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Play fairway analysis of geothermal resources across the state of Hawaii: 3. Use of development viability criterion to prioritize future exploration targets

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ABSTRACT

A recent Play Fairway Analysis of geothermal prospects in Hawaii identified and compiled data relevant to subsurface heat, fluid, and permeability, and developed and applied a statistical method to integrate the compiled data to produce a map of resource probability across the state. As a final screening of prospective geothermal resources, we considered the *viability of development* in areas showing an elevated resource probability. This screening was intended to prioritize prospects that have a greater likelihood of proceeding through regulatory review to production in a timely and cost-effective manner. Development viability was determined to be high, medium, or low based on four factors: i) grid accessibility, ii) vulnerability to natural hazards, iii) current and probable future land uses; and iv) community sentiment and acceptance. Development viability was assessed in > 10 areas of interest that were selected based on the results of the probability and confidence mapping, and was a guiding criterion used to develop a prioritized roadmap for the next phase of exploration activity in Hawaii. Planned activities include a groundwater sampling and analysis campaign in ~10 broad areas, and the collection of magnetotelluric and gravity data in 2–5 locations statewide.

1. Introduction

Play Fairway Analysis (PFA) refers to an integration of individually weighted quantitative datasets that individually and collectively indicate the potential for a subsurface resource (a Play) in a given geographic area (a Fairway). This is the third paper in a series describing a recent PFA of geothermal resource potential in Hawaii. The papers describe the three main goals of the project:

1) ***Data.*** Identify the critical data types that are relevant to geothermal resource prospecting in a volcanic ocean island environment, rank the datasets in order of their relevance to the essential characteristics of a geothermal prospect (heat, fluid, and permeability), and compile all the accessible relevant data. These activities are described in the first paper in this series (Lautze et al., 2017);
2) ***Model Resource Probability.*** Develop a Bayesian statistical method to produce maps of geothermal resource probability across the state using the data collected in step one; and develop a method to assess confidence in the probability maps. These modeling activities are described in our second paper (Ito et al., 2016).
3) ***Exploration Plan.*** Devise a prioritized roadmap for future exploration (investment/effort/activities). To best construct this plan, we first considered the plausibility of development, or development viability, in areas of interest that resulted from steps one and two.

The purpose of this development viability assessment was to prioritize exploration activities in resource prospects most likely to contribute to Hawaii's renewable energy portfolio in the foreseeable future; and to defer additional investment in prospects that currently have low or no likelihood of development to a time when economic and/or technological conditions may be more favorable. Specifically this analysis asked the question: If an elevated temperature, permeable, and fluid-rich resource is identified, what is the likelihood that it could be developed to produce electrical power for the local grid in a realistic, timely, and cost effective manner? The development viability analysis considered four factors: i) ease of access to the existing grid; ii) vulnerability to natural hazards; iii) current and prospective land use; and iv) the surrounding community perception and acceptance of geothermal power production.

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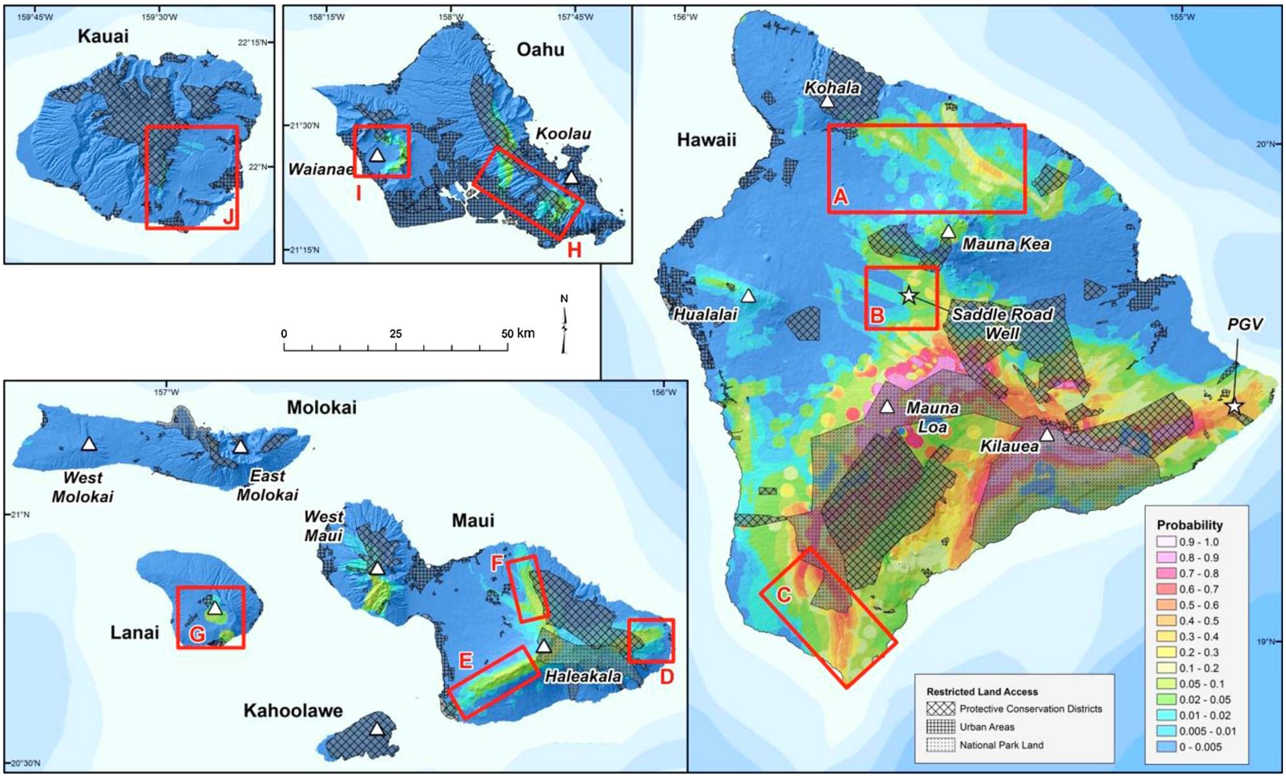

Fig. 1. Results of the DOE Phase 1 geothermal play fairway probability analysis for the State of Hawaii. Probabilities of a geothermal resource are colored. Areas with restricted land access are shown in stippled and crosshatch patterns (e.g., National Park lands, protective conservation districts, and urban areas). Red boxes outline areas proposed for Phase 2 study. White triangles indicate the calderas of the main shield volcanoes. White stars mark the locations of the Saddle Road well and Puna Geothermal Ventures (PGV). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2. Background

2.1. Probability and confidence results

Fig. 1 shows the results of the probability analysis described in detail in paper two (Ito et al., 2016). The probability of a geothermal resource is the joint probability of the three key qualities: elevated subsurface heat, permeability, and fluid, as supported by datasets described in paper one (Lautze et al., 2017). Not surprisingly, locations with the highest resource probability occur along the rift zones and at the calderas of the active shield volcanoes, Kilauea and Mauna Loa. However, results show some elevated probability on each island. Fig. 1 also shows areas with restricted land access in shaded patterns. These are areas in which further exploration and/or resource development would be challenging to impossible; such regions were excluded from our consideration for future work. The areas in red boxes are included in our recommendation for future (Phase 2) exploration based on results from probability modeling, our confidence in those results, and development viability. Other locations that were considered, but not included, in the Phase 2 targets, due to low development viability (as discussed below), are Kilauea's lower east rift zone, Hualālai, and the southern segment of West Maui (Fig. 1).

Fig. 2 shows results of the confidence analysis. This analysis provides a measure of confidence in the probability results, and is based on the number of datasets available at a given location, the quality of the data, and the relative importance of each dataset for the probability (Ito et al., 2016). In considering future exploration recommendations, areas of elevated resource probability, and areas with low to high confidence, were considered for future work, subject to viability as noted above. For example the confidence value south of Mauna Loa and north of Mauna Kea is moderate. South of Mauna Kea it is high (due to findings of the Saddle Road well), and in target areas on the other islands it is moderate to low. Areas with moderate and low confidence are in need of more data to better ascertain resource probability.

2.2. Criteria for ranking development viability

2.2.1. Grid integration potential and access to market

For an otherwise viable play, how difficult would it be to integrate the power into that island's electricity transmission grid? In 2015 the Hawaii legislature passed a bill mandating that 100% of the state's electricity come from renewable sources by 2045; the political climate for geothermal development is therefore extremely favorable. However one of the unique challenges of Hawaii's electric utility system is that the islands are separated by large stretches of ocean, and each island's grid is autonomous. Therefore, in the absence of an interisland cable, each island must meet the 2045 policy mandate individually.

Our first consideration is the simple engineering issue of whether the prospect is physically near a transmission line, and whether that transmission line has the necessary capacity. Transmission capacity may be more easily upgradeable than construction of new line. Although transmission distances in Hawaii are generally short compared to those in North America, the relatively small increments in power production for Hawaii's market, coupled with anticipated high costs and challenging regulatory review incurred by installation of new transmission lines, could render development of a resource in remote locations impractical or uneconomic.

Our second consideration is the sufficiency of "head-room" in the utility's mix of power sources. Headroom is the difference between total energy sales and energy produced from renewable sources for each island. This gap must be filled by 2045 to meet the policy mandate. Table 1 shows renewable energy production values from 2014. The gap is minimal for Kauai (total sales exceed renewable energy production by 354,722 MWh), larger for Hawaii Island (546,474 MWh), still larger for Maui (734,798 MWh), and extremely large for Oahu (5,594,454 MWh). Moreover, for those islands with diminished