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Play fairway analysis of geothermal resources across the State of Hawaii: 1. Geological, geophysical, and geochemical datasets

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ABSTRACT

Phase 1 of a Play Fairway Analysis (PFA) of geothermal resource potential across the State of Hawaii was recently completed. The final products of this work include a statewide geothermal resource probability map, a map of confidence in this probability, an assessment of the viability of development in areas of interest, and a prioritized list of recommended future exploration activities. The intersection of subsurface heat (H), permeability (P), and fluid (F) is necessary for an optimum geothermal play. This study: (1) identified and compiled all legacy and current data relevant to Hawaii's geothermal resource; (2) ranked these datasets in terms of their relevance to subsurface H, P, F; (3) developed a Bayesian statistical method to incorporate the data and their rankings, and produce a statewide resource probability map; (4) developed a method to assess confidence in the probability values; and (5) assessed what we term 'development viability' in resulting areas of interest across the state. This paper details the basic project workflow, and activities (1) and (2). It describes the rationale for including this study's datasets: surface geologic mapping data (calderas, rift zones, volcanic vents, dikes, faults), groundwater data (temperature, Chloride:Magnesium, SiO_2) and geophysical data (gravity, magnetotelluric, seismic, geodetic strain), and justifies their relative rankings in terms of H, P, and F. A second paper by Ito et al. (2016) describes activities (3) and (4) related to the statistical methodology, and a third paper (Lautze et al., 2017) describes activity (5), the development viability criteria, as well as our suggested roadmap for future exploration activities. Overall, we find that the likelihood of abundant of geothermal resources is highest on the youngest island of Hawaii, but groundwater indicators suggest there may also be resources on the other, older islands. The higher demand for renewable energy on the more populated islands of Maui and Oahu, as well as a high viability of development on Lanai, also motivate further exploration on these islands.

1. Introduction

Play Fairway Analysis (PFA), which originated in the oil and gas industry, involves identifying the characteristics necessary for a resource to exist; 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 is then used to define an assessment program that can most cost-effectively identify the viable resources within the Fairway. As defined by this project's funding agency (the US Department of Energy), the required elements for a viable geothermal Play are subsurface heat (H), permeability (P), and fluid (F). Heat is needed for the resource to exist, fluid is needed to transport heat from the resource to the surface, and permeability is required so that fluids can be extracted and replenished in the subsurface. The major undertakings of this project then, were to i) identify the datasets relevant to H, P, and F in Hawaii; ii) rank them in terms of their ability to inform each of H, P, and F in a way that is consistent with Hawaii'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 Hawaii Fairway; and v) devise an exploration plan for Plays deserving of more site specific resource analysis. The results of i)–iii) are the focus of this paper; the details of the probability modeling are presented in the second paper of this series (Ito et al., 2016); and the final step of developing a roadmap for future explo-

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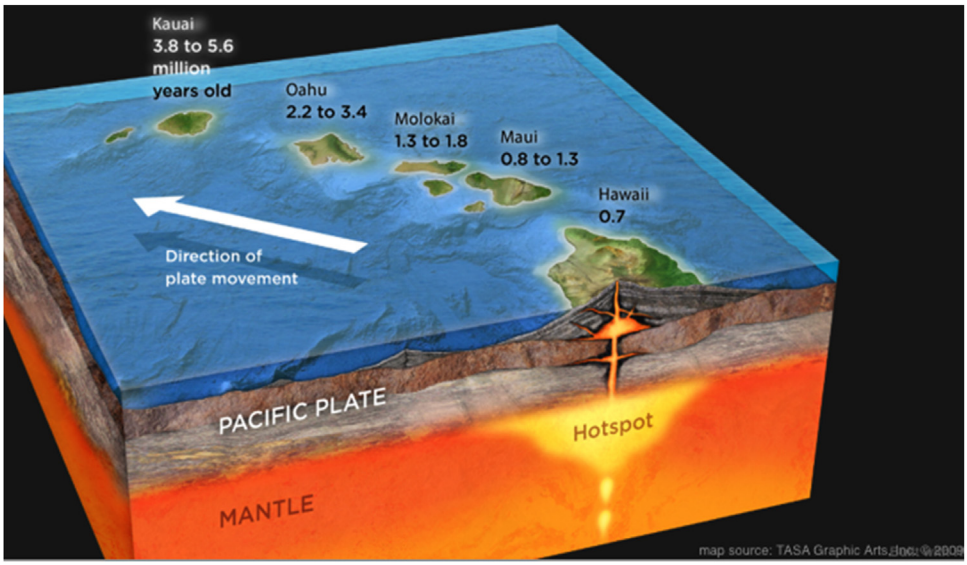

Fig. 1. Map showing the mantle hotspot origin of magma, which provides the heat for Hawaii's geothermal resource. The names of the state's five biggest islands and the average age of the shield building stage of volcanism are shown. Note this age increases to the northwest. (Map Source: TASA Graphic Arts, Inc.© 2009).

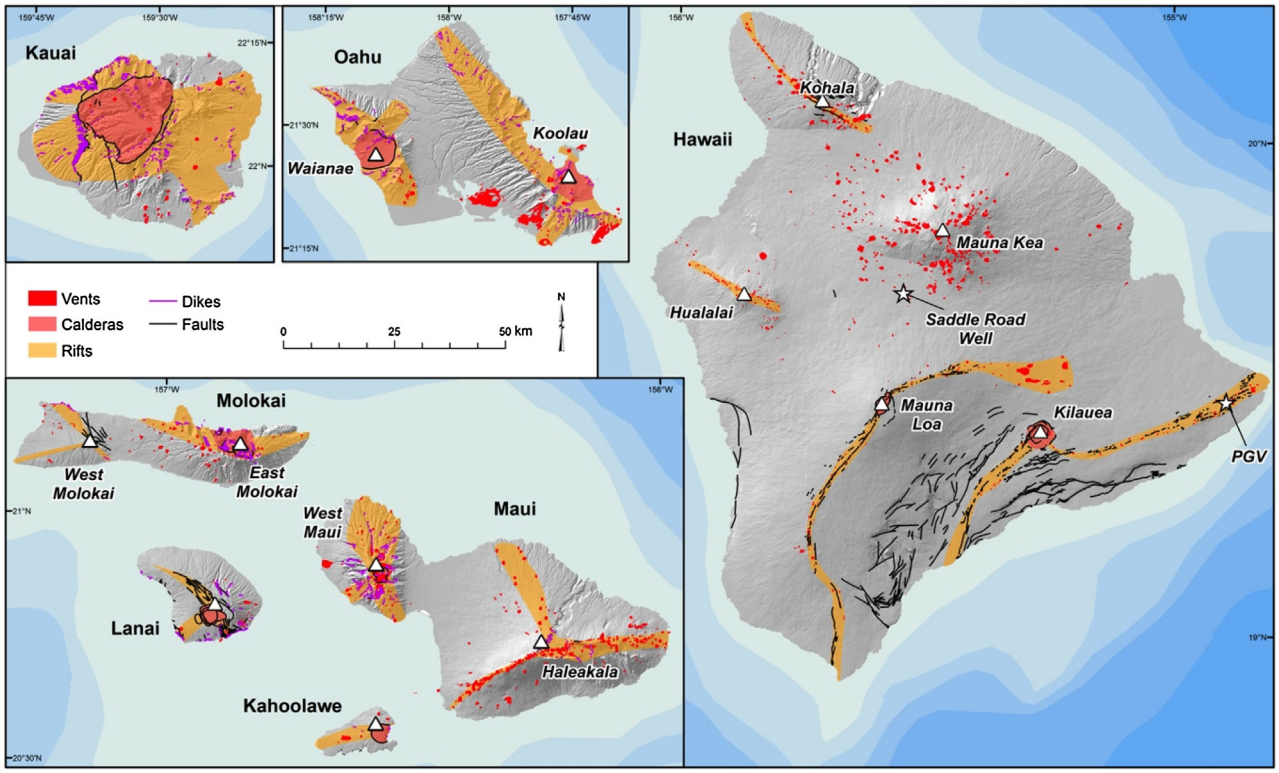

Fig. 2. Statewide map showing the seven islands that comprise the State of Hawaii. A white triangle designates the summit of each shield volcano. Surface geologic features including calderas, rift zones, volcanic vents, dikes, and faults were mapped following Sherrod et al. (2007) and other sources listed under "Geology" in Appendix A.

ration activities is the subject of the third and last paper in this series (Lautze et al., 2017).

There is timeliness to this Hawaii PFA. The Hawaiian Islands originate from a mantle hotspot (Fig. 1) such that subsurface heat can be expected; however, the last statewide geothermal resource assessment was published in 1985 (Thomas, 1985). The 1985 assessment indicated potential prospects on all of the main Hawaiian Islands, but little additional broadly focused exploration work has been done since. In 2013, team member D. Thomas led a U.S. Army-funded drilling effort in search of groundwater in Humu'ula Saddle region between Mauna Kea and Mauna Loa volcanoes (Fig. 2, 'Saddle Road Well') resulting in the discovery of water at an elevated temperature (~140 °C) at a depth of ~1.7 km – with a temperature gradient of 165 °C/km from ~1 km depth – in a location not previously recognized as a geothermal area of interest (Thomas et al., 2014). This discovery not only expanded the state's resource potential but also demonstrated that our understanding of Hawaii's geothermal resource is far from

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