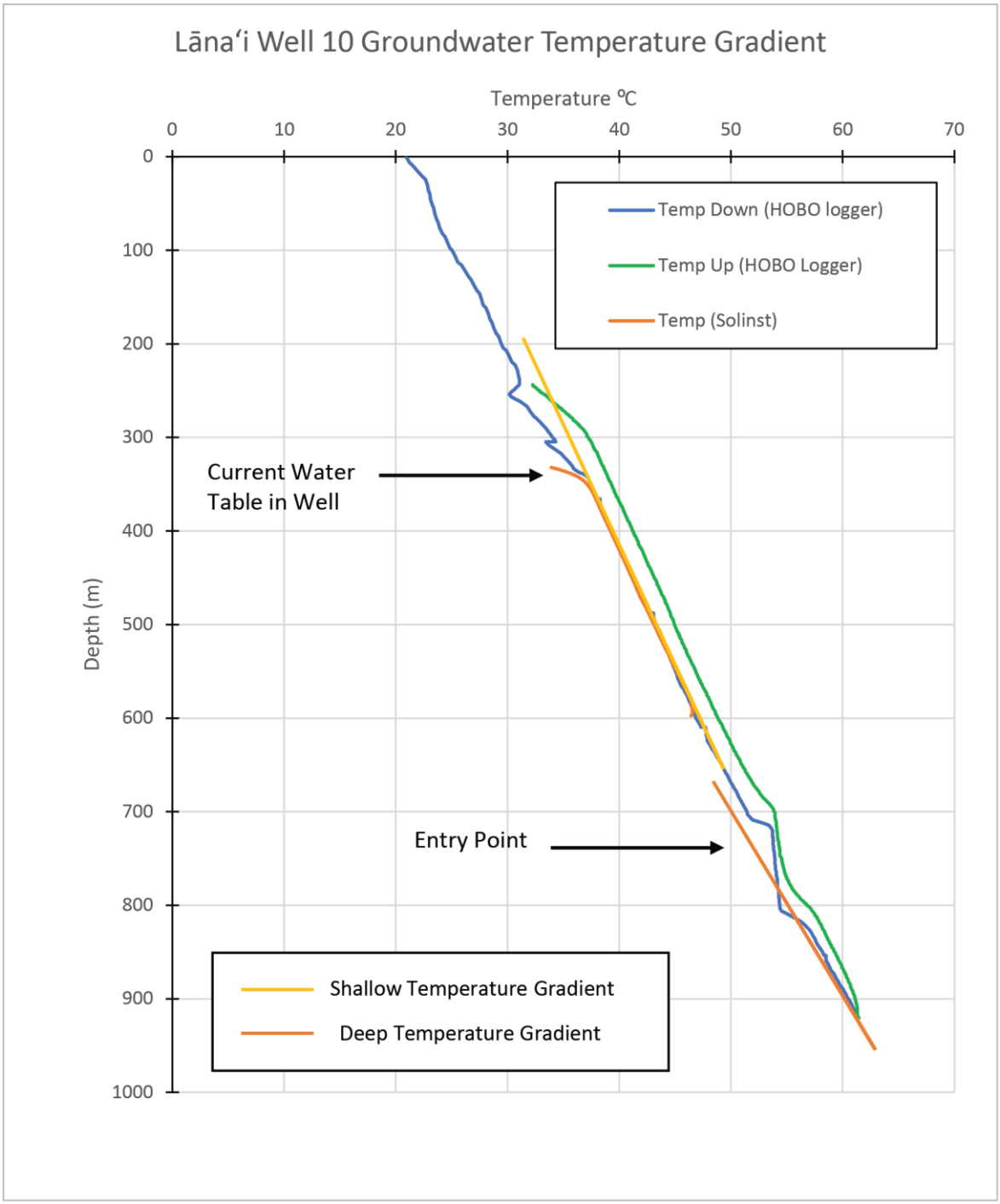


Figure 20. Plot of temperature versus depth measured after drilling in Lānaʻi Well 10. The isothermal zone is interpreted to be a zone of groundwater flow entering the well at the lower inflection point in the temperature curve and exiting at the upper inflection point. We note too that the difference between the downward and upward temperature surveys is an artifact of the equilibration time of the temperature sensor during a constant rate survey over the length of the water column.

blocked the bottom 156 m (512') of the well. During these surveys, a maximum temperature of ~61°C (141°F) was measured, with a temperature gradient of approximately 42°C per km. This gradient is more than double Hawai‘i’s background gradient of 18°C per km (Büttner and

Huenges, 2003). Following this gradient to our maximum depth (1057 m) the temperature indicated is 67.6°C, which accords nicely with the maximum bottom hole temperature measured during drilling (66°C).

Figure 9 displays the temperatures measured at Lāna‘i Well 10 versus other deep wells, which are exclusive to Hawai‘i Island. The wells in orange are geothermal exploration wells drilled into Kīlauea’s summit (the Keller Well) and East Rift Zone (HGP-A, Lanipuna, SOH -1, -2, -4); the wells in blue are located off of Kīlauea Volcano and were drilled to understand the growth of Hawaiian volcanoes (KP-1, HSDP-2) or as a groundwater assessment (KMA-1; PTA-2). PTA-2 (referred to as the Saddle Road Well below) is located to the S of the summit of Mauna Kea, and is the only deep well off Kīlauea to encounter prospective geothermal temperatures. Note that the elevated temperature gradient within this well is not apparent until below 1km, or the max depth we achieved on Lāna‘i. In fact, Lāna‘i Well 10 has a higher temperature at a depth of ~900 m (2955') than the PTA-2 test hole. In the next 800 m of PTA-2, the bottom hole temperature increased to ~140°C at 1700 m depth, and the final temperature gradient reached 165°C per 1000 m towards the maximum bottom hole depth of ~1.8 km below the surface. Lāna‘i Well 10 also has a comparable temperature profile to the first 600 m or more of the SOH-1, 2, and 4 wells in Kīlauea East Rift Zone (KERZ) on Hawai‘i Island. As above, the KERZ is an area of a known geothermal resource and volcanic activity, and is currently the site of Hawai‘i’s only geothermal power plant, Puna Geothermal Venture.

1.3.2 Estimated Resource Temperature: Geothermal Gradient and Geothermometry

Given an expected geothermal reservoir depth in Hawai‘i of at least 2 km, the Lāna‘i drilling clearly did not drill INTO this. Can we project our results to estimate the reservoir temperature? There are two generally accepted methods by which to estimate geothermal reservoir temperatures below borehole penetration depth: 1) projecting the measured temperature gradient to the expected reservoir depth, and 2) applying geothermometry equations using the results of the major ion chemistry of borehole fluids. The second relies on interpreting the measured ion ratios according to fluid compositions at equilibrium with primary and secondary mineral phases deeper in the reservoir. Both methods are subject to a range of uncertainties and can only provide an approximate estimate of deeper temperatures.

Computing the geothermal gradient is straightforward, but assumes that heat-flow is dominantly conductive, i.e. that there is no fluid flow through the formation or in the wellbore. Within Lāna‘i Well 10, this caveat is not apparent in the deeper portion of the hole. The temperature depth profile shows sharp “kinks” at depths of ~700 m (2300') and 808 m (~2650') below ground surface (**Fig. 20**). These kinks are evidence of intra-borehole flow: water is entering the wellbore at 808 m (~2650') through a fracture or other permeable zone, and rising to a second permeable interval at 700 m (2300') where it re-enters the formation. We computed the temperature gradient above and below the exit and entry, respectively, which are approximately

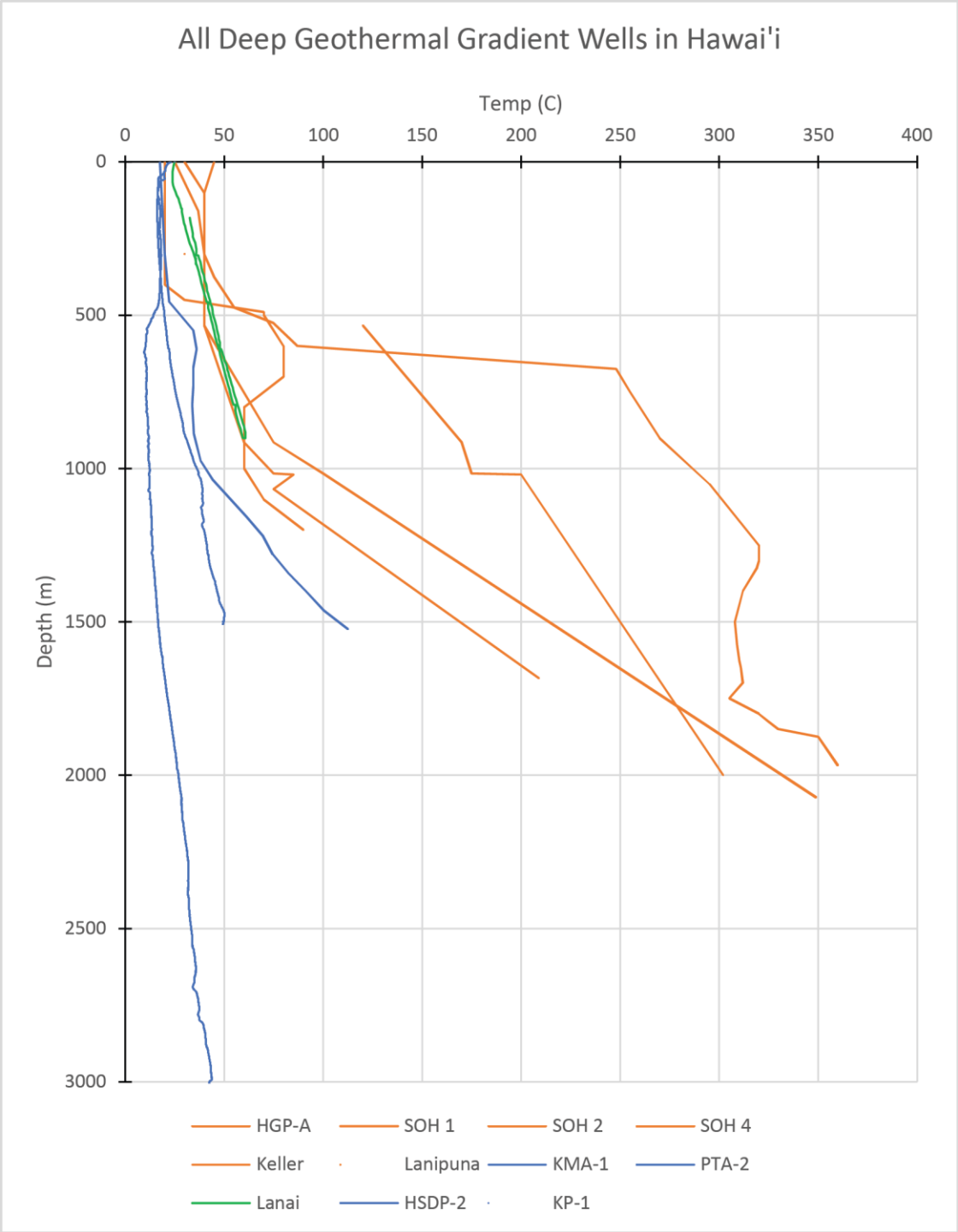


Figure 21. Temperature profile of Lāna‘i Well 10 as compared to geothermal exploration wells drilled into the volcanically active summit or East Rift Zone of Kīlauea Volcano (in orange) or elsewhere on Hawai‘i Island (in blue).

40 (yellow dashed line) and 50 ºC/km (orange dashed line), respectively (**Fig. 20**). These gradients, while not especially high, are well above the natural geothermal gradient of 18 ºC/km measured in deep basalts removed from a volcanic center in Hawai‘i (Büttner and Huenges, 2003; Stolper et al., 2009). Further, there are several reasons to believe that these values are minima for the thermal reservoir associated with Lāna‘i’s caldera dike complex:

1) As noted above, our site selection process was largely based on limited funding. Rather than drill into the conductive zone within the caldera imaged by our MT data, we deepened an existing, unused, well on the caldera rim roughly 1.2 km from our preferred drill target. The existing well had already penetrated more than 365 m (1200') of shallow formation - our experience suggests the shallow zones can offer challenging drilling conditions, where little useful thermal gradient data is gained.
2) Well 10, located on the edge of the caldera, places it closer to more permeable rocks on the flanks of the volcano than less-permeable dike complexes anticipated within the caldera. This equates to the expectation that circulation of cooler groundwater will have a greater impact on the observed temperature gradient at Well 10.

Finally,

3) Due to both the limited drilling budget, combined with challenging drilling conditions associated with hole stability, we were only able to penetrate to a total depth of just over 1000 m below ground surface. As demonstrated in Figure 9, even within the active East Rift of Kīlauea Volcano, some deep boreholes did not exhibit temperature gradients reflective of reservoir conditions until below this depth. The explanation for this is high rates of cold recharge and rapid groundwater flow in the shallow subsurface – a phenomenon often referred to as the “rain-shadow” effect – which is also exemplified in the relative paucity of groundwater temperature and/or chemical geothermal indicators observed statewide (Lautze et al., 2020).

For these reasons, we believe that the 50 ºC/km gradient measured in the deeper interval of the Lāna‘i Well 10 is lower than the gradient likely to exist over Lāna‘i’s caldera region. If we apply this conservative gradient from a starting temperature of 66 and 68ºC at 1057 m depth the ***prediction is temperatures of 124 to 129 ºC at 2 km depth below the surface and 187 to 193 ºC at 3 km***.

In terms of geothermometry, there are a number of published formulae that are based on the chemical equilibria of a variety of chemical and mineral constituents that occur in geothermal reservoirs. Dissolved ion and gas equilibria ratios are achieved in a reservoir formation and such ratios can be maintained, to varying degrees, as fluids exit the reservoir and rise to shallower depths. Empirical studies of these fluids over time has yielded a number of formulae from which to compute approximate reservoir temperatures that can be based on concentrations of silica (Fournier and Rowe, 1969), sodium, potassium, and calcium (Fournier and Truesdell, 1973), sodium, potassium, calcium, and magnesium (Fournier and Potter, 1979; Giggenbach, 1988; Henley et al., 1984), and isotopes and gases (Arnórsson, 2000; D’Amore and Arnórsson, 2000). Each of these constituents can be subject to a number of processes that affect their ability to accurately reflect reservoir equilibrium, e.g. silica geothermometer temperatures are substantially influenced by the mineral assemblage with which the fluid was last in equilibrium (e.g. chalcedony vs. quartz), by fluid boiling and steam loss from rising fluids, and by re-equilibration to lower formation temperatures during transport. Ion geothermometers are less susceptible to re-equilibration during transport, but their inferred temperatures can be seriously impacted by mixing with waters (especially saline waters) during transport to the surface.

We applied three ion geothermometry equations to compute equilibria temperatures for two fluid samples collected from Lāna‘i Well 10. Although the borehole was cleared of the

drilling fluids at the cessation of drilling and casing, the generally low formation permeability (see next section on core) had us concerned that the borehole fluids may not have come to chemical equilibrium. Thus, we collected two samples from the borehole for geothermometry calculations: one from the accessible bottom of the well (884 m | 2900') and one at the interval where the temperature surveys indicated that interzonal flow was occurring (732 m | 2400'). Samples (including those from Lāna‘i Well 9) were collected on 2/12-14/21 and analyzed at UH’s Water Resources Research Center lab using argon plasma spectroscopy. The three equations applied are: the Na-K geothermometer of Fournier (1981), the K-Mg geothermometer of Giggenbach (1988), and the Na-K-Ca geothermometer of Kai and others (2020). The ion compositions are shown in Table 1, and the temperatures computed in Table 2.

	Depth	Na	K	Ca	Mg	Ca/Na
Lāna‘i 10	732 m (2400')	362.2	9.45	97.48	0.15	0.27
Lāna‘i 10	884 m (2900')	269	10.87	80.36	15.28	0.30
Lāna‘i 9	280 m (922')	64.69	7.12	123.80	117.62	1.91

Table 2: Major Ion Composition of fluids in Lāna‘i Wells 9 and 10

	Depth	Na-K	K-Mg	Na-K-Ca
Lāna‘i Well 10	732 m (2400')	130ºC	120ºC	76ºC
Lāna‘i Well 10	884 m (2900')	157ºC	63ºC	82°C

Table 3: Computed Geothermometer Results

The computed temperatures for the interzonal flow (2400') sample indicate a relatively consistent equilibrium temperature of 120 to 130 °C for the Na-K and K-Mg temperatures but a substantially lower computed Na-K-Ca temperature. The deeper (2900') sample shows a diverse range of temperatures among all three of the geothermometers. We interpret this to suggest that the deeper sample is more likely representative of either shallow formation water, or that the drilling water has not chemically equilibrated with the formation fluids. An example of the shallow formation water is listed as Lāna‘i Well 9 in Table 1. Clearly, the major ion compositions of the deeper Lāna‘i Well 10 sample is much different from that within the flow zone: magnesium, which is typically strongly depleted in Hawai‘i’s geothermal fluids, is at a much higher concentration in the deeper sample than in the interzonal flow sample, and is nearly two orders of magnitude higher in the shallower groundwater sample of Lāna‘i Well 9.

Likewise, the calcium concentration in the shallow well water from Lāna‘i Well 9 is, relative to sodium, at a concentration more than an order of magnitude above that in the Lāna‘i Well 10. Both the elevated calcium and magnesium values suggest mixing with shallow waters (drilling fluid) and as such, the computed temperatures are probably minimum formation temperatures and not representative of the deeper reservoir associated with the Lāna‘i volcano caldera. We anticipate revisiting the well and collecting additional samples to determine how longer equilibration times may affect the computed geothermometer temperatures.

In summary, the geothermal gradient determinations and the computed chemical geothermometer temperatures indicate that accessible temperatures within the thermal regime are between 130-200 ºC between 2 and 3 km depth, and could be substantially higher within the central portion of the caldera.

1.3.3 Core

Rock core recovered from the 427 to 1057 m deepening of the Lāna‘i Well 10 is almost certainly entirely tholeiitic ocean island basalt; previous rock chemistry studies of Lāna‘i indicate it never experienced a post-shield or rejuvenated stage that could produce more geochemically evolved lavas. Due to its location at the southern edge of the Pālāwai Basin, which is the modern expression of the ancient Lāna‘i shield’s caldera, the geothermal heat in the well, and the known water-saturated nature of the rock across the entire depth of this drilling, virtually all of the recovered rock core is highly altered from hydrothermal circulation. There are virtually no fresh grains of olivine which, though generally the most common mineral in Hawaiian shield-stage lavas, is also the most susceptible to alteration. Olivine grains are generally altered to brown or red iddingsite clay or even entirely replaced by black smectite clay. This black clay is abundant throughout the section and, based on other core examination of the progressively hotter-with-depth KMA2 core drilled in the saddle of Hawai‘i island, its black color is thought to be related to elevated temperatures. The black smectite clay permeates the micropore groundmass of the rock, and is also present as connected vein, fracture, and vesicle fill in most of the core. There is additional vesicle fill and less common vein and fracture fill by mainly white zeolite minerals, a common byproduct of tholeiitic basalt weathering in Hawai‘i. While some vesicles are open, this is much less common, and even those intervals do not appear less altered outside of that one characteristic. Other than the most altered lithologic units that are highly friable, the result of alteration by hydrothermal circulation has been to weld and cement the rock together, thereby producing core with fewer fractures than typically seen when drilling less altered Hawaiian rock.

Initial volume estimates of the rock types recovered are, by abundance: lava flows, intrusive dikes, and volcanic breccia deposits. Detailed characterization of this rock has just begun, but initial impressions from the period of drilling can be stated here: The lava flows are difficult to distinguish from each other because of their highly altered nature, and contacts between lava flow units or between multiple lobes within a compound flow unit are heavily obscured by alteration. Despite this difficulty, the dominant flow type appears to be pāhoehoe as is typical in a setting so close to the eruptive vents these flows probably originated from in the caldera region. Any ‘a‘ā flow determinations will take careful examination to identify clinker zones and massive interiors characteristic of this flow type, through the alteration that permeates

them. Overall, lava flows are the dominant lithologic unit type in the drilled interval, composing an estimated 60-70% of it.

The easiest lithologic unit type to identify in the core is usually the intrusive dike rock. Our initial estimate of the fraction of the drilled section composed of dikes is 25-35%, a somewhat large value but typical of caldera regions and fitting for the caldera rim location of Well 10. Despite the strong alteration, the abrupt change in rock character from lava flow to intrusive dike is clear: The dikes are usually more massive and finer-grained as well as less vesicular than the lava flows, and these characteristics really make the dike units stand out to a trained eye. Some of these massive dike interiors may also be the best candidates for geochemical analysis, as they are essentially the only places that were somewhat able to resist being penetrated and altered by hydrothermal circulation. The dike contacts are no longer glassy, but the alteration of their glass has usually not destroyed their typical sharpness and high-angled nature. The real issue in characterizing the dike rock will be the complexity it adds to the section; dikes intrude through lava flows and even other dikes, making stratigraphic interpretation more difficult. At times, dike and flow rock are adjacent in the core as well, undulating back and forth as the dominant rock type over a given depth interval. It is clear that these dikes commonly disturbed the rock they intruded into, but the subsequent hydrothermal alteration/fill/cementation at depth produced mostly solid core recovery even in areas of high dike density. Oddly enough, no dikes were identified in the upper ~200 m (~600') of the drilled interval. This seems to indicate a change in the active location(s) of magma supply and eruptive vents toward the end of Lāna‘i’s growth.

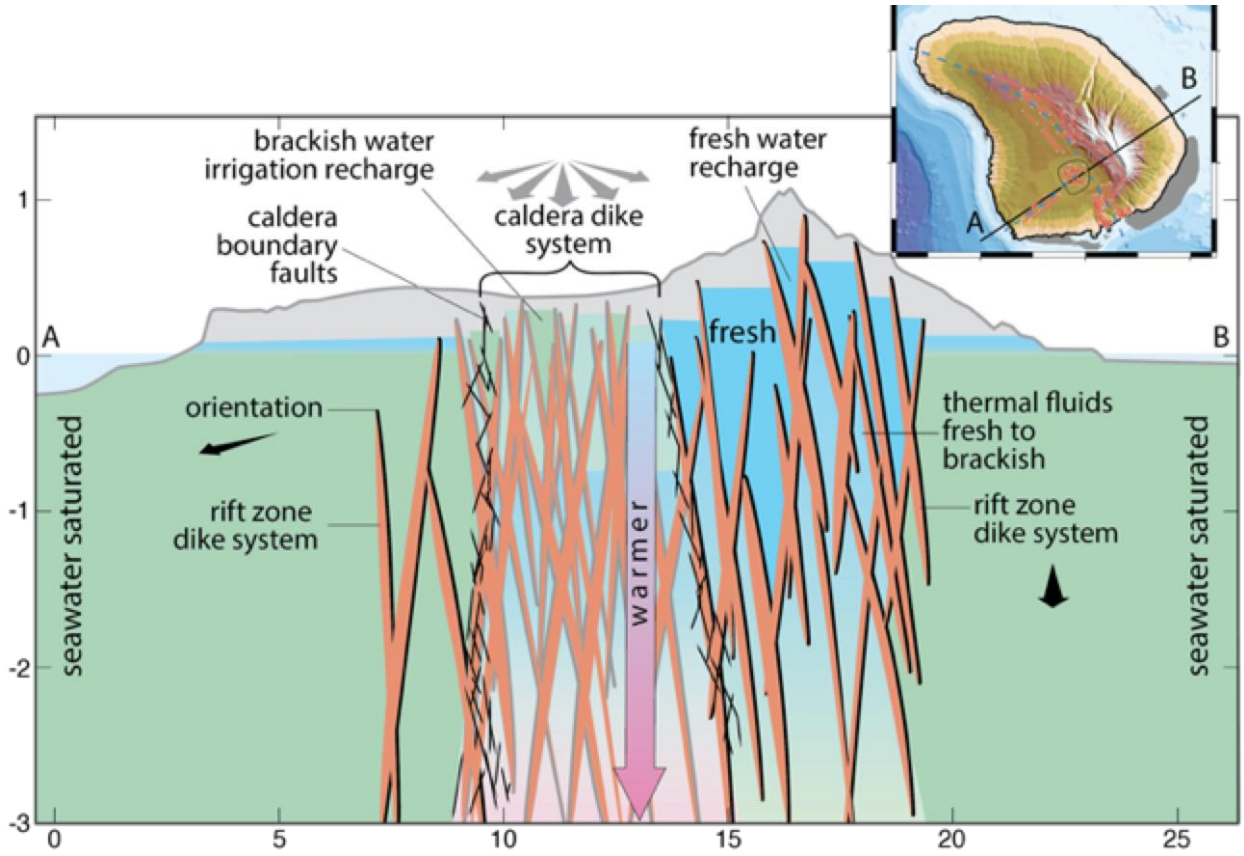
The other indicator of a change in the Lāna‘i shield as it grew is the least common lithologic unit type in the Well 10 core, volcanic breccia. Unlike the dikes which are exclusively deeper, this material is only found near the top of the drilled interval – over the first ~100 meters (a few hundred feet). It is composed of large and variably-sized basalt clasts in a finer-grained matrix and appears to represent multiple landslide deposits with lava flows in between them that were part of the growth and evolution of Lāna‘i’s ancient caldera. Earthquakes that trigger landslides at caldera rims are common, and these deposits are visible at younger Hawaiian volcanoes like Kīlauea and Mauna Loa today, yet finding such material almost immediately when deepening Well 10 on Lāna‘i was still a bit of a surprise compared to the expected lava flows and dikes. The breccia is well-cemented (again probably due to hydrothermal circulation and alteration), producing mostly unbroken rock core from these once entirely fragmented deposits. The volcanic breccia units seem to be separated by lava flows, so comprise 5% of the drilled interval at most.

1.3.4 Comment on Lāna‘i’s Unique Hydrology

Groundwater within Lāna‘i’s Pālāwai Basin not only has elevated temperatures, but also elevated salinity. This presence of brackish groundwater hundreds of meters above sea level is unique in the state and lacks a clear explanation. Convection of sea water has been invoked, but we believe the abundance of dikes expected within this caldera would make large-scale convection unlikely (**Fig. 22**). A large tsunami is another possible explanation, but tsunami deposits have

not been found at an elevation as high as the Pālāwai Basin. A third possible explanation is decades of ‘drip irrigation’ of pineapple fields that covered the Basin between 1922 and 1992.

Figure 22. Conceptual model of Lāna‘i’s hydrology along cross-section AB (inset top right). Red hatches are relatively impermeabile dikes; black hatches are caldera boundary faults. We postulate the presence of three aquifers: a thin basal low



level aquifer at the coast; a warm brackish high-level aquifer within the Pālāwai Basin that is bounded by the caldera faults; a cold, fresh higher-level aquifer within the rift zone. The water composition and temperature is known at the water table of each aquifer. We use the data from Lāna‘i Well 10 to propose that within the Pālāwai Basin, the water will get warmer and fresher with depth.

The drip irrigation technique would likely concentrate salts in the water that recharges the aquifer. If drip irrigation was in fact, the cause of the increased salinity in Lāna‘i’s high level groundwater, we would expect to see a freshening at some depth. To assess this, we measured the conductivity of the Well 10 groundwater to the maximum depth (pressure) our Solinist Levelogger^{R} 5 Conductivity Temperature Depth (CTD) tool could withstand. In fact, we do see a decrease in conductivity with depth that is consistent with freshening. More data are needed to fully resolve this.

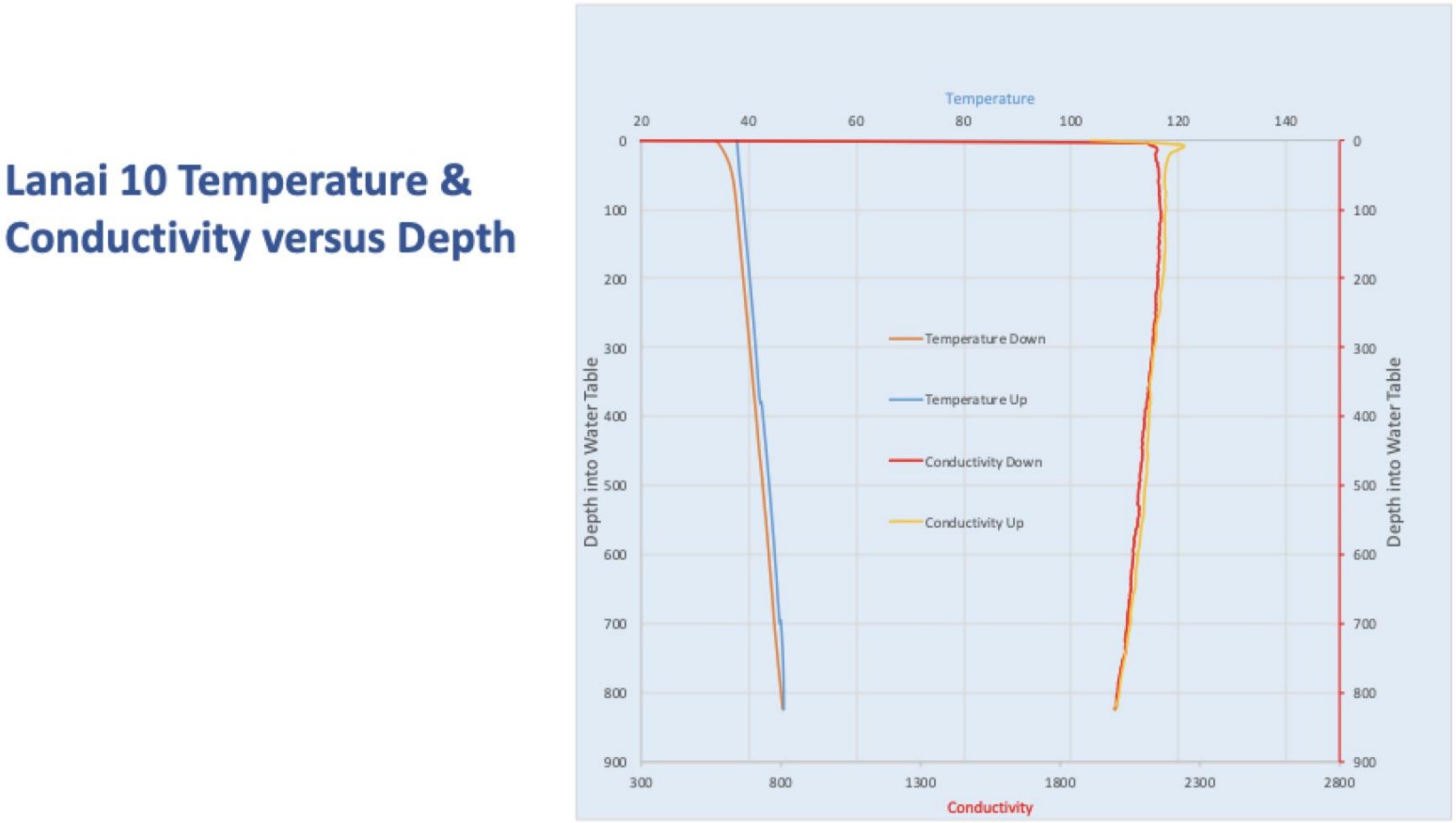


Figure 23. Data from the Solonist CTD tool. Depth is in feet. Notice that the temperature increases but the conductivity decreases with depth. Decreasing conductivity is consistent with decreasing salinity.

1.4 DRILLING SUMMARY

Previously submitted to NREL for PF Retrospective.

Results:

- ➔ Deepened existing water well on the rim of Lānaʻi caldera from ~1500' to ~3500'
- ➔ Measured roughly linear temperature gradient between 40 and 60 ºC to a max bottom hole temp of 66 ºC
- ➔ Prior to drilling: submitted an EA and obtained a FONSI, lowered camera down well, performed gyroscopic log, and engaged with community
- ➔ The gradient measured is more than twice the background in Hawaiʻi and this is now the deepest well off of Hawaiʻi Island!
- ➔ Had funds been adequate (roughly additional $1M total), we would have drilled into a conductive zone (identified by Phase 2 MT survey) within the Lānaʻi caldera, to a depth closer to 2 km. *Expect this would have generated significantly more exciting results…would still like to do this, in addition to much more slim hole drilling across the state!*

Key elements to our success include:

- ➔ Experience with deep core drilling in Hawaiʻi via Don Thomas (UH Professor and project lead for 4 former very successful deep wells on Hawaiʻi Island) and drilling supervisor (Ron Fierbach)
- ➔ dedicated effort to build a relationship with landowner through land management company (Pūlama Lānaʻi). This started in Project Phase 2, continued through Phase 3 and continues today, inc through briefings on findings and possible plans, and answering their questions of interest wrt to energy and water on Lānaʻi. Their logistical support of the drilling project was huge.
- ➔ dedicated effort to inform and engage local community, including through community meetings and a Drilling Open House
- ➔ ensuring nearly any/all equipment and supplies for drilling or to support drilling were on site prior to the crew (this project gained from Dr. Thomas' prior drilling projects too, as much equipment, including vehicles, and a Grade-All were owned by UH and shipped over to Lānaʻi)
- ➔ writing of an EA, and obtaining a FONSI
- ➔ hire of 1 highly competent (post-Masters) staff member to assist project, including with EA and procurement (Daniel Dores)
- ➔ Hawaiʻi-based drill hand extraordinaire, experienced with welding and machinery (Donald Mullikan)
- ➔ experienced "Lead Drill Core Archivist" (Eric Haskins) who recruited a team to assist him
- ➔ on Lānaʻi, emphasizing the test well as a "2 for 1" in that it informs of fresh groundwater AND geothermal potential
- ➔ successfully advocating for 'off-campus' overhead of 24%, and both "in-kind" and donation funds from Lānaʻi landowner
- ➔ A PI very committed to project success!

Challenges:

- ➔ UH Drill Rig had been sitting between projects so needed maintenance
- ➔ with Timberline Drilling
- ➔ Formation of or Partnership With a dedicated scientific drilling company would be beneficial!

2. OTHER PHASE 3 ITEMS

2.1 OUTREACH

We were cognizant of the need to engage with the Lāna‘i community and made a dedicated effort to do so, with much success (**Fig. 24**). Our drilling project was the focus of three community meetings on Lāna‘i, attended by N. Lautze and D. Thomas, that were part of a regular series of meetings organized by Pūlama Lāna‘i. We hosted a drilling Open House in which the community was invited to witness the active drill site from a safe distance and ask questions that were fielded by N. Lautze, D. Thomas, E. Haskins (lead core archiver) and/or members of the crew. All outreach activities were well attended to by a very inquisitive community! Most recently (March 2022), a crew supervised by N. Lautze and postdoctoral researcher Xavier de Bolos spent 3 weeks on Lāna‘i conducting a Self Potential survey. Pūlama Lāna‘i provided housing and a vehicle at no cost, and we involved 4 local students in the field research, again with much success :)

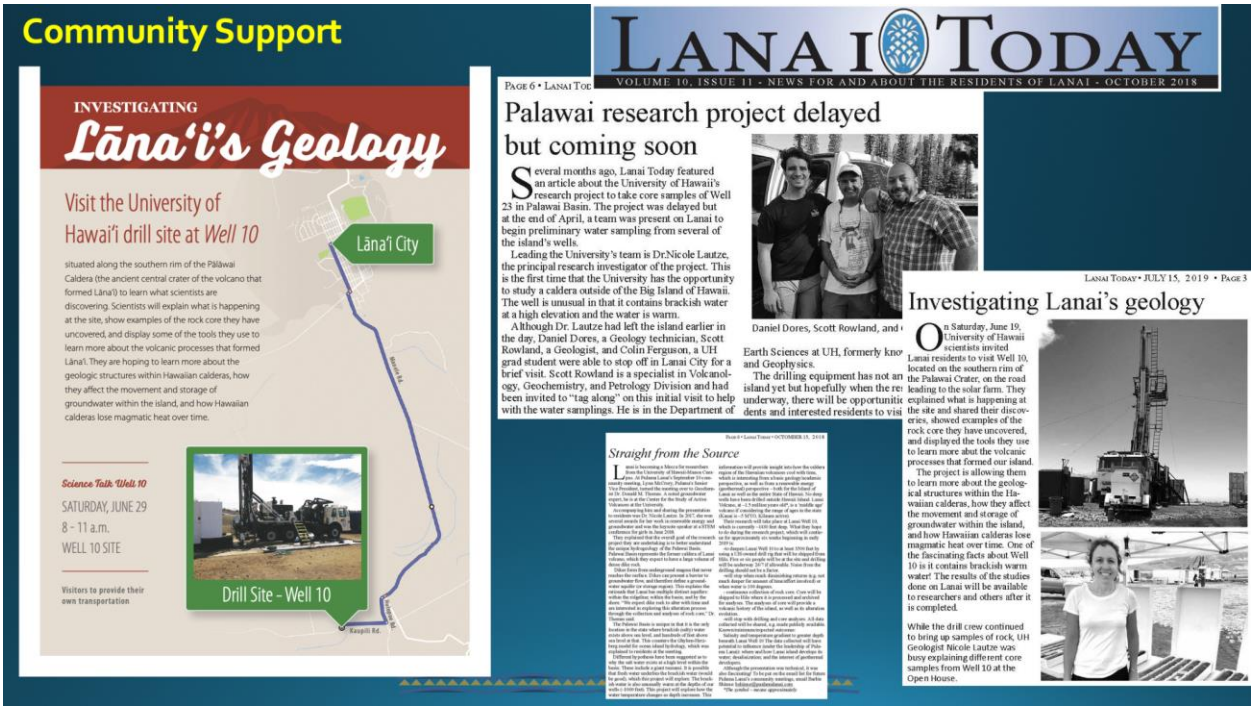


Figure 24. Summary slide of Lāna‘i outreach efforts, which included 3 in-person evening community meetings at the invitation of Pūlama Lāna‘i, who holds community meetings routinely and a drilling open house (left). In the open house, Lāna‘i residents were invited to visit the active drill site from a safe distance, and Lautze, Thomas, and Haskins were present to discuss drilling and provide a ‘show and tell’ of the rock core and drilling fluids The editor of Lāna‘i Today took an interest in our project and published several articles on it (articles center and right).

In the last six months, Lautze and Thomas have received a flurry of requests to provide seminars and participate in meetings (**Fig. 25**), and the legislature and utility are recognizing the need for geothermal and firm renewable energy. Segments of the Hawaiian community are, at times, initiating this discussion. Sustainable Energy Hawai‘i (SEH) is a non-profit organization whose president Richard Ha is Native Hawaiian. SEH believes geothermal paired with hydrogen is the future for Hawai‘i and the planet (see impactful SEH video). Since the start of 2022, Lautze and Thomas have been asked to give a total of six presentations to a combination of SEH, Department of Hawaiian Home Lands (DHHL) and the Hawaiian Homes Association (HHA). Additionally, the utility filed a draft Request for Proposals for 500-700 MW of firm, dispatchable renewable energy on O‘ahu on February 28, 2022, which surprised many. There is an expectation that this RFP will largely ‘go by the wayside’ given the absolute lack of tangible (deep) data on O‘ahu’s geothermal. Our PFA groundwater results lead us to believe a geothermal resource is present on O‘ahu, and Lautze and Thomas (2020) describe why the next exploration step for O‘ahu is deep slim hole drilling.

The Hawai‘i State Legislature’s 2022 session was the first session to progress geothermal-related bills since the 2018 Kīlauea eruptions (which threatened the Puna Geothermal Venture power plant and made PGV a household name). During this legislative session, the following bills supporting geothermal and firm renewable energy were introduced:

- House Bill 1808: Relating to Geothermal Royalties
- Senate Bill 2510: Relating to Renewable Energy
- Senate Bill 2511: Relating to Taxation
- Senate Bill 2513: Relating to Renewable Energy
- Senate Bill 3195: Relating to Hawaiian Home Lands
- Senate Bill 3229: Relating to Geothermal Royalties

HGGRC has been encouraging supporters to submit supportive testimonies for these bills.

As of April 2022, the following bills were still in consideration (still “alive”) at the Hawai‘i State Legislature awaiting the House Finance committee, the last committee before the bills go for final votes and governor approval:

- Senate Bill 2510: Relating to Renewable Energy requires a balance of renewables including firm renewable energy
- Senate Bill 2511: Relating to Taxation provides an income tax credit for firm renewable energy
- Senate Bill 3195: Relating to Hawaiian Home Lands appropriates money to DHHL for investigation of geothermal resources on Hawaiian Home Lands.
- Senate Bill 3229: Relating to Geothermal Royalties caps the amount of geothermal royalty funding to the county and state and deposits the balance in a fund for the University of Hawai‘i to use for geothermal exploration!!

If passed into law, Senate Bill 3229: Relating to Geothermal Royalties will provide ~$400k/yr - once PGV’s expansion to 48MW is complete - to the Hawai‘i Groundwater and Geothermal Resources Center (HGGRC) to conduct further geothermal exploration in Hawai‘i. Lautze is the Director of HGGRC, which is within the Hawai‘i Institute of Geophysics and Planetology. Senator Glenn Wakai and Representative Nicole Lowen are vocal in their support of firm renewable energy. Sen. Wakai, who proposed SB3229 in his support of geothermal, recently

sent a letter of support for Hawai‘i Electric Light Company Inc.’s Application for Approval of the Amended and Restated Power Purchase Agreement between HELCO and Puna Geothermal Venture.

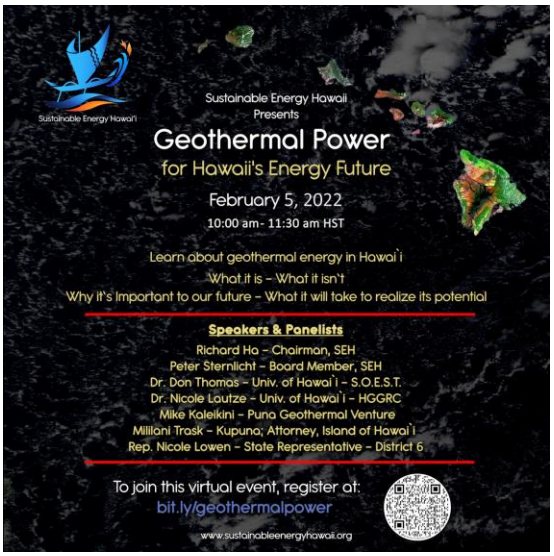


Figure 25. Example fliers advertising talks by HGGRC researchers.

2.2 NOBLE GAS SAMPLING AND GEOPHYSICS

Our Phase 3 Statement of Project Objectives included, should time and funding allow, additional geophysics on Kaua‘i and East Maui, and sampling of noble gases (namely Helium) distributed across the state. Time and funding did not allow for completion of any additional geophysics through this project, although some funding from the State allowed us to obtain some additional magnetotelluric data around Mauna Kea; such data was included in our PF Phase 3 model.

A noble gas study was conducted by graduate student C. Ferguson, who collected samples from 23 wells across the state and obtained data previously collected by the USGS and Ormat Inc. Interestingly, and consistent with our broad PFA results, the newly collected data provide evidence of magma degassing across the state, including on Kaua‘i (Ferguson, 2020).

3. FINAL PROBABILITY AND CONFIDENCE MAPS

At the conclusion of Phase 1, in Ito et al. (2017), we published maps for each island in the State of Hawai‘i showing the calculated a) probabilities of each of Heat (Pr_H), Fluid (Pr_F), and Permeability (Pr_P), b) the combined probability of a Resource (Pr_R) calculated as the product of the individual three probabilities, and c) our computed Confidence in Pr_R. **Fig. 26** shows such Phase 1 results for the Island of O‘ahu. With the mathematical details provided in Ito et al. (2017), here we recall our reference to the equation used to calculate each of Pr_H, Pr_F, and Pr_P as the “Voter Equation” because it allows each data type to influence the Pr(x) outcome positively or negatively. We referred to the equation used to calculate Pr_R as the “Veto Equation” because with each independent Pr between 0 and 1, if any independent Pr is low, so will be the resource probability. Not surprisingly, as shown in **Fig. 14**, our Phase 1 resource probabilities (Pr_R) are low: less than 10% across most of the state, never above 30% off of Hawai‘i Island, and only 45% at the state’s only proven site, PGV!

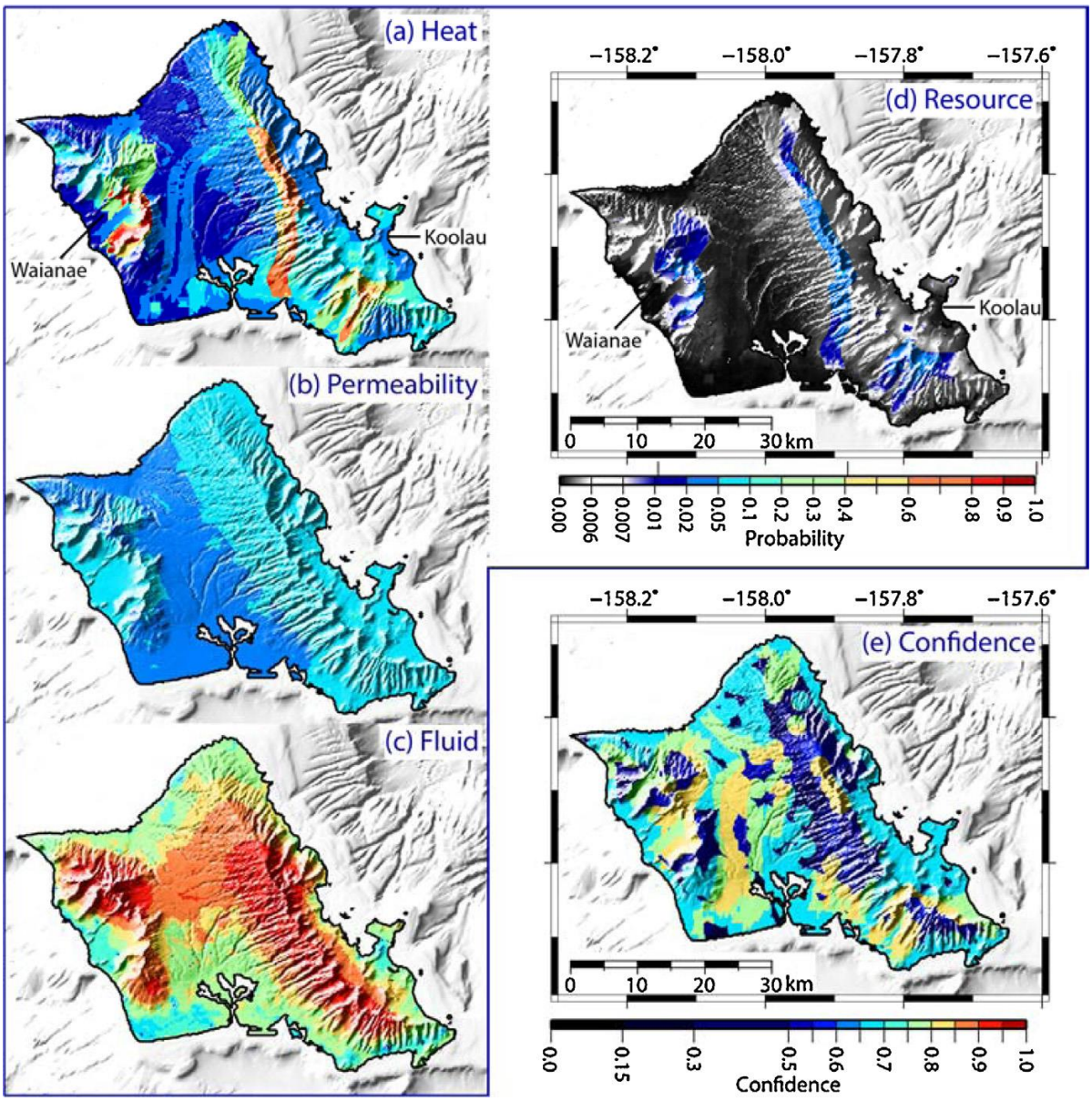


Figure 26: Phase 1 Probability and Confidence results. This is Figure 6 in Ito et al. (2017).

While significant thought was put into our calculation and presentation of a combined resource probability (Pr_R) in Phase 1, we now believe that our Phase 1 results were too conservative. While valuable to include in a generalized assessment of resource probability, we also now recognize that, in Hawai‘i, the Pr_F will universally be equal to 1 at any resource depths (below sea level). Further, due to the paucity of deep drilling data in Hawai‘i (outside the one known geothermal resource region along KERZ), we have little ability to constrain Pr_P at expected resource depths (further discussion in section **3.4**). Thus, for this final report, we present confidence not in the Pr_R but instead in Pr_H, and emphasize that the statewide maps of Pr_H and Confidence in the Pr_H should drive future exploration activities.

3.1 PROBABILITY OF HEAT (PR_H) AND CONFIDENCE IN PR_H, INCLUDING LĀNA‘I DRILLING DATA

Figs. 28 and **29** show the probability of heat in the subsurface across the State of Hawai‘i, as calculated following the method outlined in Ito et al. (2017), however here excluding all groundwater data. **Fig. 29** shows the same probability results as **Fig. 28** but with water well temperatures overlaid. These final probability values incorporate all of the Phase 2 geophysical data, as well as an updated function for “heat decay with time since last eruption” based on the new Lāna‘i Well 10 temperature measurements. **Fig. 30** shows the calculated confidence in Pr_H.

Why exclude groundwater data from the probability calculation? The team discussed three issues with using groundwater data, which we have in abundance, in the Heat probability and confidence calculations: i) the absence of a positive thermal indicator in groundwater should not decrease the Pr_H given the conservative nature of such indicators where high rainfall rates can overwhelm even significant discharges from active hydrothermal systems; ii) large uncertainties in groundwater flow direction and our inability to unequivocally determine the ultimate source of the thermal anomalies where observed; and iii) new investigations show there are confounding factors that impact the silica geothermal indicator.

The first issue is related to the fact that Hawai‘i’s geothermal resource is deep, while most of our water wells are shallow, and there is an abundance of cold rainfall in much of the state. We expect this to mute the appearance of geothermal anomalies in existing water wells. Quantitatively, this issue could be addressed by having a threshold above which the groundwater data would serve to increase the probability and using only such data. We took this approach in Phases 1 and 2, but still this does not solve the groundwater flow issue. Establishing more accurate groundwater flow paths is a monumental task that other large projects are attempting to take on. Note in Figure 2, the lines emanating from the summit of Mauna Kea. These are modeled groundwater flow paths that we now know have large inaccuracies. As our understanding of groundwater in the State increases, we intend to bring the groundwater temperature, chemistry, and flow data into our probability calculation. As of this writing, we opt to incorporate only those data in which we have a high level of confidence; thus we do not use existing groundwater flow models, and we analyze the groundwater well data in a qualitative rather than quantitative fashion (**Fig. 29**).

How did the “heat loss with time” function change? Table 3 below lists the shield volcanoes within the State of Hawai‘i, along with the time since their last volcanic eruption, and an estimated temperature at between 2 and 3 km depth. Note that Hawai‘i’s shield volcanoes exhibit multiple stages, the shield stage, +/- a post-shield stage, +/- a rejuvenation stage (more in section 3.5). The only volcano in which the listed temperature is proven (or such depths reached) is at Kīlauea Volcano. *Outside of Kīlauea, and across the entire state, only two wells deeper than 1km have been drilled into elevated temperatures. Lāna‘i Well 10 is the only well outside of KERZ in which a key purpose for drilling was to assess temperatures.* The other well is the Saddle Road Well (or PTA-2), which penetrated to 1.8 km in search of potable water and in which a maximum temperature of 142ºC and a gradient of 170 ºC/km between 1 and 2 km was measured.

Island	Volcano	Shield (Ma)	Post Shield (Ma)	Rejuvenation	Last Shield Eruption (Ma)	Temperature (ºC)
Hawai‘i	Kīlauea	0.275 to present	n/a	n/a	0	310
	Mauna Loa	0.75 to present	n/a	n/a	0	310
	Hualālai	1.0 to 0.15		n/a	0.15	300
	Mauna Kea	0.9 to 0.25		n/a	0.25	290
	Kohala	1.3 to 0.30		n/a	0.4	200
Maui	Haleakalā	1.6 to 0.6		none	0.6	290
	West Maui	2.3 to 1.3	1.3 to 1.1	0.61 to 0.39	1.3	290
Lāna‘i	Lāna‘i	2.1 to 1.1	none	none	1.1	250
Moloka‘i	East Moloka‘i	2.5 to 1.5	1.5 to 1.3	0.8 to 0.6 Ma	1.5	250
	West Moloka‘i	2.5 to 1.7	1.4 to 1.7	none	1.7	250
O‘ahu	Ko‘olau	3.2 to 1.8	none	1.1 to 0.08 Ma	1.8	220
	Wai‘anae	>3.9 to 3.2	3.2 to 2.9	none	3.2	180
Kaua‘i	Kaua‘i	5.6 to ~3.9	~3.9 to 3.7	2.6 to 0.38 Ma	3.9	150

Table 3. Lists the age of volcanism and an estimated geothermal reservoir temperature for each subaerial shield volcano in the State of Hawai‘i

Table 3 uses the results of the Saddle Road Well and Lāna‘i Well 10 to make an ‘educated guess’ at the temperatures at anticipated reservoir depths in the volcanic calderas and rift zones of the older volcanoes across the state. These temperatures were used to construct a plot of the temperature versus time since the last ***shield stage*** eruption, which was incorporated into our calculation of Pr_H. Specifically, the temperature age decay function is $t_0/(t_0+t)$ where t is age since the last shield phase and t_0 a constant (Ito et al., 2017). In Phases 1 and 2, we applied t_0 = 0.8 Myr, which gave a relatively rapid temperature decay with age. With the revised Phase 3 temperatures and plot (**Fig. 27**) t_0=5.4 Myr, which provides a more modest decay in temperature with time that favorably influences Pr_H.

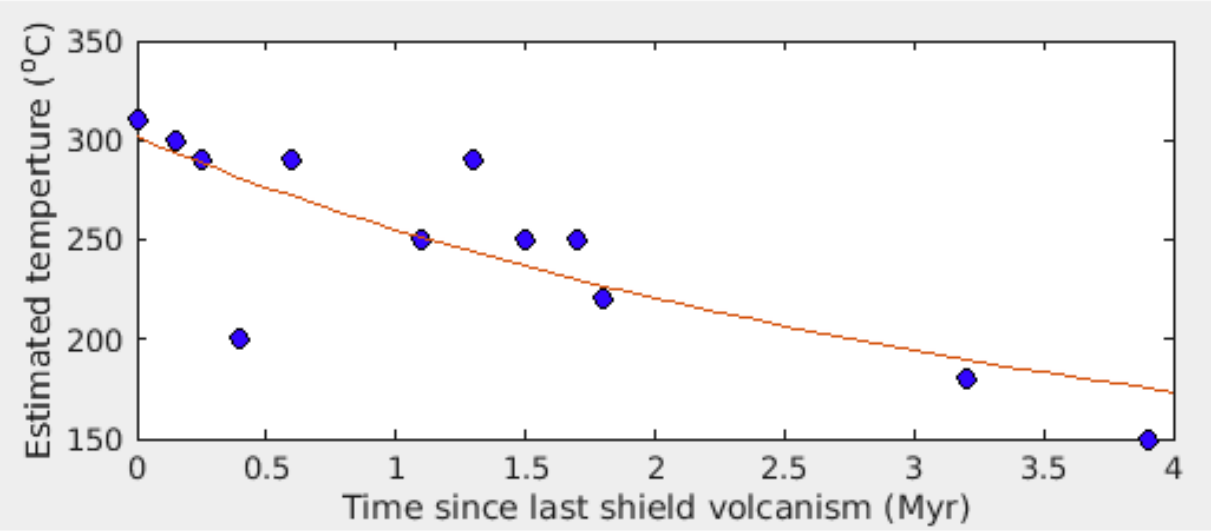


Figure 27. Empirical fit to establish temperature-time decay, with temperatures updated based on Phase 3 results.

We opt to prioritize use of the last shield stage (versus post-shield or rejuvenation) given that the shield stage is associated with the largest volume of magma erupted to form the volcanic edifice. We envision that the large, long-lived (~1Myr) magma reservoirs associated with shield-stage activity are most likely to cool slowly over time. Lāna‘i Volcano, oddly, ceased erupting in its shield stage. The post-shield stage occurs at the conclusion of the shield-stage and is marked by a change in magma composition. Rejuvenation stage eruptions can occur up to millions of years after shield stage volcanism, and they are typically small-volume. Current knowledge accounts for magma generation through the post-shield and rejuvenation stage of activity, but we do not know how much of the magma that migrates through the crust is erupted versus intruded into the deeper parts of the island in these later phases.

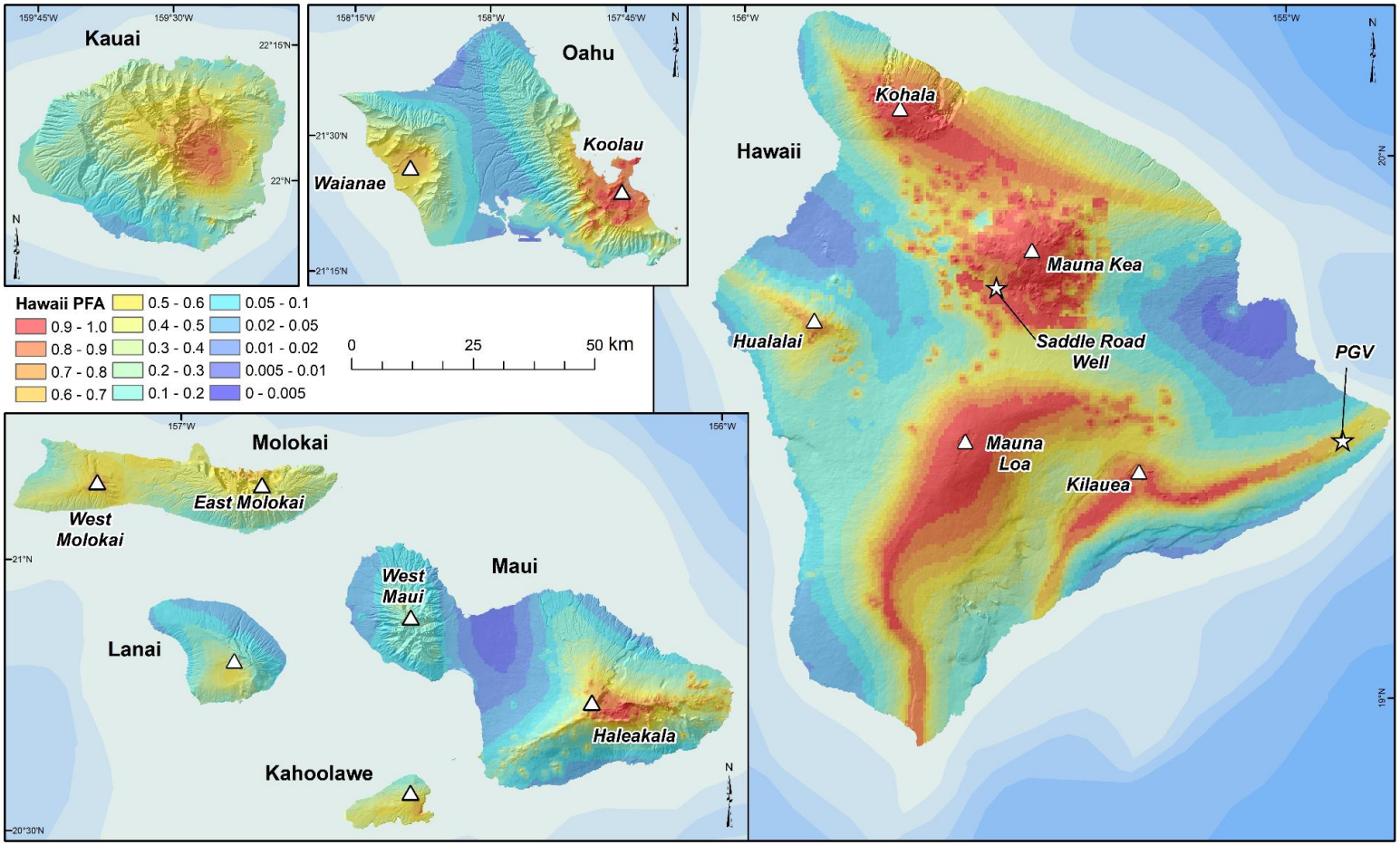


Figure 28. Probability of subsurface Heat across the State of Hawai‘i.

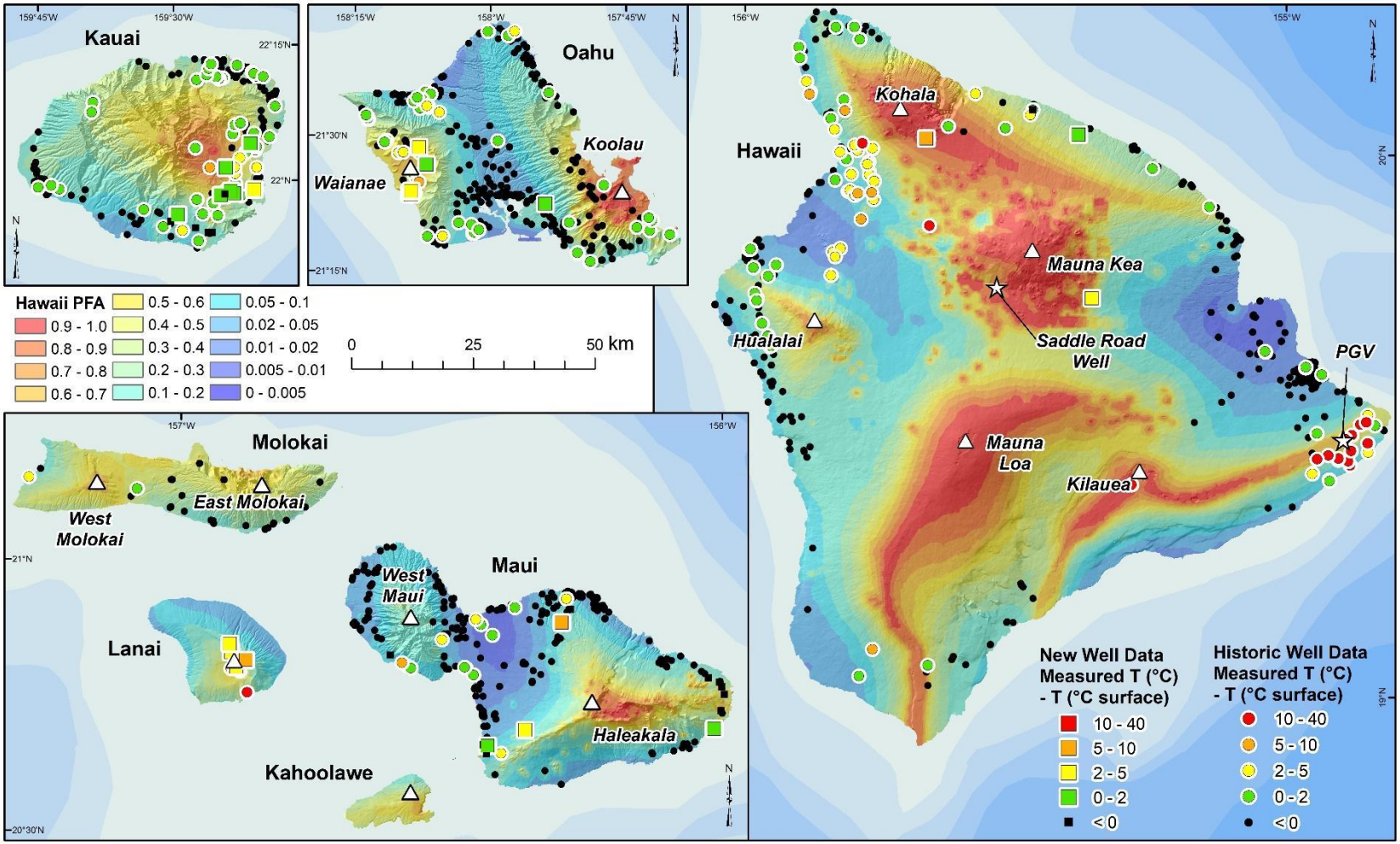


Figure 29. Probability of subsurface Heat across the State of Hawai‘i, overlaid with the location and temperature of groundwater wells. “New Well Data” (squares) were collected in Phase 2 of this Play Fairway project. Wells in which no temperature anomaly was measured are shown as small black circles.

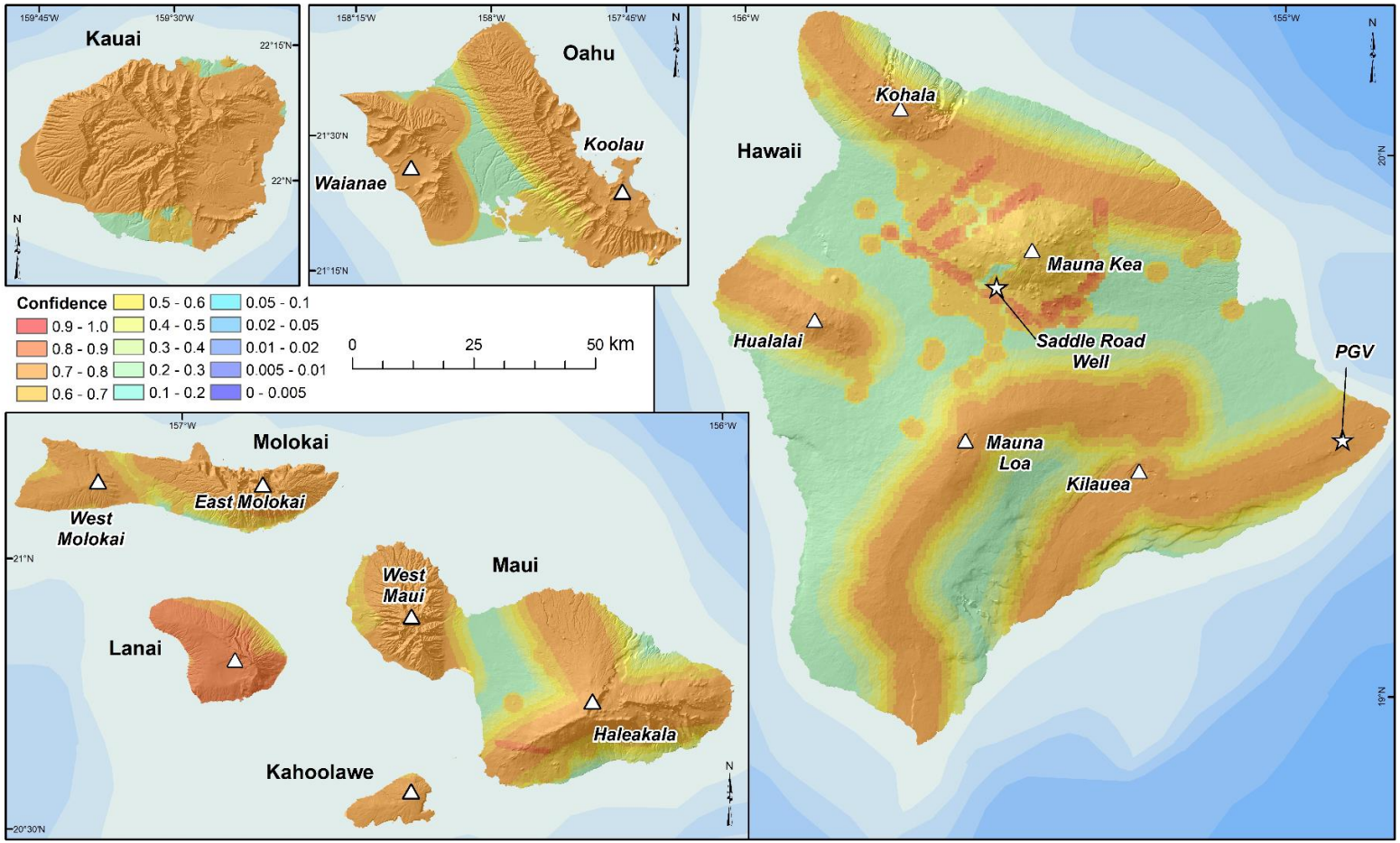


Figure 30. Map of Confidence in Pr_H across the State of Hawai‘i.

3.2 CONFIDENCE IN PR_H

Fig. 30 shows the calculated confidence in Pr_H shown in **Figs. 28** and **29**. Given our revised focus on Pr_H, the datasets that determine confidence in Pr_H at each location **x** are now exclusively: gravity, MT, proximity to rifts zones, and proximity to volcanic vents. Our confidence estimates are based on the general equation defined by Ito et al. (2017):

For the effect of vents and rift zones, the "quality" factor $q(\mathrm{x})$ diminishes as a Gaussian function

$$C(\mathbf{x}) = \left[1+\exp\left(-w_0 - \sum_{i=1}^{m} w_i z_i^{+} q_i(\mathbf{x})\right)\right]^{-1}.$$

of distance d from the feature with a decay distance d_0:

$$q(\mathbf{x}) = \exp\left[-\frac{1}{2}\left(\frac{d}{d_0}\right)^2\right].$$

The decay distance is 2 km and 4 km for vents and rift zones, respectively. Also, the geographic coordinate of a point is one type of data, regardless of what geologic features are proximal to that point; therefore adding the effects distance to both vents and rifts zone would lead to an overestimate of confidence. We therefore take the greater effect between proximity to vents and

$$C(\mathbf{x}) = \left[1+\exp\left(-w_0 - w_1 z_1^{+} q_1(\mathbf{x}) - w_2 z_2^{+} q_2(\mathbf{x}) - \max\left[w_3 z_3^{+} q_3(\mathbf{x}),\, w_4 z_4^{+} q_4(\mathbf{x})\right]\right)\right]^{-1}$$

rift zones, not both effects:

In the exponent, we sum the effects of three independent data types, where i = 1 and 2 denote gravity and resistivity, respectively, and i = 2 and 3 denote proximity to vents and rift zones, respectively.

Not surprisingly, our confidence in Pr_H is moderate (~70%) across the state within 2 km of vents and 4 km of rift zones (tan-colors), and highest (~855) on Lāna‘i and surrounding Mauna Kea, where extensive MT data have been collected.

3.3 FLUID

Hawai‘i may be unique within the USA given our island environment - we know that water is present below sea level. This is a fact based on drilling of every well, whether water, monitoring, or deep discovery well in the state. Given Hawai‘i's geothermal resource depth 2-3 km below ground surface, there is sparse area in the state where a resource might be present above sea level. Such areas are the peaks of Hawaii's tall volcanoes (Mauna Kea, Mauna Loa, Hualālai and Haleakalā) which are protected areas and thus not developable land areas. Hence in this Phase 3 update to our Hawai‘i PFA, we take Pr_F=1 statewide. Our universal method for incorporating Pr_F remains valid (Ito et al., 2017), and can be used in other geographical areas.

3.4 PERMEABILITY

Fig. 13 shows the datasets used to calculate Pr_P in Phase 1. In Phase 2, we incorporated a topographic stress model to estimate failure potential with depth into the Pr_P calculation (Lautze et al., 2020). Discussions among the team in Phase 3 illustrated that, although the datasets and model remain useful predictors, there remains a large degree of uncertainty in permeability at resource depths given a dearth of deep drilling data into calderas and rift zones outside of KERZ. Given this, plus the conservative nature of our ‘veto equation’ in calculating Pr_R (as above, if any of Pr_H or Pr_F or Pr_P are low, so would be Pr_R) and finally, given emerging technologies that may not require permeability, we again emphasize Pr_H as the key quality to drive future exploration. As data on permeability comes in with more deep wells, and if traditional development remains the desired technique, we can bring Pr_P back into the resource calculation.

For completion’s sake, **Fig. 31** presents a map of Pr_P derived following Ito et al. (2017) but using a time decay in permeability that follows the same function as the updated time decay in heat (**Fig. 27**). We also offer the discussion below.

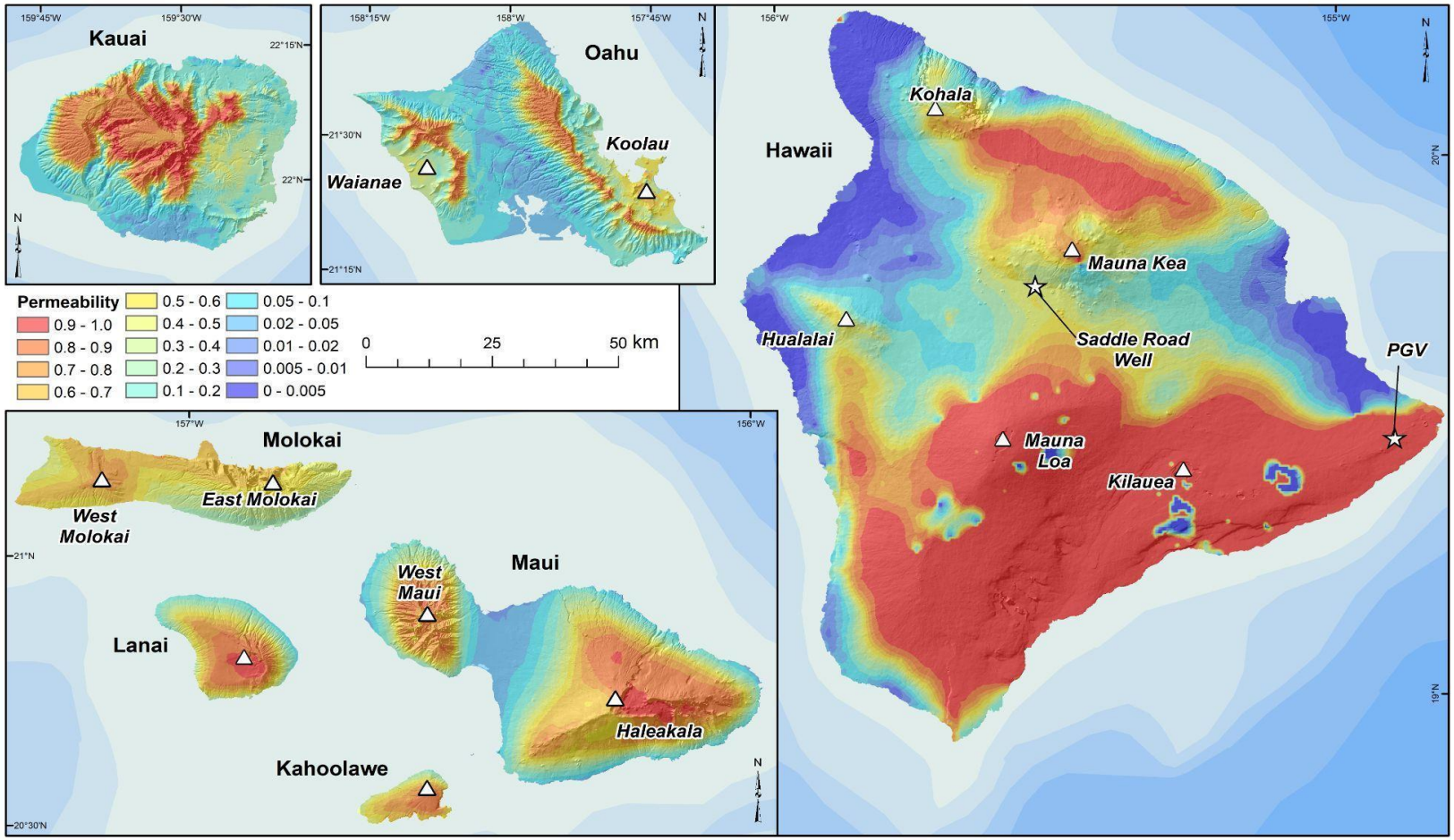


Figure 31. Map showing the Probability of Permeability across the State of Hawai‘i.

General comments on permeability. The permeability is controlled by the volcanic geology, with calderas and rift zones being the two most dominant geothermal systems. Certain aspects of the geology of these systems are predictable, and so some characteristics of the permeability are predictable in general sense as well. Permeability is a tensor quantity, and over sufficiently large distances it will have three perpendicular principal directions, the directions of maximum, intermediate, and least permeability. Fractures play a large role in controlling the permeability of basaltic systems, however, and hence we expect fluid flow to be largely discontinuous, in contrast to fluid flow in many sedimentary rocks. The discontinuous aspect of fluid flow, the geologic heterogeneities inherent to volcanic systems, and gaps in our understanding of the geologic history of Kīlauea, coupled with sparse field measurements of permeability, combine to introduce uncertainty in our evaluation of the permeability. As a result, our appraisal of the permeability in the major volcanic systems on Kīlauea is necessarily largely qualitative.

Expected permeability within calderas. Within a caldera, fractures form by four main processes. These are:

1) Cooling of the basalts (this will tend to generate vertical fractures in the nearly horizontal basalts),
2) Bending of the basalt layers resulting from the accumulation of magma at depth (this will tend to open or close pre-existing vertical fractures).
3) Bending of the basalt layers resulting from the withdrawal of magma at depth.
4) Bending of the basalt layers as a result of differential subsidence during cooling, with this form of bending being concentrated at the caldera margin.

These processes, along with volcanism and faulting at the caldera margin, will affect the directions of the maximum, intermediate, and minimum permeabilities, the magnitudes of these permeabilities, and how the intra-caldera permeability changes with time.

Within a caldera, the first three processes listed above will tend to open vertical fractures that strike in a variety of directions. As the basalt layers cool, they develop a well-connected network of vertical, prismatic columnar joints. These networks would tend to have relatively high permeabilities owing to the connections among the joints and their apertures, which can reach several centimeters or more. The horizontal permeability within most of a caldera thus is likely to be relatively independent of azimuth. The vertical permeability is likely to be different than the horizontal permeability. The vertical extent of the fractures will largely be determined by the thickness of the basalt flows. In contrast, the fractures in map view tend to display polygonal patterns at a variety of scales, with the lateral extent of the polygonal network extending to the caldera margins. Calderas have horizontal dimensions much greater than their vertical dimension, so within a caldera the effective horizontal permeability likely exceeds the vertical permeability.

The permeability at the margin of a caldera is likely to be much different from that inside a caldera. The permeability at the margin of a caldera is likely to be dominated by the steep circumferential faults and associated subparallel fractures that enclose the caldera, and by vertical circumferential fractures formed by differential subsidence. Thus, at the margin of a caldera, the greatest permeability is likely to be horizontal and parallel to the caldera margin. The

intermediate permeability is likely to be vertical. The least permeability is likely to be horizontal and in a radial direction across the circumferential faults.

The permeability within a caldera will change with time. Competing effects within a caldera can both seal these fractures and re-open them. For example, subsequent molten lava ponds within a caldera would allow vertical cooling fractures in the underlying solidified basalt to be filled by molten lava: this would decrease the fracture permeability. Minerals from fumaroles, which are particularly common in calderas, will also tend to precipitate in the cooling fractures, reducing the effective aperture of the fractures and decreasing their permeability. On the other hand, the bending processes mentioned above, as well as faulting at the caldera boundary, will re-open cooling cracks and possibly generate new cracks. The net impact of these competing processes on the permeability of the intra-caldera basalt layers is unclear. Quite possibly, the permeability in intra-caldera layers could vary spatially and fluctuate with time. Data from pumping tests could illuminate trends in how the permeability evolves within intra-caldera layers, but this sort of data is exceedingly sparse now.

Expected permeability within rift zones. Along a rift, we expect the permeability distribution to be different from that within a caldera owing to differences in the way the fractures form in the two areas. Observations at the surface, as well as theory, indicate that along a rift the longest faults and fractures dip steeply and strike parallel the rift. These are also the structures likely to have the largest apertures and hence to control the bulk permeability. We expect the structural anisotropy will cause the permeability along a rift to be greater than the permeability across a rift. Lava flows, which are nearly horizontal, can cover rift zones, and we expect the lava flows would generally interrupt the permeability in a vertical direction. Thus, along a rift, the greatest permeability is likely to be horizontal and parallel to a rift. The intermediate permeability is likely to be vertical. The least permeability is likely to be horizontal and perpendicular to a rift.

Unique aspects of Kīlauea's East Rift Zone. Although other rift zones on Kīlauea, Mauna Loa, and Hualālai have been active since 1800, the East Rift of Kīlauea has exhibited active volcanism, seismicity, and dike intrusion for the last 40 years. Owing to the fractured nature of the volcanic rock on Hawai‘i, the sensitivity of fracture aperture to the prevailing stress field, and the importance of fracture aperture and connectedness to permeability, we expect the permeability in Hawai‘i to be controlled largely by the dominant fracture systems and the present stress field. Geologic mapping and mechanical theory both indicate that the dominant fracture systems along the rifts strike parallel to the rift, that rift-zone fractures are interconnected, and that these fractures are affected by seismic activity. The stresses arising from the weight of the overlying rock, coupled with the stress changes resulting from recent earthquakes and dike intrusion, are likely to impact the fracture permeability in a predictable way. The ongoing volcanic and seismic activity along the East Rift is likely to re-open and reconnect fractures in the rift and keep the hydraulic conductivity higher than other rifts that are less active or dormant.

Permeability at depths of 2-3 km. The principal permeability directions at depths of 2-3 km are likely to reflect the aforementioned trends, but the principal permeability magnitudes are likely to be quite different from those at the surface. The permeability magnitudes in all directions probably decrease with depth for two reasons. First, the deeper flows are older, and fractures in those flows are more likely to contain mineral precipitates than the fractures in the younger flows. Second, the deeper flows experience a higher mean compressive stress than the shallow

flows, so fractures in deeper flows are more likely to be closed, or have smaller apertures, than younger flows. Both effects would also tend to cause the fracture permeability magnitudes of the older deeper flows to be less than that of the younger shallower flows. Owing to the great sensitivity of fracture permeability to fracture aperture, the magnitudes of the expected permeability decreases are difficult to predict with confidence. Data from drilling, pump tests, and/or from carefully designed geophysical surveys would help greatly in quantifying the magnitudes of these permeability changes.

3.5 PR_H RESULTS

Fig. 28 illustrates a probability of heat above 50% at each shield volcano in the state except West Maui, with the largest and highest probabilities near the summit regions of the active Kīlauea and Mauna Loa volcanoes. Each shield volcano on Hawai‘i Island has a probability of heat >90% except Hualālai at ~70%. Moving westward, Haleakalā has a Pr_H of 70-80% at the summit which reduces to 60% or below along its rift zones; Lāna‘i, West and East Moloka‘i, and Wai‘anae have a Pr_H ~60 -70 %, and Kaua‘i and Ko‘olau have a slightly higher Pr_H ~80%. These probabilities in general accord with the size and lifespan of the volcanoes, and are further supported by groundwater data. Figure 18 shows a presence of notably warm groundwaters in the vicinity of PGV along KERZ, along Mauna Loa’s S rift, on and South of Kohala volcano (waters to the south have a mixed sourced on Kohala and Mauna Kea; Tachera et al., in prep), on Lāna‘i, in Wai‘anae caldera, and on Kaua‘i. Broadly, and not surprisingly, the statewide Pr_H shown in Figure 16 closely aligns with our current state-of-knowledge regarding Hawai‘i’s prospective geothermal resource at 2-3 km depth below the surface. Of course, the viability of development in all locations should be taken into account as well, for example, the summits of Kīlauea, Mauna Loa, Mauna Kea, Hualālai, and Haleakalā are protected. In the next section, we provide a roadmap for (hopefully not-too-distant) future exploration activities that takes development viability into account.

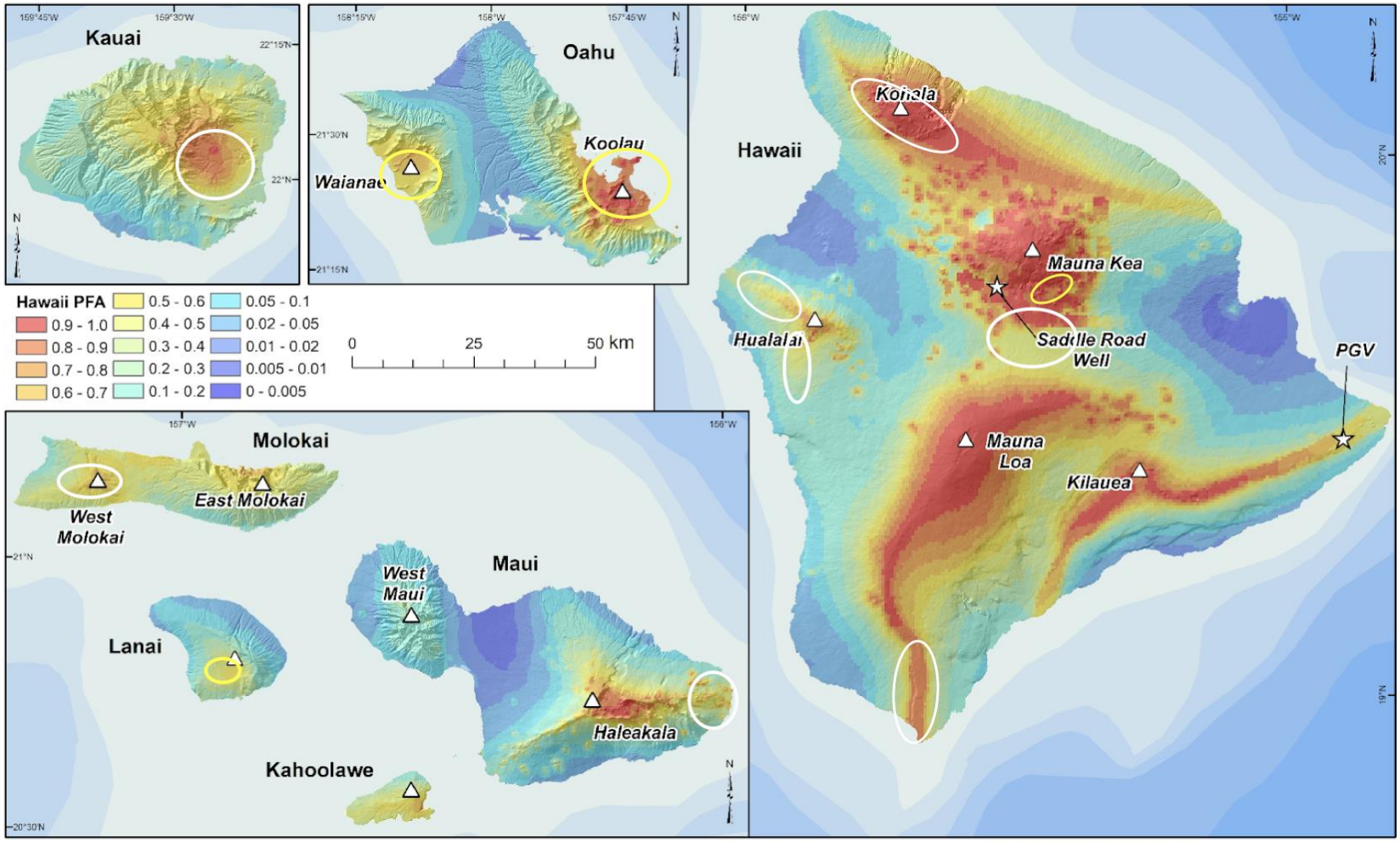


Figure 32. Map showing the Pr_H across the State of Hawai‘i, with ellipses highlighting locations where either slim hole drilling (yellow) or MT geophysics (white) is the exploration step we recommend next. Encircled areas are approximations. On Hawai‘i Island, high-priority locations are encircled, but an island-wide MT survey would be best.

NEXT STEPS FOR HAWAI‘I GEOTHERMAL

This project provided a major step forward in Hawai‘i. We have now compiled all data relevant to Hawaii’s geothermal resource into a statistical methodology whose Pr_H output we have a high degree of confidence in. This allows us to, with similar confidence, elaborate on the next exploration steps that are needed to better constrain the state’s geothermal resource. **Fig. 32** shows locations where slim hole drilling to 2 km depth is the next prudent exploration step encircled in yellow ellipses. These include: i) SE of Mauna Kea’s summit (on DHHL, outcome of Phase 2 PFA), ii) into Lāna‘i’s caldera (outcome of Phase 3 PFA), iii) on O‘ahu (too much noise for MT geophysics; Lautze and Thomas, 2020); need is highest here as per current firm energy RFP). **Fig. 32** shows locations where MT geophysics plus gravity data collection are the next prudent step. These locations include: i) the Saddle between Mauna Loa and Mauna Kea, ii) the rift zones of Hualālai, ii) the South Rift of Mauna Loa, iii) Kohala volcano, iv) Haleakalā’s East Rift Zone, v) West and potentially East Moloka‘i, and iv) Kaua‘i. Other possible locations to consider drilling directly include the SW rift of Haleakalā (the terrain is challenging for MT and recency of volcanism suggests a resource would be present) and S rift of Mauna Loa (where a single water well was drilled into quite high temperature).

As Lāna‘i holds high-level brackish water, a unique feature in the state, Pūlama Lāna‘i and the project team are interested in the results of the Lāna‘i drilling for both the hydrological findings and groundwater temperature results. As a main theme throughout the Environmental Assessment, the data from the drilling project will provide insight into Lāna‘i’s hydrology, which, in turn, will enable more efficient and sustainable management of Lāna‘i’s groundwater. As the Pālāwai Basin is a remnant caldera, geologically similar locations exist around the state. Hence, the information gained in this project will inform groundwater management across the state.

The hydrological findings on Lāna‘i attracted great interest. Pūlama Lāna‘i Chief Operating Officer Kurt Matsumoto requested Dr. Lautze to develop a proposal to better understand Lāna‘i’s groundwater island-wide. In July 2020, Dr. Lautze provided him with a $390k proposal to this effect. This proposal follows a $6-$8M proposal submitted to him in October 2019 as part of discussions between UH President David Lassner and Mr. Matsumoto on behalf of island owner Larry Ellison to form a Lāna‘i Center of Excellence. Hawaii State Department of Land and Natural Resources’s Commission of Water Resources Management also expressed great interest in the groundwater aspect of drilling and has twice invited Dr. Lautze to give presentations to their staff in 2020.

Leveraging the project’s work, Dr. Lautze played a key role in developing National Renewable Energy Lab (NREL)’s proposal “IslandHEAT.” The DOE Geothermal Technologies Office’s Funding Opportunity Announcement cited one of Hawaii Play Fairway Project’s 2017 Geothermics papers. This proposal solicitation required a national laboratory (NL) lead, so Dr. Lautze worked with Los Alamos NL, Lawrence Livermore NL, and NREL to submit Hawai‘i-focused proposals. The winner, NREL and the IslandHEAT project, will leverage and enhance Hawaii Play Fairway Project’s existing data and use the team’s prior relationships with landowners to facilitate additional data collection and high-level modeling of multiple datasets. Dr. Lautze currently serves as an Institutional Principal Investigator of UH for IslandHEAT.

The University of Hawai‘i owns a diamond-wireline coring rig capable of reaching ~2 km depth and 8 Phoenix Magnetotelluric Systems. We estimate a cost of ~$3M per slim hole to 2 km including pre-drilling regulatory activities and post-drilling data collection. While more geophysics will be useful if/when specific landowners or the utility become interested in geothermal development in a particular area, and models such as Machine Learning (which we performed using the PFA-generated Lāna‘i data; Friedel et al., 2022) are interesting, we emphasize the need for more deep data sourced from drilling to refine our PFA model in order to more time- and cost-efficiently plan each next step. Politically, now is an opportune time to move this forward.

While it is nice to say that every little bit helps, with $10M, $20M, or $50M over the next 5-10 years, HGGRC would be able to increasingly better define the nature and extent of Hawai‘i’s resource, and an informed conversation on where and how to develop can begin. Geothermal must be a part of Hawai‘i’s renewable energy portfolio for the state to fulfill its 100% renewable source mandate by 2045.

CONCLUSIONS

As all of the major Hawaiian Islands hold geothermal potential, the Hawaii Play Fairway Project expanded the existing knowledge of Hawai‘i’s geothermal resources. The project used the Play Fairway Analysis to discover locations of geothermal resources as most of Hawai‘i’s geothermal resources are blind and do not exhibit any obvious signs above ground surface such as steam vents or hot ponds. For the first phase, the project compiled and integrated geologic, groundwater, and geophysical datasets relating to heat, fluid, and permeability across the State, developed a statistical methodology to integrate these data into a resource probability map, and identified 10 locations for exploration activities. For the second phase, the team collected new groundwater data in 10 locations across the state and new geophysical data on Lāna‘i, Maui, and central Hawai‘i Island, modeled topographically induced stress to better characterize subsurface permeability, and integrated the results to produce maps of resource probability and confidence. For the third phase, the team conducted further exploration by drilling a groundwater well in Lāna‘i’s Pālāwai Basin and performing more geophysical surveys.

Phase 3 i) deepened an existing water well on Lāna‘i Island, and ii) integrated the Phase 2 and Phase 3 drilling data into final statewide probability and confidence maps. The Phase 3 work builds on two earlier project phases, summarized across four publications in *Geothermics*, which provided an updated statewide geothermal resource assessment via a newly established methodology to integrate multiple datasets into a resource probability calculation, or map. Deepening of the well on Lāna‘i from ~427 m to ~1057 m (1400' to 3467') validated our earlier work given measurement of a maximum bottom hole temperature of 66°C (151°F) and a gradient of 42°C/km. This gradient is roughly twice the measured background for the state. The temperatures within Lāna‘i Well 10 exceed those of two-2 km deep wells drilled into Kīlauea’s East Rift Zone and a third well drilled into the Saddle, all of which showed a substantial increase in the temperature gradient below 1 km. Note that these promising results are despite the fact that - due to funding limitations - this well was not optimally located, nor did it achieve an ideal target depth for exploration wells in Hawai‘i. This is now the deepest well located off of the Big Island of Hawai‘i and the first temperature-gradient well drilled outside of the active rift of Kīlauea Volcano (Lāna‘i Volcano last erupted 1 Ma). Our findings on Lāna‘i have exciting implications for the volcanically older islands in the State of Hawai‘i, in particular O‘ahu, which uses more electricity than the rest of the islands combined, and whose utility recently called for 500-700 MW of firm renewable energy production.

This report detailed the Lāna‘i drilling activity and results as well as present final statewide probability maps independently for heat (Pr_H) and permeability (Pr_P); we now take Pr_F as equal to one. This differs from our Phase 1 presentation of a combined resource probability achieved by multiplying the three together. Our updated thinking is to stress Heat as fundamental to current geothermal prospecting in Hawai‘i. We now recognize that a) the probability of Fluid at resource depths equals one at the 2+ km depth of Hawai‘i’s geothermal resource given Hawai‘i’s ocean environment, and b) we have little to no field data on permeability at depth (outside of Kīlauea’s East Rift Zone), with which to calibrate a model of permeability. We also present a map of confidence in our Probability of Heat based on the number and quality of data at a given location. Finally, we present a geothermal prospecting roadmap for Hawai‘i, emphasizing a

primary need for more deep temperature-gradient wells in order to truly understand the resource potential statewide. Given the social, economic and environmental implications associated with the fact that Hawai‘i continues to pay ~$5B annually to import fossil fuels, while simultaneously coming to recognize a need for firm renewables, now is an opportune time to move forward with geothermal.

Acknowledgements. We thank the Department of Energy Geothermal Technologies Office for funding this project. We graciously thank the too-numerous-to-mention students, field assistants, the drilling and core-archiving crews, the water well and landowners who enabled this project’s success, and the UH-HIGP administrative staff. In particular, Lautze acknowledges Daniel Dores and Alice Kim for their calm, behind-the-scenes supportive genius.

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PRODUCTS FROM THE HAWAI‘I PLAY FAIRWAY PROJECT

This section lists work resulting from the project: 7 journal articles, 13 conference papers, 7 theses, 26 conference presentations, 11 University and community presentations, core photos from the Lanai drilling, 21 datasets, 18 media reports, 8 television interviews, 4 community events, a blog about the drilling effort on Lāna‘i, and awards and recognition.

Publications

Journal Articles

Lautze N.C., Ito G., Thomas D., Frazer N., Martel S., Hinz N., Tachera D., Hill G., Pierce H.A., Wannamaker P.E., and Martin T., 2020, Play Fairway Analysis of Geothermal Resources across the State of Hawaii: 4. Updates with new groundwater chemistry, subsurface stress analysis, and focused geophysical surveys, Geothermics, v. 86, doi: 10.1016/j.geothermics.2019.101798.

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Brennis, Theodore, 2019, Renewable Energy in Hawaii: A Comparative Analysis of Wind, Solar, and Geothermal Energy Resources. Undergraduate Thesis, Department of Geology and Geophysics, University of Hawaii at Manoa. Advisor: Nicole C. Lautze.

Dudoit, Tineill, 2019, The Use of Groundwater Geochemistry to Prospect for Blind Geothermal Resources in the State of Hawaii. Undergraduate Thesis, Department of Geology and Geophysics, University of Hawaii at Manoa. Advisor: Nicole C. Lautze.

Tachera, Diamond K., 2018, A Hydrogeochemical Analysis of Geothermal Resources in the State of Hawaii. Master of Science Thesis (Plan B), Department of Geology and Geophysics, University of Hawaii at Manoa. Advisor: Nicole C. Lautze.

Powell, Daniel B., 2017, A Hydrogeochemical Assessment of Geothermal Potential in the Hawaiian Islands. Undergraduate Thesis, Department of Geology and Geophysics, University of Hawaii at Manoa. Advisor: Nicole C. Lautze.

Waller, David G., 2016, Identification of Geothermal Resources in Hawaii Utilizing Aqueous Geochemistry. Project Report, Master of Geosciences, Department of Geology and Geophysics, University of Hawaii at Manoa. Advisor: Garrett Ito.

Schuchmann, Hannah, 2015, Prospecting Geothermal Resources in Hawaii: Application of GIS Mapping and Groundwater Chemistry. Undergraduate Thesis, Global Environmental Science, Department of Oceanography, University of Hawaii at Manoa. Advisor: Nicole C. Lautze.

Conference Papers

Friedel M.J., Lautze N.C., Wallin E., and Rothfolk A., 2022, Multimodal Machine Learning for 3D Characterization of Hidden Groundwater and Geothermal Resources: Case Study, Lanai, Hawaii, Proceedings, Stanford Geothermal Workshop, Stanford University.

Lautze N.C., Thomas D.M., Ito G., Hinz N., Frazer N., and Martel S., 2021, Overview of the Hawaii Play Fairway Project, Phase 1-3, World Geothermal Congress.

Lautze N.C., Kim A., Dores D., Brennis T., Ferguson C.M., and Thomas D.M., 2021, Outreach Efforts of the Hawai‘i Groundwater and Geothermal Resources Center, World Geothermal Congress.

Lautze N.C., and Thomas D.M., 2020, Geothermal Prospecting of Ko‘olau and Wai‘anae Volcanoes, O‘ahu, Hawai‘i, Geothermal Resources Council Transactions, v. 44, Clean, Renewable and Always On, p. 613-627.

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Ferguson C.M., Lautze N.C., Thomas D.M., Tachera D.K., and Dores D., 2019, Hawai‘i Statewide Geothermal Play Fairway Analysis: Final Phase Aqueous Geochemistry Results and Work in Progress, Geothermal Resources Council Transactions, v. 43, p. 550–562.

Lautze N.C., and Thomas D.M., 2019, Update to the Hawai‘i Play Fairway Project, Now in Phase 3, Proceedings, Stanford Geothermal Workshop, Stanford University, 6pp.

Lautze N.C., Thomas D.M., Ito G., Frazer N., Martel S., Hinz N., and Whittier R., 2018, Review of the Hawai‘i Play Fairway Phase 2 Activities, Proceedings, 43rd Workshop on Geothermal Reservoir Engineering, Stanford University, SGP-TR-213, 9 pp.

Lautze N.C., Thomas D.M., Whittier R., Martel S., Ito G., Frazer N., Hill G., Martin T., Wannamaker P., and Hinz N., 2017, Improving a 2015 Map of Geothermal Resource Probability Across the State of Hawai‘i, Proceedings, 42nd Workshop on Geothermal Reservoir Engineering, Stanford University, SGP-TR-212, 8 pp.

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Lautze N.C., Thomas D.M., Hinz N., Ito G., Frazer N., and Waller D., 2016, Hawai‘i Play Fairway Analysis: Discussion of Phase 1 Results, Proceedings, 41st Workshop on Geothermal Reservoir Engineering, Stanford University, SGP-TR-209, 7 pp.

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Presentations

Conference Presentations

Friedel M.J., Lautze N.C., Wallin E., and Rothfolk A., 2022, Multimodal Machine Learning for 3D Characterization of Hidden Groundwater and Geothermal Resources: Case Study, Lanai, Hawaii, Proceedings, Stanford Geothermal Workshop, Stanford University, Stanford, CA.

Lautze N.C., Thomas D.M., Ito G., Hinz N., Frazer N., and Martel S., 2021, Overview of Hawaii Play Fairway Project, Phases 1-3, World Geothermal Congress, Reykjavik, Iceland.

Lautze N.C., Thomas D.M., Ferguson C.M., Wallin E., and Dores D., 2021, Hawaii Play Fairway: Phase 3 Results, World Geothermal Congress, Reykjavik, Iceland.

Lautze N.C., Kim A., Dores D., Ferguson C.M., and Thomas D.M., 2021, Outreach Efforts of the Hawai‘i Groundwater and Geothermal Resources Center, World Geothermal Congress, Reykjavik, Iceland.

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Dores D., and Lautze N.C., 2020, Initial evaluation of ground-source heat exchangers for cooling applications in Hawai‘i, Geothermal Resources Council meeting.

Lautze N.C., and Thomas D.M., 2020, Geothermal Prospecting of Ko‘olau and Wai‘anae Volcanoes, O‘ahu, Hawai‘i, Geothermal Resources Council meeting.

Ferguson C., and Lautze N.C., 2020, Exploration for Blind Geothermal Resources in the State of Hawai‘i utilizing Dissolved Noble Gases in Well Waters, Geothermal Resources Council meeting.

Lautze N.C., 2020, Overview of Geothermal in Hawaii, Energy Week 2020, Q-PIT Annual Symposium, Kyushu University, Fukuoka, Japan.

Lautze N.C., and Thomas D.M., 2019, Hawai‘i Play Fairway, Phase 3 Update, Geothermal Resources Council meeting, Palm Springs, CA.

Ferguson C.M., Lautze N.C., Thomas D.M., Tachera D., and Dores D., 2019, Hawaii Statewide Geothermal Play Fairway Analysis: Final Phase Aqueous Geochemistry Results and Work in

Progress, Geothermal Resources Council meeting, Palm Springs, CA (awarded first prize for posters).

Lautze N.C., and Thomas D.M., 2019, Update to the Hawai‘i Play Fairway Project, Now in Phase 3, Proceedings, Stanford Geothermal Workshop, Stanford University, Palo Alto, CA.

Ferguson, C.M., Tachera D.K., and Lautze N.C., 2019, A Play Fairway Exploration for Blind Geothermal Resources in the State of Hawai‘i, Energy Week 2019, Q-PIT Annual Symposium, Kyushu University, Fukuoka, Japan. *Invited presentation.*

Lautze N.C., Thomas D.M., Ito G., Frazer N., Martel S., and Hinz N., 2018, Overview of a New Geothermal Resource Assessment for the State of Hawai‘i, Cities on Volcanoes 10, Napoli, Italy.

Lautze N.C., Thomas D.M., Ito G., Frazer N., Martel S., Hinz N., and Whittier R., 2018, Review of the Hawai‘i Play Fairway Phase 2 Activities, Stanford Geothermal Workshop, Palo Alto, CA.

Tachera D.K., and Lautze N.C., 2018, A Hydrogeochemical Assessment of Geothermal Resources in the State of Hawai‘i, Energy Week 2018, Q-PIT Annual Symposium, Kyushu University, Fukuoka, Japan. *Invited presentation.*

Thomas D.M., Pierce H.A., and Lautze N.C., 2017, Reconsidering Volcanic Ocean Island Hydrology: Recent Geophysical and Drilling Results, AGU Fall Meeting, New Orleans, Louisiana.

Lautze N.C., 2017, An Overview of the Hawai‘i Play Fairway Project, Invited presentation at Abstracts with Programs, GSA Annual Meeting, Geological Society of America, Seattle, WA.

Thomas D.M., Pierce H.A., and Lautze N.C., 2017, Integrated Geophysical and Drilling Results for Mauna Kea Volcano: Hydrologic Implications, Abstracts with Programs, GSA Annual Meeting, Geological Society of America, Seattle, WA.

Tachera D.K., Lautze N.C., Thomas D., and Whittier R., 2017, A Geothermal resource assessment for the State of Hawai‘i using Hydrogeochemical Analysis, Abstracts with Programs, Cordilleran Section - 113th Annual Meeting – 2017, Geological Society of America, Honolulu, HI.

Thomas D.M., and Lautze N.C., 2017, Geothermal Energy in Hawai‘i: A Historical Perspective, Abstracts with Programs, Cordilleran Section – 113th Annual Meeting – 2017, Geological Society of America, Honolulu, HI.

Frazer N., Ito G., Lautze N.C., Thomas D.M., Hinz N., and Whittier R., 2017, Two Simple Methods in Geothermal Reconnaissance: The Voter-Veto-Confidence Method and the Back-Propagation of the Advected Geochemical Signals, Abstracts with Programs, Cordilleran Section - 113th Annual Meeting – 2017, Geological Society of America, Honolulu, HI.

Lautze N.C., Thomas D.M., Whittier R., Martel S.J., Ito G., Frazer N., Hill G., Martin, Wannamaker P., and Hinz N., 2017, Improving a 2015 Probability Map of Geothermal Resource Probability Across the State of Hawai‘i, Stanford Geothermal Workshop.

Lautze N.C., Thomas D.M., Hill G., Wallin E., Whittier R., Martel S.J., Ito G., Frazer N., and Hinz N., 2016, Phase 2 Activities to Improve a 2015 Play Fairway Analysis of Geothermal Potential Across the State of Hawai‘i, Geothermal Resource Council.

Lautze, N.C., 2016, Introducing two projects with a focus on Groundwater in Hawai‘i, Association of Environmental and Engineering Geologists, Annual Meeting, Waikaloa Hawai‘i.

Lautze N.C., Thomas D.M., Hinz N., Ito G., Frazer N., and Waller D., 2016, Hawai‘i Play

Fairway Analysis: Discussion of Phase 1 Results, Proceedings, 41st Workshop on Geothermal Reservoir Engineering, Stanford University.

University & Community Presentations

Donald M. Thomas and Nicole C. Lautze, 2022. Geothermal Power for Hawaii's Energy Future. A Sustainable Energy Hawaii panel presentation via Zoom, February 5, 2022.

Nicole C. Lautze, 2022. Hawaii's Groundwater and Geothermal Resources: What We Know and Don't Know! A training seminar for the Association of Energy Engineers – Hawaii Chapter via Zoom, January 27, 2022.

Donald M. Thomas, 2021. History of Geothermal Exploration on DHHL Lands (Lands of Department of Hawaiian Homelands, State of Hawaii). A Sustainable Energy Hawaii presentation via Zoom, November 5, 2021.

Nicole C. Lautze, 2021. Hawaii's Groundwater and Geothermal Resources and Magnetotellurics. For students in Dr. Julia Hammer's course Earth Sciences 402, Hawaiian Geology, University of Hawaii at Manoa, September 15, 2021.

Donald M. Thomas, 2021. SEH Pau Hana Friday with Dr. Don Thomas (geothermal and hydrological exploration). A Sustainable Energy Hawaii presentation via Zoom, April 11, 2021.

Nicole C. Lautze, 2021. What We Know and Don't Know about Hawaii's Geothermal Resource. Virtual Van Tuyl Lecture (via Zoom), Department of Geology and Geological Engineering, Colorado School of Mines, March 25, 2021.

Nicole C. Lautze, 2021. Hawaii's Groundwater and Geothermal Resources … What We Know, What We Don't Know. Invited by Sustainable Energy Hawaii, January 15, 2021.

Nicole C. Lautze, 2020. Geothermal energy and potential. For undergraduate students in Professor Floyd McCoy's course Oceanography 120, Global Environmental Challenges, Windward Community College, February 3, 2020.

Nicole C. Lautze, 2019. Hawaii's groundwater and geothermal resources: what we do know and don't know. Department of Earth Sciences Seminar. University of Hawaii at Manoa, November 3, 2019.

Nicole C. Lautze and Garrett Ito, 2019. Groundhogs Lightning Talks: Everything Under the Sun. Department of Earth Sciences Seminar. University of Hawaii at Manoa, February 1, 2019.

Nicole C. Lautze and Garrett Ito, 2015. An integrated Geologic, Geochemical, and Geophysical Data Analysis of Geothermal Energy Prospects across the State of Hawaii. Department of Geology and Geophysics TGIF Seminar. University of Hawaii at Manoa, September 18, 2015.

Core Photos

Lāna‘i Preliminary Core Photos: https://www.higp.hawaii.edu/hggrc/lanai-preliminary-core-box-photos/

Datasets

Links to the Datasets: https://www.higp.hawaii.edu/hggrc/projects/hi-play-fairway/pf-project-data/. The Geothermal Data Repository archives these datasets as well.

- Hawaii Play Fairway Analysis: Lanai Daily Drilling Reports
- Hawaii Play Fairway Analysis: Noble Gas Raw Data for Hawaii, Maui, Oahu, Kauai, and Lanai islands
- Hawaii Play Fairway Analysis: Groundwater Chemistry
- Hawaii Water Chemistry Data
- Hawaii Play Fairway Analysis: Hawaii Conservation District Subzones
- Hawaii Play Fairway Analysis Model
- Deformation Data, Hawaii Island
- U.S. Geological Survey 2007 Map of the State of Hawaii
- Hawaii Play Fairway Analysis: Hawaii State Land Use Districts
- Hawaii Play Fairway Analysis: National Park Boundaries
- Oahu Groundwater Recharge Data
- Hawaii Water Well Temperature and Hydraulic Head
- U.S. Geological Survey data for Geothermal Wells in Hawaii
- Hawaii Play Fairway Analysis: Hawaiian Place Names
- Hawaii Play Fairway Analysis Results
- Hawaii Gravity Model
- Maui Groundwater Recharge Data
- Magnetotelluric and Audiomagnetotelluric Survey along the Saddle Road, Hawaii
- U.S. Geological Survey Quaternary Fault and Fold Database
- Kauai Groundwater Flow Model
- Hawaii Rifts
- Oahu Groundwater Flow Model
- East Maui Groundwater Flow Model
- Hawaii Island Groundwater Flow Model
- Hawaii Faults
- Island Boundaries, Hawaii
- West Maui Groundwater Flow Model
- Recharge Data for Hawaii Island
- Recharge Data for the Islands of Kauai, Lanai, and Molokai, Hawaii

Project Outreach

Media Coverage

HGGRC is tracking its media coverage at http://www.higp.hawaii.edu/hggrc/hggrc-in-the-news/.

Nicole Lautze’s election to Geothermal Rising’s Board of Directors was covered in GR’s news release “Geothermal Rising Announces 2021 Board of Directors Election Winners” and ThinkEnergy.com, January 2021

Geothermal Resources Council Bulletin interviewed Nicole Lautze as an advocate of geothermal in “Chatting Geothermally With…”, September/October 2019 issue, p. 50-51

Rock-head Science blog featured Daniel Dores in a profile article, “Geothermal Geology Technician, Daniel Dores @RootsandRocks: A Day in the GeoLife Series,” Sept. 5, 2020

The Women in Geothermal campaign (by Geo Energy Marketing Services) featured team members Nicole Lautze and Alice Kim on Facebook and Twitter, and Women in Geothermal (WING) shared Lautze’s profile, 2019

The *2019 Hawaii Energy Facts and Figures*, a report by the Hawaii State Energy office, recognized HGGRC as “cataloguing much of the completed and ongoing geothermal-related explorations in Hawaii” and highlighted the Play Fairway project

Hawaii Public Radio highlighted work of undergraduate senior thesis student Theodore Brennis, “Unexplored Geothermal Potential May Offer Solution to Renewables’ Reliability Problem,” July 2019

HGGRC authored “Geothermal Well HGP-A: Hawai‘i’s First Successful Geothermal Well,” *Geothermal Resources Council Bulletin*, July/August 2019 issue

Lanai Today featured the Lāna‘i drilling project in “Investigating Lanai’s Geology,” July 15, 2019

Lanai Today featured HGGRC’s Lāna‘i Hydrogeochemistry project in “Palawai Research Project Delayed But Coming Soon,” May 15, 2019

Geothermal Resources Council Bulletin published a one-page feature article about HGGRC in the March/April 2019 issue.

The Maui News reported our groundwater research proposal and interviewed Lautze, “UH Proposes Brackish Water Study on Lanai,” Oct. 19, 2018

Lanai Today featured the Lāna‘i drilling project in “Straight from the Source,” Oct. 15, 2018

In *the Geothermal Resources Council Bulletin* July/August 2018 issue, Lautze shared her expertise, “Lava Eruption Disrupts the Puna Geothermal Venture,” pp. 56-57

The *Geothermal Resources Council Bulletin*, Jan./Feb. 2018 issue, reported Lautze winning the C3E award, “Geothermalist Nicole Lautze Wins Clean Energy Education & Empowerment Award,” and featured this news in GRC’s blog and social media

University of Hawai‘i Sea Grant’s *Voice of the Sea* television series interviewed Lautze and featured HGGRC’s work, October 2018

KITV’s (ABC news affiliate) morning segment “Morning Shakas” congratulated Lautze for winning the 2017 Clean Energy Education & Empowerment (C3E) Award and got featured on Kaunana (UH Mānoa’s research publication) and the Geothermal Resource Council’s blog

A UH Mānoa news release reported Lautze’s C3E award, “UH Mānoa researcher honored for clean energy education and empowerment,” 2017

Television Interviews on ThinkTech Hawaii

- “Hawaii’s Groundwater and Geothermal Limits (Hawaii: State of Clean Energy),” Nicole C. Lautze, Sept. 17, 2021
- “Learning about Sustainable Energy,” Nicole C. Lautze, Dec. 8, 2020
- “Water Resources Research,” On TV show Voice of the Sea, episode featuring WRRC research. Explained how lava types affect storage of groundwater, Sept. 2018 (this episode won a Bronze Telly Award)
- “Geothermal Energy in Hawai‘i (Research in Manoa)” Nicole C. Lautze, May 1, 2018
- “Latest Research in Hawai‘i’s Geothermal Resource,” Nicole C. Lautze, Sept. 14, 2017
- “Groundwater and Geothermal Discoveries in Hawaii with Nicole Lautze,” Nicole C. Lautze, Jan. 9, 2017
- “Advances in Hawaii’s Renewable Energy Resources: Where Are We?”, Donald M.

Thomas, October 26, 2016
- “How Hot is Your Hawai‘i,” Nicole C. Lautze, 2015

Community Outreach

Preschool Field Trip for UH Mānoa Children’s Center, Nicole C. Lautze, June 2019 and May and November 2021

UH-School of Ocean Earth Science and Technology Open House exhibit: “What’s inside a volcano: rocks, water and geothermal heat;” Nicole C. Lautze; Daniel Dores, Colin Ferguson, Diamond Tachera, and Theodore Brennis; 2015; 2017; and 2019

Open house for the Lāna‘i community, “Well 10,” Nicole Lautze and Don Thomas. Lāna‘i residents visited the Lāna‘i Well #10 drill site, learned about the project, and gave questions or comments to the project’s leaders, October 14, 2019.

Informational meeting, “Drilling Open House at Lāna‘i Well 10,” for the Lāna‘i community, June 19, 2019

Blog

Lāna‘i Drilling Updates: https://www.higp.hawaii.edu/hggrc/category/lanai-island-project-updates/

Awards, Prizes, and Recognition

Nicole C. Lautze, 2022, nominee for the Karl W. Böer Renewable Energy Mid-Career Award (coordinator: University of Delaware). Nominator: Eve Sprunt.

Nicole C. Lautze, 2021-2023, elected Member of the Board of Directors for Geothermal Rising (formerly known as Geothermal Resources Council). Nominated by Dr. Kelly Blake Fujii (of the US Navy Geothermal Office; current board member).

Nicole C. Lautze, 2021, promotion to rank-5 faculty specialist, Hawai‘i Institute of Geophysics and Planetology, University of Hawai‘i at Mānoa.

Donald M. Thomas, 2021, Citizen’s Award for Exceptional Service, Department of the Interior, U.S. Geological Survey.

Nicole C. Lautze, 2020, nominee for a Women in Geothermal (WiNG) Award. Nominator: Erin Fitch.

Nicole C. Lautze, 2020, University tenure, Hawai‘i Institute of Geophysics and Planetology, University of Hawai‘i at Mānoa.

Nicole C. Lautze, 2020, nominee for the Advisory Board of the International Continental Scientific Drilling Program (sponsor: National Science Foundation). Nominator: Donald Thomas.

Colin M. Ferguson and Nicole C. Lautze, 2019, Best Student Poster Award, Geothermal Resources Council Annual Meeting, Palm Spring, CA. Poster title: “Dissolved Noble Gas Exploration for Blind Geothermal Resources in the State of Hawaii – Part of Hawaii Play Fairway Phase 3.”

Donald M. Thomas, 2018 Lifetime Achievement Award, Western States Seismic Policy Council. The WSSPC Lifetime Achievement Award recognizes leaders in earthquake risk reduction.

Throughout their careers, the recipients demonstrated an extraordinary commitment, level of service, and application of earthquake risk reduction to public policy.

Nicole C. Lautze, 2017, Clean Energy Education & Empowerment (C3E) Education Award, MIT Energy Initiative and the Stanford Precourt Institute for Energy. “This $8000 C3E Award recognizes the outstanding leadership and extraordinary achievements of mid-career women working to advance clean energy in the U.S.” Nominator: Eve Sprunt.

Nicole C. Lautze, 2017, promotion from Assistant Faculty to Associate Tenure-Track Faculty position, Hawai‘i Institute of Geophysics and Planetology and Water Resources Research Center, University of Hawai‘i at Mānoa.

Nicole C. Lautze, 2015 & 2016, nominee for the Clean Energy Education & Empowerment (C3E) Award and finalist for the 2016 award. Nominator: Eve Sprunt.

Other

Nicole thanks the Play Fairway project for seeing me through Tenure (in 2019) and Promotion to Full (in 2021) and the birth of babies (2015 and 2017)

Appendix A - Response to Comments to Environmental Assessment for Lāna‘i Drilling

Author's Responses to Individual's Comments on Draft EA: Hydrogeochemical Investigation, Pālāwai Basin

December 12, 2018

Dear Ms. Kaye,

Thank you for your interest in this project. Please find below a response to your questions.

Kind Regards,

Nicole Lautze

Nicole Lautze

1.) Gaining more data about the hydrology of Lāna‘i will improve our understanding of Lāna‘i's groundwater resource and therefore allow for more responsible management of the resource.

2.) We consider greater scientific understanding of a resource to be beneficial to the community to which such a resource is valuable. In this case, the current socioeconomic health of Lāna‘i is implicitly dependent upon the sustainability of Lāna‘i's groundwater resource. The Final EA text has been modified to state as follows, "Positive impacts of the project can be reasonably expected from our understanding of Lāna‘i's groundwater resources and the consequential long term sustainability of that resource, benefitting the socioeconomic environment".

3.) The cited literature regarding Lāna‘i's current water sources and usage available to the investigators include the 2016 Lāna‘i Community Plan and the 2011 Lāna‘i Water Use and Development Plan. One primary source of recharge on the island is rainfall. Due to climate change, rainfall patterns and rainfall intensity may change. This poses a question of how a changing pattern of recharge will affect Lāna‘i's freshwater availability and sustainability. Having more definitive data on the extent and quality of the water within the Pālāwai Basin will help with preparation for future scenarios and provide guidance for future groundwater exploration. We posit that increased available scientific information and knowledge will yield more informed and efficient decision making that will benefit the management of the groundwater resource. We propose to use two existing wells for this research, which should eliminate the need to drill two new wells.

4.) What you have cited above is not a "trigger" under Chapter 343, Section 343-5 HRS, but rather relates to the scope of the environmental impact disclosure. This scientific study and project is not a prelude to nor does it have any nexus to a future land development project or phase.

5.) The proposed action is not intended to define "high level" water sources. Our reference to "high level" is in regard to Lāna‘i wells 9 and 10, which are both located several hundred feet above sea level and are situated substantially above the island's basal aquifer. To avoid any confusion, we have removed the words "so-called" from the text.

6.) The project investigators recognize the need for continued efforts in understanding the geology and hydrology of the Hawaiian Islands. The unique aspect of the Pālāwai Basin is the brackish high-level water. This is the only known location in the State of Hawai‘i where brackish water exists at such a high level. However, the caldera regions of the Hawaiian volcanoes are expected to share many other similar geologic and hydrologic features. Improved understanding in the Pālāwai Basin can be expected to yield important information relevant to other geologically similar locations, such as the Ko‘olau and Waianae calderas on O‘ahu or the Līhue Basin on Kaua‘i.

7.) We recognize that there are contending theories for the origin of saline water present at high elevations in the groundwater of Lāna‘i. At this point we do not know which theory is correct. Our intent is to collect more data to better constrain which theory is more likely.

8.) The intent of this research is not to critique existing water management. The objective of this research is to gain more data on the water resource and make such data available so that water managers can make better-informed decisions.

9.) There are a number of topics for which the proposed action is designed to increase current information. These include: source and extent of brackish waters, permeability in subsurface units, interaction of groundwater with fault/fracture networks and/or dike complexes, subsurface fluid cycling, groundwater residence time, and influence of rock units/mineralogy on fluid characteristics, and other questions.

10.) There are many variables that determine which thermal gradients would make desalination or energy resource development economically viable (e.g. hydraulic conductivity of the rock; volume and quality of water at depth). We cannot constrain such variables currently and do not have the expertise to fully evaluate the technology or economics of either process. Our objective is to identify the thermal gradient and make the data publicly available.

11.) The project is designed to gather and interpret scientific information, and to make this information publicly available, which will lead to increased understanding, and allow for more-informed management. We make no distinction between public and private interest. The State has committed to a 100% renewable energy supply by 2045; having a better understanding of the thermal resources on all islands will help policy-makers in planning to meet that objective.

12.) We will change the narrative to read “all relevant sectors of the government.” Very few planning and permitting decisions at any level within the government can be made without an understanding of the availability and quality of groundwater.

As noted above, some of the hydrologic characteristics within the Pālāwai Basin are unique, and some are shared amongst other locations in the Hawaiian Islands. Much of the improved understanding of groundwater characteristics gained by this project will have application elsewhere around the state.

13.) There is a vast amount of literature that documents the application of groundwater chemistry to defining groundwater systems. A few references include:

(1) Clark, I., and Fritz, P., 1997, Environmental Isotopes in Hydrogeology: New York, CRC Press;

(2) Scholl, M.A., Gingerich, S.B., and Tribble, G.W., 2002, The influence of microclimates and fog on stable isotope signatures used in interpretation of regional hydrology: East Maui, Hawaii: Journal of Hydrology, v. 264, p. 170-184;

(3) Scholl, M.A., Ingebritsen, S.E., Janik, C.J., and Kauahikaua, J.P., 1996, Use of precipitation and groundwater isotopes to interpret regional hydrology on a tropical volcanic island: Kilauea volcano area, Hawaii: Water Resources Research, v. 32, p. 3325-3357.

The project will provide more scientific information, leading to an increased understanding of the resource, and allowing for more-informed management.

14.) The main drilling fluid will be brackish water to which bentonite clay and Alcomer 120L will be added. The use of bentonite clay and Alcomer 120L is consistent with Best Management Practices for drilling in hard rock (basalts, granites, etc.). Both bentonite clay and Alcomer 120L are used for water well drilling and both are National Sanitation Foundation certified. The quantity used will be dependent upon the drilling conditions and cannot be known at this time, however the amount used will be tracked throughout the project. The intent of adding both bentonite clay and Alcomer 120L to the fluid is to minimize the amount of fluid loss. The amount of fluid loss will be tracked such that leakage outside the hole can be appropriately estimated.

15.) The specific reference in section 3-8 refers to any user of groundwater on Lāna‘i, the scientific community in general, as well as any decision-makers involved in regulating groundwater resources on Lāna‘i.

16.) Re-naturalization of the land will be done in accordance with guidance from the landowner.

17.) The placement of shipping containers is intended to protect the site from prevailing wind direction. If placement of shipping containers is not sufficient we will use brackish water also, for dust control. This will be added to the final EA.

18.) A major rain event would have negligible impact in terms of movement of drilling fluid because rainwater would infiltrate to the top of the water table but we will be drilling/working several hundred feet below.

The drilling polymer is widely used in agriculture as a means of reducing soil erosion in irrigated fields. Studies of its degradation under these conditions has been shown to occur at a rate of ~10% per year. However, degradation occurs at varying rates depending on chemical, thermal, photolytic, and biological conditions. We currently cannot specifically identify the time period due to unknown conditions at depth in the drill hole. At the warmer water temperatures in the boreholes in the Pālāwai Basin, degradation rates are expected to be higher than those at surface-ambient conditions of the published studies. The statements in this paragraph will be added to the final EA.

19.) We will publish notices in the Lāna‘i Today to keep the community informed as to the status of the project, and the Pūlama Lāna‘i hotline [(808) 565-3911] will be available for the community to call should they have any concerns.

20.) We have consulted with the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office and Pūlama Lāna‘i’s Director(s) of Conservation on the issue of this project’s potential impact on Lāna‘i’s birds and bats. We will take all actions recommended and/or required by them, which may include daylight-only drilling. The Final EA has been updated on this matter.

We considered the ‘best available science’ for the entire island of Lāna‘i. The documents related to the Big Wind project are a part of the best available science.

21.) We gathered publicly available data for Maui County through the Hawai‘i Department of Health (HDOH) Clean Air Branch (Hawaii Department of Health, 2016; Hawaii Ambient Air Quality Data, 2018), the U.S. Environmental Protection Agency (Air Now, 2018), and the American Lung Association (State of the Air, 2018). These references and additional explanation to support our contention that the air quality in the Pālāwai Basin is expected to be good have been added to the final EA. We will work HDOH to obtain a temporary non-covered source permit and will take all recommended actions to minimize the effects of our operation on air quality.

22.) Re-naturalization of the land will be done in accordance with the landowner’s guidance.

23.) The equipment is stored at 6000 feet elevation on the Big Island where it regularly freezes overnight, reducing the potential for coqui frog habitation. Pūlama Lāna‘i has an existing process for quarantine and inspection for coqui frogs that the equipment shipped from Big Island will undergo.

24.) Our use of the term potable refers to water with chloride concentrations below 250 ppm, as per the U.S. Environmental Protection Agency’s National Secondary Drinking Water Regulations and resultant secondary maximum contaminant levels, and the current Water Use Development Plan as adopted by the County of Maui and the State Commission on Water Resources for Lāna’i.

The project can confirm that the 25,000 GPD will be brackish water, with anticipated 60 days of use at this rate.

25.) Final EA has been amended to differentiate between the duration of the proposed action and the time of active drilling to minimize misunderstanding.

The anticipated duration of drilling at each site has been estimated at one month. The Draft EA offers a conservative estimation of project time described as “several months” as this allows time for other tasks associated with the proposed action, including moving equipment to and from the site, transition time between the two sites, data collection at each well after drilling, and removing materials from the site at the project’s completion.

26.) The project investigators estimate there will be a total of 5-8 trips per day using 3-4 different vehicles.

27.) Two to three short term employment opportunities for site preparation and drill hands.

Five local drill hands from Hawai‘i Scientific Drilling Project (HSDP) ended up working in drilling industry either locally or on mainland. Another two who worked on the Humuula Groundwater Research Project (HGRP) were offered long term employment on the mainland but opted not to accept it. At least three individuals on the HGRP project currently work as intermittent employees with the University of Hawai‘i.

28.) The anticipated outcome of the project is an increased knowledge of the geology and hydrology within the Pālāwai Basin. There are a number of topics for which the proposed action anticipates increasing current information. These include: source and extent of brackish waters, permeability in subsurface units, interaction of groundwaters with fault/fracture networks and/or dike complexes, subsurface fluid cycling, groundwater residence time, and influence of rock units/mineralogy on fluid characteristics. Increased data on Lāna‘’i’s water resources will help our understanding and allow for more-informed management.

29.) The proposed action is designed to provide further scientific insight into the hydrology of the Pālāwai Basin. It is outside the purview of the project to speculate exactly how this information will be utilized although the anticipation is that it will assist with more efficient planning and management of the resource into the future.

30.) The proposed project will use core drilling technology which in and of itself uses roughly 10% the amount of water and drilling fluid that is required of rotary drilling (every existing well on Lāna‘i was installed using rotary drilling). Drilling “material” is the same as drilling “fluid”, so please refer to question 14.

31.) We consulted with the Pūlama Lāna‘i Directors of Conservation, who confirm there are no record of rare threatened or endangered species in the immediate vicinity of the drilling sites. A memo was provided citing the findings of their recent studies on the federally-protected seabirds and bats that exist on Lanai. This memo has been added to the Final EA as Appendix E.

A decision on plugging the well holes has not yet been made, and will be made in concurrence with Department of Land and Natural Resources – Commission of Water Resource Management and the landowner.

All funding for this project is derived from the US Department of Energy.

We will not inject any fluids into subsurface rock under high pressure in the execution of this project and, hence, there will be no immediate or long-term risk of earthquakes resulting from proposed drilling.

The inadvertent topographical errors have been corrected, and a number of other small edits have been made to correct grammatical errors and to help clarify the concepts and/or the intent of the specific text modified.

Appendix B - Lāna‘i Daily Drilling Reports

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/13/2019	to 6:00 am	5/14/2019	Well No.:	Lanai #10
GENERAL						Report No.:	1
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	0
	UTM 4 Q 716597.00 m E, 2297546.00 m N					Current Depth (ft):	~1455
	Lat/Long: 20.765103°N -156.919493°W					Planned TD (ft):	NA
	Elevation (ft): 1,240					Hole Made Last 24hrs:	0
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547					Day Shift:	
	POST 602, 1680 East-West Rd, Honolulu HI 96822					Night Shift:	
Supervisor:	Ron Fierbach					Note: All depths ground level.	
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: Site preparation; organization of logistics for moving equipment to site; work with Lanai contacts to arrange support services.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments

PLANNED OPERATIONS

site prep and rig up

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Meet Doug Stephenson of Pulama Lanai at HNL airport (at 17:00) regarding moving equipment to site and arranging site preparation (staking, clearing, leveling) activities. We are woking with an existing bore that extends to an approximate depth of 1455'. Site preparation begins tomorrow.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/14/2019	to 6:00 am	5/15/2019	Well No.:	Lanai #10
GENERAL						Report No.:	2
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	0
	UTM 4 Q 716597.00 m E, 2297546.00 m N					Current Depth (ft):	~1455
	Lat/Long: 20.765103°N -156.919493°W					Planned TD (ft):	NA
	Elevation (ft): 1,240					Hole Made Last 24hrs:	0
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547					Day Shift:	
	POST 602, 1680 East-West Rd, Honolulu HI 96822					Night Shift:	
Supervisor:	Ron Fierbach				Note: All depths ground		
	ron.m.fierbach@gmail.com				level.		

OPERATIONS

Primary activities: Site preparation; organization of logistics for moving equipment to site; work with Lanai contacts to arrange support services. Met with Pulama Lanai Utilities (Joy and Duke) to discuss site and delivery of containers; arrangement of water for site. Spoke with Doug (who handles heavy equipment work - he arranged for site work). Met with PL Logistics re: delivery of containers currently on island - arranged for delivery to site. Flagged out 180'X180' site boundaries.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
						NA

PLANNED OPERATIONS

site prep and rig up

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Site has been cleared of brush and scraped clean. Sloping area around wellhead has been built up with soil and is relatively flat. Dozer and excavator are at site and working to grade site to flat and slightly sloping. Former use of site has windrows for pineapple...

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/15/2019	to 6:00 am	5/16/2019	Well No.:	Lanai #10
GENERAL						Report No.:	3
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	0
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: site prep and logistics for water.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
						NA

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Surface work was continuing – excavator scraping surface – fill material is being moved in for the well pad so that we will have a stable surface. Met with Malcolm Ross and James Jackson who were touring the drone site nearby and collecting some drone imagery of the drill site. Barge was not able to offload containers but did offload the drill rig. Arranged for moving the rig from the dock to the solar farm staging area for Thursday morning.

Met with Joy and Duke about water supply. We are not able to truck brackish water in their freshwater trucks – we will have to arrange to acquire brackish water by other means – their permits do not allow us to purchase potable water from them for drilling; we can purchase brackish water from them for that purpose. Talked with SunBelt leasing company: no trucks available for several weeks – the one that may become available is 2000 gals. Probably not feasible for us. Investigated whether there was any existing data on irrigation pipelines in the area that could be adapted to transport water from the reservoir to our site – no data available and Joy indicated that the condition of the old irrigation pipelines was so questionable that we shouldn't even attempt that. Had a look at some of the abandoned irrigation lines – open pipes exposed at the surface – horizontal runs are buried ~6' below surface and would be difficult to trace or service – abandon that idea. Will need to install a new line.

Pulled small genset and grinder with cutting wheels from shop container – took them to site and cut tack welds on the well head cover and removed it. Was able to see the bottom of the casing ~13' below the top of the casing; the diameter of the hole reduces down immediately below the casing from 27" diameter to approximately 18" – difficult to determine how far down there is a further reduction in diameter.
Went to site with Duke to look at prospective path for water line from reservoir – he will meet with his shop folks Thursday to discuss options for tapping into reservoir.
Met D Mulliken and B Alesna at airport and dropped them at their quarters.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/16/2019	to 6:00 am	5/17/2019	Well No.:	Lanai #10
GENERAL						Report No.:	4
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	0
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: site prep and logistics for water.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
						NA

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Met with Duke and Curtis at shop to discuss how to get water from the reservoir to well head. They will tap into the feed line for the reservoir – we will purchase 2" HDPE line to run water to site – pump the water using our gasoline trash pump. Went to shuttle yard to pull trash pumps – took them back to shop to show Curtis what our connections looked like – so that we could connect our pump to the line out. Met with truck driver at dock to pick up the Rig. Mobilized the rig from dock up to Solar Farm and parked there.

Went back out to well site where site work was continuing – more loads of crushed concrete delivered – having them level the pad around the wellhead and feather it out down to grade behind the dog house.

D, B, and myself measured out the distance, cross country, from the location of the water tanks at the site out to the tapping point at the reservoir. A good deal of brush and vegetation along the route so distance is approximate: 3100' – elected to purchase 3500' of line.

Duke offered to have the construction crew run the grader along a straight rout from the edge of the site to the road that encircles the reservoir to make it more feasible to run the water line. We will likely use the gradall to run that line.

Crew then worked to set up a layout of the site with specific containers being spotted as appropriate to their contents and function. This was to ensure that, when the crane was available on Friday we would be able to most efficiently get the containers spotted. Returned to Lanai City and met with Doug about the crane tomorrow – indicated that it was likely to be at the site at about 10:00 to 11:00.
Returned to site and spoke with AJ about the site and pad – he has indicated that he will have nine more loads of concrete debris brought to the site to better feather out the pad to the SE grade for placement of the containers.
The crew inspected the site and fill material – which is crushed scrap concrete – and pulled out rebar and reinforcing mesh wire that could puncture the tires of the rig or Gradall.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/17/2019	to 6:00 am	5/18/2019	Well No.:	Lanai #10
GENERAL						Report No.:	5
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	0
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: site prep and logistics for water.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
						NA

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Crane was delayed; brought 20s over and off loaded with fork lift; container with pier blocks didn't make it so have to wait on placing the 40s. Site grading and filling continued through the day. PL cleared brush along path for placement of the water line – it is possible that we are slightly downslope of the reservoir and will be able to get water by siphon. 40s were brought down on chassis and placed for setting when crane is available. Duke ordered HDPE water line in morning – should be here Wednesday next week.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/18/2019	to 6:00 am	5/19/2019	Well No.: Lanai #10

GENERAL			
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA	Report No.:	6
	5895 East 2nd St., Winnemucca, NV 89445	Well Type:	extending cable tool hole
Well Location:	Lanai Well 10	Spud Date:	1989
	UTM 4 Q 716195.61 m E, 2297652.42 m N	Days on Location:	0
	Lat/Long: 20°45'58.00"N 156°55'24.00"W	Current Depth (ft):	~1455
	Elevation (ft): 1,100	Planned TD (ft):	NA
		Hole Made Last 24hrs:	0
		Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547		
	POST 602, 1680 East-West Rd, Honolulu HI 96822		
Supervisor:	Ron Fierbach	Note: All depths ground level.	
	ron.m.fierbach@gmail.com		

OPERATIONS

Primary activities: site prep and logistics for water.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
						NA

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Began offloading essential items from the containers and began organizing supplies in appropriate locations. PL made one of their gradalls available to us which allowed us to move some of the heavier equipment (mixer, power pack, generator set) out of the containers and place them where they will be used on the site. Pulled the dog house out and got it placed at the wellhead. We were able to block up and level the 20' containers to protect the undersides from moisture and keep the containers from distorting. Moved the water tank steel and drilling supplies out of the office container and begin to set that up for long term use. Spent some more time picking steel out of the concrete fill.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/19/2019	to 6:00 am	5/20/2019	Well No.:	Lanai #10
GENERAL						Report No.:	7
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	0
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: site prep and logistics for water.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
						NA

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Assembled the steel water tanks and rigged up for placement. Decision was made to place the water tanks at the bottom of the site in an effort to allow water to flow to the tanks by siphon from the brackish water reservoir. Used the PQ drill pipe as spreader bars and ratchet straps as lifting straps for the tanks – 4 lift points on the steel rings allowed us to move them without distorting them.

Checked with Marilou Bello – the last 20' came in today as well as the gradall. Arranged for transport from the shuttle facility and the dock to our site for Monday.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/20/2019	to 6:00 am	5/21/2019	Well No.:	Lanai #10
GENERAL						Report No.:	8
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	0
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: site prep and logistics for water.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
						NA

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Met with the dozer operator and informed him of our intent to revise planned location of the water tanks; he immediately went to work levelling the field road at the base of our site to the required width for placement of the tanks. Met with AJ and informed him that we didn't need additional site work; he released the dozer and other heavy equipment operators from the site.

Checked with Marilou Bello on the prior day's barge delivery – the 20' from PTA and gradall were present but no sign of the 40' unit from Salt Lake. Contacted YB shipping coordinator and asked to do their best to get it onto the Tuesday barge to Lanai. If that fails, then will have to request that it be dropped on Friday...

Went down to the dock to retrieve the gradall; brought to the site on a trailer. The 20' container with concrete pierblocks was delivered to the site and placed.

Moved the water tanks down to the field road and placed them onto the cleared area. Prepped the base of the tanks (soil infill at tank edges and covered with carpet) and installed the liners. Began moving supplies into the shop from the PTA 20'. Moved the pierblocks out and prepped for placement of the 40's.

Ron Fierbach arrived – flight delayed, didn't get in until 22:30.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/21/2019	to 6:00 am	5/22/2019	Well No.:	Lanai #10
GENERAL						Report No.:	9
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	0
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: site prep and logistics for water.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
						NA

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Reviewed placement of the equipment and containers with Ron. All good... discussed how to set up casing support equipment around the well head; plumbed the bore down into the rock below the casing and confirmed diameter of ~14".
Crane was available for placement of the 40s. Operator and helpers showed up at the site and we worked with them to pick up and place the 40' containers that were on site. Doug indicated that the crane would be available tomorrow to pick and place the last 40' – we need that container to set up the casing hangers. Began unloading the components of the dog house and assembled that over the hole. Moved the rig from the solar facility over to the pad and lined it up over the hole.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/22/2019	to 6:00 am	5/23/2019	Well No.:	Lanai #10
GENERAL						Report No.:	10
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	0
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: site prep and logistics for water.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
						NA

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Spent most of the day working on servicing the rig – assembled the racking board on the mast; fabricated some new guards for the floor of the doghouse, replaced some gauges on the control consol. Brought all the vehicles from the port so we have our full complement of vehicles for the crew and support staff.

Had an update call with DOE to bring them up to date on progress to the present time.

Working with suppliers for a new set of seals for the hydraulic motor driving the mud mixer pump – in progress, awaiting confirmation of the Geartec part number.

Container was not yet available; spoke with Duke who had left instructions that poly pipe be delivered to the site as soon as it was recovered from Young Brothers. His crew will string the 3000' of pipe from the reservoir over to site. Spoke with Marilou Bello and was told that container could be delivered to site tomorrow. Crane operators may be available tomorrow as well.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/23/2019	to 6:00 am	5/24/2019	Well No.:	Lanai #10
GENERAL						Report No.:	11
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	0
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: site prep; logistics for water; prepararing equipment for setting up the site.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
						NA

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Spend a good part of the day installing the water line from the reservoir down to the site – supplier provided an incomplete order – 2700' of 2" rather than 3400 and we came up short – secured another 40' to complete the line from PL. Got water pumping at the source to our tanks. We're getting about 30 – 40 gpm with the one pump. Got partial tank by end of shift.

Container finally showed up in the afternoon – no crane operator available until after the weekend. Started offloading essential items for setting up the wellhead – I-beam, casing hangers, few other items.

Got the wellhead casing cut down to appropriate size. Cut lengths of I-beam for supporting the casing hangers.

Donnie M. left for Hilo – will be short-handed for Friday.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/24/2019	to 6:00 am	5/25/2019	Well No.:	Lanai #10
GENERAL						Report No.:	12
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	1
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: Set up well head and rig-up over the hole. Preparing equipment to go into hole. Setting up for core processing and core management.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
						NA

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Completed fabrication of the well head casing support arrangement. Fabricated an extension to the doghouse floor for improved safety of the hands working with the pipe.

Pulled the used PQ casing from container – will start prepping that for going into the hole. Began offloading the blocking, mainland supplies, and casing from the SLC container using gradall – time consuming because everything has to be pulled from the back end of the 40. Spent some time sorting and stowing supplies.

Eric Haskins and two core helpers showed up early afternoon. Took them to housing and then site – they took supplies loaded in van down to core processing site and began setting up there.

Contacted Lua supplier – no call back... Contacted someone to do site blessing next week – no call back... contacted oil supplier – no call back...

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/25/2019	to 6:00 am	5/26/2019	Well No.:	Lanai #10
GENERAL						Report No.:	13
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	2
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: preparing equipment to go into hole. Engine showing signs of malfunction; lining up service tech to evaluate engine for possible repairs. Setting up for core processing.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
						NA

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Finished offloading the 40' container. Started cleaning up tricone bit and collar. Picked up bit. Drill rig engine started blowing steam from valve cover casing. Diagnosis is that we may have a blown gasket; alternative is that we may have a cracked or damaged cylinder liner. If the former, then need head gasket replaced; if cylinder liner is damaged, then may need an engine overhaul. Contacted Donald Mulliken who will come over here tomorrow and bring a head gasket and begin top side tear down. Also ordered full top side gasket set in the event a rebuild is necessary. Called Julian Collins and Randy Curl to apprise them of the engine problems.

Pulled table for coring crew from container. Took it down to their site along with a couple of pallets of core boxes.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/26/2019	to 6:00 am	5/27/2019	Well No.:	Lanai #10
GENERAL						Report No.:	14
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	0
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	3
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: evaluating rig engine to determine source of moisture in engine. Reassemble engine after servicing.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
						NA

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Worked on breaking down rig engine in preparation for Mr. Mulliken arrival and diagnosis. He arrived at 11:30 in the morning and went to work on the engine. Pressure tested the coolant system; ran compression tests on all the cylinders; checked the valve cover vent valve; worked on the engine for several hours – everything checked out – checked valve cam clearances and adjusted to spec. Refilled the oil and started engine up. Diagnosis was that the valve cover vent valve filter was obstructing moisture discharge from the oil – needed to build pressure to get past the valve and be expelled – nothing wrong with the head gasket or cylinder liners. Engine ran well – no excessive moisture discharged and no evidence of moisture in the oil. He will send us a replacement breather valve/filter.

Discussed a spare replacement motor – likely to run ~$30K – less than the cost of a week of downtime with crew standing by.

Dan worked on logging unit to make it more transportable – put in a new cross bar and will build a hitch for it.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/27/2019	to 6:00 am	5/28/2019	Well No.:	Lanai #10
GENERAL						Report No.:	15
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	4
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: preparing BHA and rod string to go into hole for rotary drilling at bottom to clear any debris and infill in preparation for cementing casing in place. Contract drillers arrived at site.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	9:00	make up BHA				NA
9:00	11:00	welding safety straps				
11:00	18:30	lower pipe to bottom				

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Starting into hole – needed to weld up some support equipment for the collar and bit so that we can get into the hole, secure those, then install foot clamp and run in crossover sub and PQ drill rod.
Service tech returned home.
Measured Sandvik drill rod – each stick is 3.0 meters – 9.8424' – long; helped Ron get the rod count and length worked out.
Welding straps on the collar to ensure that it doesn't come loose... Dog collar wrench disappeared – ordered new ones.
The KMA PQ pipe is English – 10' and we now have a mixed string.
Made up pipe and began lowering pipe into hole.
IDEA drillers (2) and hands (2) arrive at Lanai. Got them set up in their lodging and showed them where store and restaurants were located in town.

UNIVERSITY OF HAWAII AT MANOA							Daily Drilling Report
Hawaii Play Fairway	Report for:	6:00 am	5/28/2019	to 6:00 am	5/29/2019	Well No.:	Lanai #10
GENERAL						Report No.:	16
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	5
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: Running into hole; drilling on bottom; pulling out of hole; training on endangered birds; forklift training for hands; site blessing.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	9:00	lower drill to bottom				NA
9:00	10:30	drill on bottom				
10:30	12:00	endangered bird trainin				
12:00	13:00	drill on bottom				not making progress; not enough weight
13:00	14:00	trip pipe				
14:00	18:00	forklift training				
18:00	18:30	site blessing				

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
						below grade where it terminates at the top of a smaller
						diameter hole

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Continue lowering to bottom; hit obstruction above bottom, pushed down to 1448’ depth; drilled on bottom for several hours without any progress. Rocks in this borehole may well be dike rock and too hard for a tricone and single collar to penetrate. Abandon the drilling effort trip pipe out of hole.

Break for training on endangered birds: Hawaiian Petrel and Hawaiian Shearwater. All hands received training and guidance on critical times of transit over our area; how to respond; recommended that we use shielded lights for the rig – to the extent possible pointing down. After September is the most critical time for fledglings transiting the island to the ocean.

Return to site, continue pulling PQ string – all came out of the hole successfully. No evidence on the bit of what the obstruction was – buttons are intact – likely not enough weight.

Begin setting up to run casing – plan is to cement to the borehole walls.

Contacted Paradise Lua – regarding delivery of a porta john to the site; informed that driver would deliver the following morning. Break for forklift training for RCUH employees – required several hours since they will have to have training for both Class 5 and Class 7 machinery. During that interval, crane operators came by to pick and place last (now empty) 40’ container and move the crane to cement batching plant. Reverend Sol Kahilikolo arrived at the site to conduct a site blessing. Proceeded to follow his standard practice of visiting the corners of the site and then calling everyone together for blessing and guidance on working safely and collaboratively. All hands attended: Ron Fierbach,
During forklift training, IDEA staff discussed approaches for running casing and cementing the casing in place the following day.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/30/2019	to 6:00 am	5/31/2019	Well No.:	Lanai #10
GENERAL						Report No.:	17
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	0
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	7
						Current Hole Size (in):	14
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: securing the base of the temporary casing prior to starting to core.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	7:30	checking for grout				no grout/casing is free
7:30	11:00	check pipe for cementing plug				
11:00	14:00	build spear/recover plug				
14:00	16:30	weld coupling on casing				
16:30	18:00	lower PQ rod				
18:00	19:00	drill through boulder				obstruction held up casing and kept off
		run to bottom				bottom; hole is now clear

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary casing/liner for drilling through

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

What was thought to be an error in counting the rods turned out to be an obstruction near the bottom of the hole, preventing the casing from going to bottom. Cement was injected and just dropped to the bottom of the hole. We will run cement up around the bottom of the casing and drill to bottom with PQ tricone.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	5/31/2019	to 6:00 am	6/1/2019	Well No.:	Lanai #10
GENERAL						Report No.:	18
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	8
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	~1455
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	17
						Current Hole Size (in):	5"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: clear bottom of hole; trip PQ pipe; cement bottom of PWT casing

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	12:00	drill with PQ tricone		1465		
12:00	14:00	realign/level drill rig				
14:00	16:00	trip PQ out and back in				trip in with open end
16:00	17:00	mix and place cement				
17:00	19:00	trip PQ out				

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary casing/liner for drilling through

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	6/1/2019	to 6:00 am	6/2/2019	Well No.:	Lanai #10
GENERAL						Report No.:	19
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	9
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	1517
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	
						Current Hole Size (in):	5"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: clean out bottom of hole and open hole to TD with tricone in preparation to begin coring; begin coring; equipment problems: wireline cable parted; transmission on the rotating head failed. Begin disassembly in preparation for repair.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	8:30	run in with PQ Tricone	1465			
8:30	12:00	drill with PQ Tricone	1465	1480		
12:00	13:30	wash hole; trip pipe	1480	1480		
13:30	17:30	run in PQ casing liner	1480	1480		
17:30	18:30	mix mud; run in HQ	1480	1480		
18:30	19:00	coring	1480	1484.8	4.8	
19:00	23:50	coring	1484.8	1507	22.2	wireline cable parted; repaired
23:50	2:30	coring	1507	1517	10	
2:30	7:00	standby for repair	1517			transmission on head failed

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary liner

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	6/2/2019	to 6:00 am	6/3/2019	Well No.:	Lanai #10
GENERAL						Report No.:	20
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	10
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	1517
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	
						Current Hole Size (in):	5"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: disassembly of chuck and drive for removal of the transmission which failed during the prior shift. Assessment shows that the failure was in the transmission - head seems to rotate normally after removal of transmission. No replacement unit on hand - likely will need shop rebuild. Limited access to vendors on a Sunday; no replacement transmissions are available from vendors contacted.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	standby for repairs				

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary casing/liner for drilling through
Surface	1465	4.5"	10.6			

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	6/3/2019	to 6:00 am	6/4/2019	Well No.:	Lanai #10
GENERAL						Report No.:	21
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	11
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	1517
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	
						Current Hole Size (in):	5"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: standby while replacement transmission is located. By the end of the day a prospective replacement transmission was located; will arrange for shipping from SLC to HNL tomorrow.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	standby for repairs				cleaning and servicing rig

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary casing/liner for drilling through
Surface	1465	4.5"	10.6			

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Spent the day contacting service companies for Funk transmissions (a common piece of equipement - company and licenses owned now by John Deere). Investigation revealed that these transmissions are not standard items: Boart Longyear modifies them for the LF230 - so limited supply. We were able to contact a network of drillers and service companies, one of which located a transmission that is thought to be compatible with our LF230 build.

Shipping to Lanai will require that we use Kamaka Air - the only air transport company that I can identify that will fly heavy items to Lanai.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	6/4/2019	to 6:00 am	6/5/2019	Well No.:	Lanai #10
GENERAL						Report No.:	22
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	12
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	1517
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	
						Current Hole Size (in):	5"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: standby while replacement transmission procured and shipped; crew working to service the rig and break out excess drill string into 20' units. Replacement transmission was shipped from SLC to Honolulu.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	standby for repairs				cleaning and servicing rig
						breaking out 30' rods to 20' for shipping

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Quality Diamond Products shipped replacement transmission from Salt Lake City; plane was delayed; arrived at 16:30 hrs; picked up from Delta Air Cargo at 18:30 (too late to transfer to interisland air cargo carrier).

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	5:00 am	6/5/2019	to 5:00 am	6/6/2019	Well No.:	Lanai #10
GENERAL						Report No.:	23
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	13
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	1517
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	
						Current Hole Size (in):	5"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547						
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Primary activities: replacement transmission received and installed;

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	8:45	standby for repairs				
8:45	12:00	install replacement				
12:00	14:00	repair lube pump				
14:00	17:00	CORING	1517	1547	30.6	finally
17:00	5:00	Coring	1547	1617	67.7	

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

New transmission provided to Kamaka Air Cargo at 05:30 for shipment; arrived t Lanai airport 08:30. Installed on the rig: everything was found to be compatible with original equipment. It was found that an oil pump had failed that may have been the ultimate cause of the transmission failure. Oil pump was replaced. Coring resumed with good progress for a short day - 100' from ~2:00 PM to 05:00 AM. Recovery is good: 98.3%

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	6/6/2019	to 6:00 am	6/7/2019	Well No.:	Lanai #10
GENERAL						Report No.:	24
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	14
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	1517
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	
						Current Hole Size (in):	5"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547					Max DH Temp (drilling)	115°F/46°C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

coring ahead at a very good rate. Core is well consolidated and we are getting good recoveries. We have full returns, reducing demand on gel and polymer. There is a fair bit of solids in the return mud which we are not set up to remove; we change out the mud after three or so core runs.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	coring	1617	1686	69	100% recovery
19:00	7:00	coring	1686	1757	71	100% recovery

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
1617	1757	basalt: fairly dense, fractured; some secondary depo	minor; infilling of vesicles and fractures
		some clay (likely from ash deposits) weathered	not yet identified

SUPPORT ACTIVITIES/RELEVANT EVENTS

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	6:00 am	6/7/2019	to 6:00 am	6/8/2019	Well No.:	Lanai #10
GENERAL						Report No.:	25
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	15
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	1877
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	
						Current Hole Size (in):	5"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		121.5°F/49.7°C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

coring ahead at a very good rate. Core is well consolidated and we are getting good recoveries. We have full returns, reducing demand on gel and polymer. There is a fair bit of solids in the return mud which we are not set up to remove; we change out the mud after three or so core runs.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	coring	1757	1817	60	100% recovery
19:00	7:00	coring	1817	1877	60	100% recovery

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
1617	1757	basalt: fairly dense, fractured; night shift less so;	minor; decreasing mineralization
		some pahoehoe	in the deeper cores of last night

SUPPORT ACTIVITIES/RELEVANT EVENTS

temperature tool is going down next run - reported temp above is from yesterday's run; will update Temperature on recovery of next core run.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/9/2019	to 7:00 am	6/10/2019	Well No.:	Lanai #10
GENERAL						Report No.:	27
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well	Lanai Well 10					Days on Location:	17
Location:	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2117
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		124.6°F/51.4°C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground		
	ron.m.fierbach@gmail.com				level.		

OPERATIONS

coring ahead with no major issues. Several short runs beginning in the later part of the day shift continuing into the night.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	coring	1997	2057	60.5	0.5' of cave recovered
19:00	7:00	coring	2057	2117	60.7	0.7' cave recovered

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
1997	2117	basalt: mostly breccia; some variable size clasts of pahoehoe	minor but variable mineralization
		and a'a; possibly some dike material; later part of the day core	some zones showing extensive
		became highly broken up possibly related to dike	infilling of vessicles

SUPPORT ACTIVITIES/RELEVANT EVENTS

temperature tool is going down next run - reported temp above is from yesterday's run; will update Temperature on recovery of next core run.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/10/2019	to 7:00 am	6/11/2019	Well No.:	Lanai #10
GENERAL						Report No.:	28
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	18
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2217
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		133.3°F/56.3°C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

We are beginning to see zones of pervasive altertion where the primary minerals are mostly replaced by clays and zeolites(?). These zones are less stable and are prone to caving: about three hours of the day were spent pulling rods and re-drilling to clean up the hole and clear it of cave material falling in behind the rods to prevent sticking the rods. We are still getting fluid returns to the surface (very uncommon here) and so much lower gel and polymer use than anticipated

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	coring	2117	2167	50	2" cave; formation sticky
19:00	7:00	coring	2167	2217	50	sections broken and sticky

PLANNED OPERATIONS

Because we continue to get mud returns, we are going to rent a backhoe/loader to construct a small mud sump so that we can more effectively separate the cuttings from the return mud

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2117	2217	basalt: mostly breccia; some solid competent intervals	fairly pervasive moderal mineralization
		some sections heavily altered to zeolites (?) and clays soft	some zones showing extensive
		some secions broken and unstable - caving/sticking the rods	breakdown of primary minerals

SUPPORT ACTIVITIES/RELEVANT EVENTS

Temperature survey for 6/11 drill day is a bit lower: 129.5 F/54.2 C

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/11/2019	to 7:00 am	6/12/2019	Well No.:	Lanai #10
GENERAL						Report No.:	29
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	19
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2257
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	40
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		129.5°F/54.2°C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

coring ahead with no major issues. Several short runs beginning in the later part of the day shift continuing into the night.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	coring	2217	2250	33	quite broken and unstable in sections
19:00	7:00	coring	2250	2257	7	stuck tube; trip pipe; chng bit;clean hole

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2217	2257	basalt: mostly breccia; some solid competent intervals	fairly pervasive moderate mineralization
		some sections heavily altered to zeolites (?) and clays soft	some zones showing extensive
		some secions broken and unstable - caving/sticking the rods	breakdown of primary minerals

SUPPORT ACTIVITIES/RELEVANT EVENTS

about three hours of the day shift pulling rods and re-drilling to clean up the hole and clear it of cave material falling in behind the rods. Night shift had stuck tube; tripped out the pipe to recover tube; changed bit; washed back into the hole and worked the holel to clear it of debris from unstable formations. We still are getting most of the mud back - need to construct a sump to properly clean the mud of cuttings prior to recycling down the hole. Temperature tool down; will report on later today.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/12/2019	to 7:00 am	6/13/2019	Well No.:	Lanai #10
GENERAL						Report No.:	30
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	20
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2327.6
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	70.6
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		119.2°F/48.4°C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

coring during the day recovered fair rock with intervals of fractured, broken, altered rock. Changing fluids out more frequently, using more gel to try to control infall into the hole; spend a lot of time pulling back and swabing the hole to stabilize the walls and control torque. Having some problems with leaking seals on mud mixer system - ordered new seals two+ weeks ago: FedEx can't find Lanai City...

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	coring	2257	2301.5	44.5	broken rock; caved in pulled & reamed
19:00	7:00	coring	2301.5	2327.6	26.1	"sandy"; tight; swab hole

PLANNED OPERATIONS

build a sump to better process the mud and separate solids from mud before recycling. Limited by availabililty of equipment

no rental backhoe available; Pulama Lanai will provide us with one when equipment and operator are available

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2257	2327.6	mostly broken/compacted/cemented rock with zones of	fairly pervasive moderate mineralization
		very heavily altered and replaced rock; a few thin lenses of	some zones showing extensive break-
		fine-grained clay - possibly an altered soil or ash layer	down/replacement of primary minerals

SUPPORT ACTIVITIES/RELEVANT EVENTS

previous night was spent swabing the hole and replacing all the circulating mud to reduce solilds suspended in the mud - temperature for 6/12 shows the effect - an apparent 10 degree drop in bottom hole temperature. We may see a similar effect for the 6/13 measurement with the swabbing being done over night.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/13/2019	to 7:00 am	6/14/2019	Well No.:	Lanai #10
GENERAL						Report No.:	31
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	21
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2327.6
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		129.4°F/54.1°C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

serious hole stability problem - believed to be running sand. Tripped out several stands, tried to go in to clean the hole, no success. Attempt to wash in and get to bottom with core bit but, as we approach bottom, hole gets tight and have to pull back. Finally decided to pull string, go in with rotary bit and try to clean and, if successful, go to coring; if not, back out while back filling the lower hole with cement. No new footage recovered.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	washing and drilling	2327.6	2327.6	0	broken rock; caved in pulled & reamed
19:00	7:00	washing and drilling	2327.6	2327.6	0	"sandy"; tight; swab hole

PLANNED OPERATIONS

build a sump to better process the mud and separate solids from mud before recycling. Limited by availabililty of equipment

no rental backhoe available; Pulama Lanai will provide us with one when equipment and operator are available

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2327.6	2327.6	sand and broken fragments	

SUPPORT ACTIVITIES/RELEVANT EVENTS

temperature measured on the first "core" run of the day - no core recovered still drilling in sand somewhat above bottom hole when the tool was pulled. But temperature recovered significantly from yesterday's low.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/14/2019	to 7:00 am	6/15/2019	Well No.:	Lanai #10
GENERAL						Report No.:	32
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	22
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2327.6
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547					Max DH Temp (drilling)	129.4°F/54.1°C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Night shift from yesterday still struggling to get to bottom - pull back the bit and any footage gained is immediately filled with sand. Day shift mixed and placed ~200 gallons of cement through the tricone bit. Cement was displaced with water to just above the bit and then pulled back to allow cement to be placed in bottom of the hole. Placement went well - rods came out fairly freely, and no evidence of cement left in the rods. Clean cementing equipment and clean site. WOC until 22:00; rotary to btm.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	cementing and WOC	2327.6	2327.6	0	pumped 250 gal cement; displaced to bit
19:00	22:00	WOC	2327.6	2327.6	0	pulled bit above cement & WOC
22:00	5:00	washing and drilling	2327.6	2327.6	0	
5:00	7:00	tripping out of hole	2327.6	2327.6	0	still some hanging in the bad zone

PLANNED OPERATIONS

build a sump to better process the mud and separate solids from mud before recycling. Limited by availabililty of equipment

no rental backhoe available; Pulama Lanai will provide us with one when equipment and operator are available

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2327.6	2327.6	sand	

SUPPORT ACTIVITIES/RELEVANT EVENTS

No temperature measurement for the day - working on hole.

Night crew drilled through stringers of cement starting at ~300' above btm. Drilled through and tagged several obstructions but producing sand all the way to bottom. Pulled up to test stability, lost footage (sand fill). Tripped out by 07:00; bit showed some hangning coming out - suggesting that the bad zone is still putting material into the hole.

Some debate among drillers and supervisors as to whether this is a "flowing sand" or we have a highly altered unstable formation that is dumping material in behind the drill string that is being milled up by the drill pipe and dropping down the hole. We have not recovered any sand zones above - but have recovered several sections of highly fractured rock that was also quite friable. We have examined samples of sand that were brought to the surface by the mud and the sand shows a broad range of sizes - prior coring through beach deposits showed a more uniform size to the sand.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/15/2019	to 7:00 am	6/16/2019	Well No.:	Lanai #10
GENERAL						Report No.:	33
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	23
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2347
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	10
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547					Max DH Temp (drilling)	129.4°F/54.1°C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Report from the night shift indicated that the cementing may not have taken. Indicated that there was sand drilling down, along with isolated cement stringers starting at 300' above bottom. Day shift discussed next steps and arrived at three options: do several more spot cementing; bring in more PQ and ream HQ open and insert PQ liner across bad zone; abandon this hole and move to Lanai 9. Had difficulty finding needed cement on Saturday (everything shut down) but Nicole made some calls to PL and

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	10:00	reviewing options	2327.6	2327.6	0	Night shift reports indicated cement job
10:00	14:00	chase cement supply	2327.6	2327.6	0	did not take
15:00	19:00	Prep. to Cem; trip TC in	2327.6	2327.6	0	no obstr.; min. drag; min sand @ btm.
19:00	0:00	Tri-cone; swab hole; trip	2327.6	2347	0	
0:00	7:00	Trip TC out; Trip CB in	2327.6	2347	0	

PLANNED OPERATIONS

build a sump to better process the mud and separate solids from mud before recycling.

Pulama Lanai will provide us with one when equipment and operator are available

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2327.6	2347	solid rock	unknown

SUPPORT ACTIVITIES/RELEVANT EVENTS

3 super sacks (2500 lbs each) cement were delivered by afternoon. Tripped rotary bit in in preparation for setting another 300' of cement - expected to find bottom of hole sanded in over the bottom 30+ feet as it had been doing previously - encoutered only about 3 ft of sand indicating that the cement may have stabilized the zone generating the sand. Discussed with drillers and elected to have night shift rotary drill ahead for one or two 10' sticks to determine whether we were still in the sand zone or if the hole would remain stable. Night crew drilled ahead and pulled back and re-swabbed the hole while checking returns for sand. Satisfied themselves that the sand was cured and tripped out the rotary bit and tripped back in with the core barrel. Day shift (16th) recovered a few inches of sand with good solid core below. No temperature taken during today's activities - feared that the hole was too unstable to run a sinker bar and temperature logger in the open hole. The temperature tool is in the hole at the present hour - will report when that is available.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/16/2019	to 7:00 am	6/17/2019	Well No.:	Lanai #10
GENERAL						Report No.:	34
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well	Lanai Well 10					Days on Location:	24
Location:	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	0
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	115.7
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		135.5/57.5
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground		
	ron.m.fierbach@gmail.com				level.		

OPERATIONS

The day's drilling went extremely well - minimal sand was encountered during the first coring run, with none after that. Torque was down. Minor rig repairs were made during the day shift that reduced the penetration for that shift but the night shift was as good as we had seen before the sand probles. Temperature measured at the beginning of the day saw a recovery to above previous highs, further suggesting that circulation was affecting the readings.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	10:00	washing, coring	2354	2406.5	45.2	2' sand rec. first run; more lost
10:00	14:00	coring	2406.5	2477	70.5	no sand, torque low
15:00	19:00				0	
19:00	0:00				0	
0:00	7:00				0	

PLANNED OPERATIONS

build a sump to better process the mud and separate solids from mud before recycling.
Pulama Lanai will provide us with one when equipment and operator are available

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2354	2406.5	mostly solid rock; some fractured zones; lithified soil contacts	vessicle and fracture filling is pervasive
2406.5	2477	solid rock; fewer fractures; variable vesicularity	vessicle and fracture fill is pervasive a few
			open voids

SUPPORT ACTIVITIES/RELEVANT EVENTS

The sand problem seems to have been rectified. Torque has been good, no more evidence of rod sticking. Took some time in the morning to repair the rod curtain (system for shielding the driller and hands from rotating rod on the rig floor. But rest of the day went smoothly - pretty good ROP for the day shift and very good ROP for the night shift. Yesterday's temperatures were back to a level higher than before we encountered the sand problems. Tool is now down; temperature will be reported later today.
One addendum to yesterday's report: during some accelerated circulation to clear the hole on the night shift of the 15th, we observed discharge of clear (fresh) water for a short period of time (several minutes). The only clear water we have circulated into the hole was displacement water during the cementing operation - that should have long since beeen circulated out. The alternative is that we have drilled through a zone that is producing water at a head sufficient to counteract the 1200' of head present in our casing and liner (the local water table is ~1200' bgs although it is highly variable in the basin here).

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/17/2019	to 7:00 am	6/18/2019	Well No.:	Lanai #10
GENERAL						Report No.:	35
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	25
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2567
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	90
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		140.5/60.3
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Today's drilling went fairly well - we had a few non-drilling episodes to repair the drillers console: corrosion is a perpetual problem in Hawaii and switch contacts had gone bad; we also lost drilling time to the construction of the sump to allow us to separate solids from the mud. It appears to be working well. Night shift cored through the night will some time spent swabbing the hole to reduce torque and expel solids.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	11:30	coring	2477	2494	17	Coring well
11:30	14:00	repairs to console	2494	2494	0	switches on control console repaired
14:30	16:00	coring	2494	2514	20	coring well
16:00	18:30	digging sump	2514	2514	0	sump constructed adjacent to rig for mud
18:30	7:00	coring	2514	2567	53	mostly good; some friable zones spallling

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2477	2514	dominanty solid, dense rock - a few fractures	vessicle and fracture filling is pervasive
2514	2567	mostly solid; some dike rock; a few zones of punky, intensively	ditto above; some zones are completely
		altered friable rock	broken down with weak secondary mass

SUPPORT ACTIVITIES/RELEVANT EVENTS

Coring is going much better in part due to a change in the rock type as well as awareness by the drillers that, when the torque increases, they need to adjust their pumping rate and the drilling fluid mix to clear the hole of debris. It is likely that the zones where we see pervasive breakdown and replacement of the rock are the ones generating the "sand": material is spalling off the walls and being milled up in the annulus and the heavier fractions are not being effectively flushed from the hole. The drilling fluid is being affected by either the pH of the mix water, the downhole temperature, or both. We are using polymer mostly - the mud was separating almost immediatey when mixed. The polymer goes into the hole highly viscous, but comes out much "thinner" - we have soda ash coming in tomorrow (none on the island) and will add that to the drilling fluid to see if we can improve the performance of the polymer and bentonite gel. We have more gel being shipped from the Mainland but will not have that here until next week or later. Temperature at beginning of the day was significant increase from prior day.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/18/2019	to 7:00 am	6/19/2019	Well No.:	Lanai #10
GENERAL						Report No.:	36
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well	Lanai Well 10					Days on Location:	26
Location:	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2677
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	110
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		140.1/60.1
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground		
	ron.m.fierbach@gmail.com				level.		

OPERATIONS

Coring ahead with only minor issues with torque. Late during the day shift penetration and water pressure increased; inspection of the core shows a different softer rock type that appears to cut poorly and generate a mud layer at the bit face, reducing the cutting ability of the stones. Drilled out of that zone into good rock at end of day shift and night shift went well. Day-to-day equipment issues require continuous import of parts and supplies to keep everything functioning.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	coring	2567	2616.8	49.8	Coring well; slow zone late in day
19:00	7:00	coring	2616.8	2677	60.2	coring went smoothly

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2567	0	some solid rock; some softer material that drills poorly	as yesterday; ~10' zone of possible seds.
2514	2567	all solid sticks of rock; some color variations suggesting rock	compacted rock cemented with secondary
		has been deformed/fragmented and recemented together	mineral deposition(?)

SUPPORT ACTIVITIES/RELEVANT EVENTS

Progressing relatively well. The sump is functioning as intended; still seeing breakdown of polymer during the round trip down the drill string. We are awaiting delivery of soda ash (today or tomorrow) to see if amending the pH of the fluids will help us maintain the consistency of the drilling fluid. We are now drilling with polymer only - no bentonite since it seems to break down almost instantly after mixing - will test whether pH adjustment will help control that.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/19/2019	to 7:00 am	6/20/2019	Well No.:	Lanai #10
GENERAL						Report No.:	37
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	27
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2767
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	90
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		140.1˚F/60.1˚C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths		
	ron.m.fierbach@gmail.com				ground level.		

OPERATIONS

Coring ahead with only minor issues with torque. Some zones were altered and we are seeing an increase in a greenish secondary mineral encountered at similar temperatures in PTA borehole: it is a zeolite that has a very soapy/waxy texture that reduces penetration due to build-up of scum at the bit face. It this further reduces penetration, we have a special bit fabricated with larger stones that can restore ROP.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	coring	2677	2727	50	Coring well; some broken and altered
19:00	7:00	coring	2727	2767	40	more broken and altered than day

PLANNED OPERATIONS

Modify water supply connections at reservoir - pump is failing and is likely due to vibration stresses on pump.

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2677	0	some solid rock; some softer material that drills poorly	some pervasively altered zones; new
2514	2567	increasing fraction of softer altered intervals	mineral suite appearing that affects the
			rate of penetration

SUPPORT ACTIVITIES/RELEVANT EVENTS

Rate of penetration is slowing somewhat with a change in secondary mineralization. We are seeing same parent rock, but the minerals infilling the vessicles and fractures is changing to a zeolite that we saw at PTA. It is quite soft - can be dug out with fingernails - but has a soapy or talc feel to it. It requires higer weight on bit, resulting in higher torque, in order for the stones in the bit to contact and cut the underlying rock.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/20/2019	to 7:00 am	6/21/2019	Well No.:	Lanai #10
GENERAL						Report No.:	38
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	28
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2852
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	85
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		142.5/61.4
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths		
	ron.m.fierbach@gmail.com				ground level.		

OPERATIONS

Day shift: coring ahead with only minor issues with torque. Serviced rig - oil and filter change, pulled bad section of wireline; flush oil in head with new oil. Variable alteration of rocks; still see variable green infill but not bad progress. Night shift: encountered intensively altered zone; hole got tight spent time swabbing and washing; replaced some fittings on water lines; repaired bean pump. Some good core but very bad zone in the last run of the night shift - broken, sandy, soft - hole got tight and

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	coring	2767	2816.9	49.9	Coring well; some broken and altered
19:00	7:00	coring	2816.9	2852	35.1	much more broken and altered than day

PLANNED OPERATIONS

Modify water supply connections at reservoir - pump is failing and is likely due to vibration stresses on pump.

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2767	2816.9	some solid rock; some softer material that drills poorly	a few small strongly altered zones in day
2514	2567	increasing fraction of softer altered intervals	shift; much more intensively altered in the
			night shift - slower penetration

SUPPORT ACTIVITIES/RELEVANT EVENTS

Temperature only slightly warmer than prior day. May well be due to increasing circulation we are doing to clear cuttings from the hole and more time the fluid spends on the surface (in our sump) to loose heat it picked up downhole. Previously we had a pretty short cycle time for the fluids in small tubs.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/21/2019	to 7:00 am	6/22/2019	Well No.:	Lanai #10
GENERAL						Report No.:	39
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	29
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2852
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547					Max DH Temp (drilling)	no temperature taken
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths ground level.		
	ron.m.fierbach@gmail.com						

OPERATIONS

Day shift spent the day attempting to clear the hole of in-fill - was not able to get to bottom; tripped out core barrel and ran in with tricone bit. Night crew spent the night trying to drill to bottom with no success - tricone bit got plugged with debris and had to be pulled. POOH by 07:15.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	14:00	cleaning swabbing	2852	2822	0	can't get to bottom
14:00	19:00	tripping out and in	2822	2822	0	swapping core bit for tricone
19:00	3:00	drilling and swabbing	2822	2822	0	cannot clear cuttings from the hole
3:00	7:00	POOH	2822	2822	0	several feet of fill behind bit all fragments

PLANNED OPERATIONS

Modify water supply connections at reservoir - pump is failing and is likely due to vibration stresses on pump.

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2852		material in drill pipe behind tricone was fragmental heavily	
		altered formation - similar to the pervasively altered intervals	
		of core from 6/20 night shift	

SUPPORT ACTIVITIES/RELEVANT EVENTS

We believe that the downhole situation is as follows: the broken and friable zone through the last several runs of 6/20 night shift are progressively caving in around the drill string and backfilling the hole with rubble. The friable formations in the recovered core are extremely weak and can be fragmented by hand. Our attempts at clearing the hole have formed a cavity in those zones that reduces our drilling fluid velocity up the annulus and, hence, we cannot clear the cuttings from the hole nor drill up the cave material. Our best alternative option is to perform another cement job to back fill those cavities and stabilize the infill material so that we can drill it up and remove it from the hole. We will drill as deeply into the rubble as we safely can and back out laying a cement slurry into the rubble and backfilling the cavity. After setting, we will drill through the cement patch and see if we can get to bottom and maintain a stable hole; if not, we expect to do another cement patch below the first.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/24/2019	to 7:00 am	6/25/2019	Well No.:	Lanai #10
GENERAL						Report No.:	42
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	32
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2852
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547					Max DH Temp (drilling)	no temperature taken
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths		
	ron.m.fierbach@gmail.com				ground level.		

OPERATIONS

Drilled to bottom during day shift; mixed and placed 300 gal. neat cement at bottom through tricone bit; night shift clean up site and WOC.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	16:00	drilling into hole	2852	2852	0	reached bottom; cleared cuttings
16:00	19:00	mix and place cement	2852	2852	0	300 gals cement mixed and displaced
19:00	7:00	clean up site; WOC	2852	2852	0	

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2852		cuttings purged from hole included bentonite and cuttings	

SUPPORT ACTIVITIES/RELEVANT EVENTS

Flushed large volume of cuttings and bentonite from hole as bottom was approached; occasionally experienced high torque and high backpressures during the drilling operation. Cementing operation went well - mixed ~300 gallons pumped down with Bean Pump and was displaced with an appropriate volume of water to get down to the bit. Pulled the drill string and bit above the cemented zone with no problem; waiting on cement for entire night shift - samples were taken of the cement mix before it went down - still soft in morning.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/25/2019	to 7:00 am	6/26/2019	Well No.:	Lanai #10
GENERAL						Report No.:	43
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well	Lanai Well 10					Days on Location:	33
Location:	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2852
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		no temperature taken
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths		
	ron.m.fierbach@gmail.com				ground level.		

OPERATIONS

Day shift: cement sample still soft at start of shift; worked on mud line to reconfigure to make it more robust and less difficult to drill with. Began drilling on cement plug at 12:00; still fairly green. Night shift drilled to bottom and 3' into solid formation. Tripped out smoothly; bit was worn but still whole; tripped in coring assembly until morning. Heavy rains at the site overnight.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	12:00	WOC; rig modifications	2852	2852	0	improve mud line from pump to swivel
12:00	19:00	drilling cement	2852	2852	0	going smothly
19:00	1:00	drilling cement	2852	2855		drilled to bottom & into solid rock below
1:00	7:00	tripping pipe	2855	2855	0	tricone out; core assembly in

PLANNED OPERATIONS

clean drilling debris out of sump.

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2852		debris purged from hole included bentonite and cuttings	

SUPPORT ACTIVITIES/RELEVANT EVENTS

end of the day shift started pumping debris from the sump with trash pump. Lowered the level by several feet so that we can continue to circulate clean drilling fluids. Baroid gel is in tranist as of today; expected in HNL by Saturday.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/26/2019	to 7:00 am	6/27/2019	Well No.:	Lanai #10
GENERAL						Report No.:	44
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	34
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	2852
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	51.5
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		135° F/57° C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths		
	ron.m.fierbach@gmail.com				ground level.		

OPERATIONS

Day shift: intense rainfall during the night - site is muddy and not safe; spent 2 hours cleaning up and bringing dry soil to fill in muddy areas; clean off stairs; clean up mud mixer and surroundings. Continued washing in the core assembly; reamed botom 20'; started coring - advanced 18'. Night shift continued coring although are encountering more cave - the prior cores were broken up but not as altered as the prior bad zones: looks to be shatter zones flanking intrusions.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	9:00	clean up site serv. rig	2855	2855	0	rain previous night drowned site
9:00	13:00	trip/wash to bottom	2855	2855	0	had to ream last 20' to bottom
13:00	19:00	coring/wash hole	2855	2873	17.5	bottom of hole still sticky;wash out fill
1:00	7:00	drilling and washing	2873	2907	34	tricone out; core assembly in

PLANNED OPERATIONS

clean drilling debris out of sump.

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2855	2907	variable lithology; broken/reconsolidated rock; appears to have	most vesicles and fractures are entirely
		some dike material; some intensively fractured	filled with secondary mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Some of the core recovered during the shifts was fairly competent but other intervals are highly fractured and are much less competent than others. The fractured zones appear to be associated with intrusions. The broken up rocks are resulting in blocked core tubes and short runs - we had two during the coring of yesterday and last night. Temperature run during the night yielded a temperature of 135 F.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/27/2019	to 7:00 am	6/28/2019	Well No.:	Lanai #10
GENERAL						Report No.:	45
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well	Lanai Well 10					Days on Location:	35
Location:	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	3007
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	100
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		139° F/59° C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths		
	ron.m.fierbach@gmail.com				ground level.		

OPERATIONS

Coring progressed well though the day and night shifts. The drilling fluid now consists of polymer entirely and is being mixed to a somewhat higher viscosity. The core was much more consolidated through the drilling day - only a few thin intervals of highly fractured material that did not appear to be intensively altered. The drillers are washing down after each core run are being more careful to avoid build up of cuttings and sand in the hole.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	coring/wash hole	2907	2947	40	coring well; little sand production
19:00	7:00	coring/wash hole	2947	3007	60	coring well; RQD is much better

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
2907	2907	variable lithology; broken/reconsolidated rock; appears to have	most vesicles and fractures are entirely
		some dike material; some intensively fractured	filled with secondary mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Drilling during the day shift was good - there were still some slow zones and a small amount of caving; as the day progressed, the quality of the rock improved - pulled one 7' continuous stick out of the core barrel at the end of the day shift. The night shift pulled two 7+ ft. sticks.

Temperature at the end of the day was 139 °F.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/28/2019	to 7:00 am	6/29/2019	Well No.:	Lanai #10
GENERAL						Report No.:	46
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	36
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	3007
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	100
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		139° F/59° C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths		
	ron.m.fierbach@gmail.com				ground level.		

OPERATIONS

Coring progressed well though the day and night shifts. The core is holding together nicely - some 6' and 7' sticks coming out of the core tube. No real issues today at all.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	coring/wash hole	3007	3046.8	39.8	well into final run at crew change
19:00	6:30	coring/wash hole	3046.8	3107	60.2	no significant problems core and wash
6:30	7:00	clean up site				prep for open house for Lanai public

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
3007	3107	variable lithology; broken/reconsolidated rock; appears to have	most vesicles and fractures are entirely
		some dike material; some intensively fractured	filled with secondary mineralization

SUPPORT ACTIVITIES/RELEVANT EVENTS

Planned for Saturday 6/29 is an open house - the night crew cleaned up the site, and ran caution tape around the rig and working site in preparation for that event. Temperature in the morning was 139 °F.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/29/2019	to 7:00 am	6/30/2019	Well No.:	Lanai #10
GENERAL						Report No.:	47
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	37
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	3007
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	106
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		139° F/59° C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths		
	ron.m.fierbach@gmail.com				ground level.		

OPERATIONS

Coring progressed reasonably well though the day. We encounted one minor problem - the first pull of the day shift lost much of the core from the tube. Once the tube was pulled, we found that a small ding in bottom of the core lifter case had prevented the core spring from fully engaging with the core in the tube (details count...). The driller was able to recover the lost core, but lost time in the process. Night shift went very well 60' of core recovered.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	coring/wash hole	3107	3157	46	frist run slipped core; retrieved most
19:00	6:30	coring/wash hole	3157	3217	60	coring well; rock is very solid
6:30	7:00	clean up site				

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
3107	3217	mostly consolidated breccia with intermittent dikes	vesicles and fractures are dominantly
		some dikes seem to be fractured but not recemented	filled with secondary mineralization
			no intervals of intensive alteration

SUPPORT ACTIVITIES/RELEVANT EVENTS

Open house was very successful - substantial number of people came by to visit the site. We had tents and tables set up with displays of core, various drill bits, samples of drilling fluids showing the returned cuttings. Although the rig was roped off, the public area was close enough for people to see what was going on on the rig floor and we were able to explain the process to the visitors. Nicole, Eric Haskins (our core manager) and Don were at the displays to describe the drilling and the research that was was being done. .....

We had the temperature tool in the core tube when we lost the core and it took a beating as the driller tried to wash back over the lost core. The tool did survive and yielded a temperature of, again, 139 F, but probably won't survive another trip into the hole (the top was badly deformed and probably won't seal if used again). I have a back up that will be used through the rest of the drilling exercise.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	6/30/2019	to 7:00 am	7/1/2019	Well No.:	Lanai #10
GENERAL						Report No.:	48
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	38
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	3337
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	120
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		145° F/62.8° C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths		
	ron.m.fierbach@gmail.com				ground level.		

OPERATIONS

Coring progressed well through the day. No significant issues were encountered. Very few and very thin intervals of hydrothermal breakdown of the rock - seemingly associated with intrusive contacts. Night shift went quite well as well.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	coring/wash hole	3217	3276.9	59.9	well into final run at crew change
19:00	7:00	coring/wash hole	3276.9	3337	60.1	no significant problems; core and wash

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
3217	3337	variable lithology; broken/reconsolidated rock; appears to have	still seeing substantial mineralization of
		some dike material; some intensively fractured	vessicles and fractures but also seeing a few
			open vessicles - reduced mineralization?

SUPPORT ACTIVITIES/RELEVANT EVENTS

The hole is progressing well. We have arranged a pumping system to remove solids from the bottom of the first sump so that we can continue to use it as a settling basin and recycle drilling fluid from the second sump. The cuttings being generated are distinctly different from those that were produced while we were having trouble with the hole: the latter were dominated by fragments having the texture of fine sand whereas we are currently producing much finer, more clay like, solids from the hole. This material is much easier to flush from the hole using polymer alone. .....

We deployed the back-up temperature tool into the hole during the morning (6/30) and it recovered a maximum temperature of 145 F.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	7/1/2019	to 7:00 am	7/2/2019	Well No.:	Lanai #10
GENERAL						Report No.:	49
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	39
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	3417
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	80
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		146.7° F/63.7° C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths		
	ron.m.fierbach@gmail.com				ground level.		

OPERATIONS

Coring progressed well through the day. One issue was encountered: we are now using a pure polymer compound that requires special mixing in order to hydrate properly - a change in mixing procedure allowed it to be used. Overall had good recovery through the day. Night shift encountered serious downhole problems with excess water pressure - apparently, driller did not follow instructions for polymer mixing and over-dosed the mix which caused high circulation pressures.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	19:00	coring/wash hole	3337	3397	60	well into final run at crew change
19:00	7:00	coring/wash hole	3397	3417	20	downhole problems with excess pump
						pressure

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
3337	3417	variable lithology; broken/reconsolidated rock; appears to have	still seeing substantial mineralization of
		some dike material; some intensively fractured	vessicles and fractures but also seeing a few
			open vessicles - reduced mineralization?

SUPPORT ACTIVITIES/RELEVANT EVENTS

Downhole problems during the night shift were largely self-inflicted. That shift used more than a 55 gal drum of nearly pure polymer compound - ten times what a normal shift would use. At shift change, the drillers got into a dispute over whose fault the problem was with the outcome that the night shift driller was terminated and sent home by the company. After consultation with our drilling supervisor and the company operations manager, the decision was made to go to a single daytime shift and suspend further night time operations through the planned end of the current drilling interval, July 8. As we have two local hires who are fully qualified drill hands working on the project, we have released the other two company hands from further work on this phase of drilling. We will assess the risks associated with daytime only drilling over the next several days to determine whether we are at risk of sticking the rods or of having debris accumulation in the hole that will cause other problems. If it is determined that those risks are unacceptably high, we will terminate activities before July 8.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	7/2/2019	to 7:00 am	7/3/2019	Well No.:	Lanai #10
GENERAL						Report No.:	50
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	40
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	3466.6
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	49.6
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		151˚F/66˚C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths		
	ron.m.fierbach@gmail.com				ground level.		

OPERATIONS

As noted in previous report, a dispute between the day and night drillers resulted in termination of the night driller and an immediate transition to day shift only operations. Day shift operations will evaluated on an ongoing basis to ensure that operations are safe and of minimal risk to the hole. After a thorough wash of the hole, coring operations proceeded smoothly for the remaining duration of the day shift. At end of shift, site was secured and crew returned to quarters.

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	9:00	standby	3417	3417		resolve situation with company
7:00	17:45	coring/wash hole	3417	3466.6	49.6	wash hole 1 hour at end of shift
17:45	19:00	trip 220' rod out	3466.6	3466.6		ensure hole is clear for tomorrow's shift
19:00	7:00	night shift terminated				

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
3417	3466.6	variable lithology; broken/reconsolidated rock; appears to have	still seeing substantial mineralization of
		some dike material; some intensively fractured	vessicles and fractures but also seeing a few
			open vessicles - reduced mineralization?

SUPPORT ACTIVITIES/RELEVANT EVENTS

When the hole was flushed, and through out the day, poorly-hydrated fragments of polymer were flushed from the hole but gradually cleaned up by the end of the day. During the day shift, the temperature tool yielded a temperature of 151 F. At the end of the shift, we ran the tool down to the bottom of the drill string at ~220' off bottom and left it in place over night. Temperature showed a slow increase over night with a maximum temperature of 146 F - which is consistent with the temperature taken while drilling at this depth.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	7/3/2019	to 7:00 am	7/4/2019	Well No.:	Lanai #10
GENERAL						Report No.:	51
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well	Lanai Well 10					Days on Location:	41
Location:	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	0
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547				Max DH Temp (drilling)		151˚F/66˚C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths		
	ron.m.fierbach@gmail.com				ground level.		

OPERATIONS

Day shift began with lowering drill string from 220' off botttom to 30' off bottom - encountered no obstructions; driller hooked up swivel to wash to bottom and hole pressured up. Rod would rotate, but limited movement up or down - when pressured no movement at all. With low water pressure, driller was able to back ream out of that depth and began pulling rods. Made it to 330' off bottom and rods locked up. Worked rods for rest of the day with no significant movement up/down/rotating.....

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	18:00	work drill rod	3466.6	3466.6		attempting to pull drill rod from hole
18:00	19:00	secure site				pulled up 330' off bottom; rod became
						completely stuck - no up, no down
						unable to circulate fluids into hole; pulled
						tube and came up easily

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
Surface	1465	4.5"	10.6			temporary PQ liner to proived further stability to
						HQ string

LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
3466.6	0	variable lithology; broken/reconsolidated rock; appears to have	still seeing substantial mineralization of
		some dike material; some intensively fractured	vessicles and fractures but also seeing a few
			open vessicles - reduced mineralization?

SUPPORT ACTIVITIES/RELEVANT EVENTS

hole is unable to take water - as soon as we add water to the rods, we get substantial back pressure. Rods left hanging in hole overnight. _____

temperature measurement made overnight at 220' off bottom in the hole came back 145 F with slilght but progressive increase over night.

UNIVERSITY OF HAWAII AT MANOA **Daily Drilling Report**

Hawaii Play Fairway	Report for:	7:00 am	7/4/2019	to 7:00 am	7/5/2019	Well No.:	Lanai #10
GENERAL						Report No.:	52
Operator:	IDEA Drilling, Inc. Contact: Julian Collins 888-634-IDEA					Well Type:	extending cable tool hole
	5895 East 2nd St., Winnemucca, NV 89445					Spud Date:	1989
Well Location:	Lanai Well 10					Days on Location:	42
	UTM 4 Q 716195.61 m E, 2297652.42 m N					Current Depth (ft):	0
	Lat/Long: 20°45'58.00"N 156°55'24.00"W					Planned TD (ft):	NA
	Elevation (ft): 1,100					Hole Made Last 24hrs:	0
						Current Hole Size (in):	3.825"
Rig:	UH Manoa Contact: Don Thomas 808-895-6547					Max DH Temp (drilling)	151˚F/66˚C
	POST 602, 1680 East-West Rd, Honolulu HI 96822						
Supervisor:	Ron Fierbach				Note: All depths		
	ron.m.fierbach@gmail.com				ground level.		

OPERATIONS

Day shift resumed working the driill rod in an effort to recover drill string. Water levels in the drill string and the annulus were equalized to alleviate any possibility of hydrostatic "sticking" with no discernable effect on the drill rod. The driller and drilling supervisor concluded that mud or cuttings have trapped the bottom hole assembly and that the best aproach to recovering the drill string will be to cut the string immediately above the core barrel and go back into the hole and drill out the BHA

DRILLING ACTIVITIES

From (hrs)	To (hrs)	Operation	Start MD	End MD	Ft Recovered	Comments
7:00	12:00	work drill rod	3466.6	3466.6		In the absence of any progress at moving
12:00	19:00	clean up site secure				the drill string, we have concluded that
		equipment for standby				we will have to cut the BHA loose and re-
						enter the hole with a milling bit to drill
						out the BHA.

PLANNED OPERATIONS

CASING

From (ft)	To (ft)	Diameter	Wgt. Ppf	Grade	Thread Type	Comments
surface	11'	24"	unk	unk	welded	existing conductor pipe at top of hole: extends to ~11'
Surface	1448'	5.5"	14			temporary PWT casing/liner for drilling through
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LITHOLOGY

From (ft)	To (ft)	Description	Mineralization
3466.6	0	variable lithology; broken/reconsolidated rock; appears to have	still seeing substantial mineralization of
		some dike material; some intensively fractured	vessicles and fractures but also seeing a few
			open vessicles - reduced mineralization?

SUPPORT ACTIVITIES/RELEVANT EVENTS

Further activity at the site will be suspended until we are able to procure and ship NQ drill rod and a cutter tool to cut the BHA loose. Drillers and crew have been released effective today and are returning home.