A comprehensive study of reservoir pressure trends and future performance in the Olkaria East and Southeast geothermal fields,Kenya

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論 文 名　：A comprehensive study of reservoir pressure trends and future performance in the Olkaria East and Southeast geothermal fields, Kenya
（ケニア共和国オルカリア東部及び南東部地熱地域における貯留層圧力変化の傾向と将来の挙動に関する包括的研究）

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論　文　内　容　の　要　旨

Olkaria East and Southeast geothermal fields started power production in 1981 with Unit I (15 MWe). It has since increased its capacity from Olkaria I-VI units to 278.3 MWe in 2022. Despite the steady increase in power generation, there has been a notable pressure decline of 10-15 bars. A frequent appraisal is necessary to ensure optimum resource utilization to track productivity and management practices that will guide future investments.

The objective of the dissertation is to comprehensively study the geoscientific principles and components that govern geothermal resources, evaluation techniques and management. Therefore, this dissertation provides knowledge for further and future evaluation of geothermal projects in Olkaria East and Southeast.

The dissertation consists of seven chapters described below.

Chapter 1 provides the general introduction and literature that has been used to construct the conceptual understanding of the Olkaria geothermal complex. These included geoscientific tools and interpretation previously used in exploring and evaluating the project feasibility and calibration approach to confirm previous resource estimations. The certainty and reliability of the conceptual understanding relied on the scientific discussion. These were used to develop the hypotheses and justification presented in this research approach, such as the geometric surface structure of the study area, that is, lineament and fault network that support fumaroles and steaming grounds, the significance and volumetric assessment of radiated heat loss, geochemical signatures and attributes of steam discharges and their information of reservoir conditions, and numerical simulation of two-phase liquid dominated reservoirs.

Chapter 2 presents the study of the magnitude of steam discharge through fractures and faults which act as conduits for hydrothermal flow. The study for the land surface temperature using LANDSAT 8 image captured on 11th July 2015 mapped geothermal-affiliated anomalies posted 11.28-15.28℃. The radiated heat flux tracked with fumarolic and steaming ground activities overlying the fault network and cumulative heat loss resulting from a surface discharge of about 0.4459 MW over 0.1494 km².

Chapter 3 outlines the method, results and analysis of manually extracted linear structures captured on satellite images, namely, ASTER and SPOT images. The density of the localized structural fractures was juxtaposed with the occurrence of fumaroles and steaming grounds. The assessment of the recorded temperatures of the fumaroles and steaming grounds illustrated the geospatial temperature anomalies below the geothermal surface features.

Chapter 4 describes the geochemical aspects of the fumarole waters and reservoir fluid. The Olkaria geothermal system has acidic fumarole water. In contrast, the deep reservoir is characterized by alkaline high temperature liquid dominated fluid. The chemical constituents of the water-rock interaction were used to determine the geothermometric relationship between the fumaroles' waters and well discharge fluids. As a result, it was discovered that isolated geological division occurs between the fumarole and reservoir sections, and the fumarole waters are recharged by surface waters that interact with calcites and magmatic rocks and tap heat from the conductive caprock.

Chapter 5 presents an empirical method used to explain the unique pressure-driven steam decline observed in the Olkaria East field. The analytical approach utilized annual flow rate datasets to compute the decline type-curve, loss ratio, and decline percentage to predict the future flow behavior from the liquid-dominated reservoir. The Olkaria East wells record an initial decline at an average of 11%/year, and flow rate rebound between 1-2 years. Most wells display exponential decline at 3-5%/year except Well OW-2 (7.9%/year) which was extrapolated to estimate future behavior. Despite the reinjection programs (trials in 1996 and then continuously from 2003), some wells discharged the predicted flow rate from the initial exponential trends.

Chapter 6 provides a comprehensive analysis of previously described geophysical and geochemical phenomena in the Olkaria East and Southeast fields. A series of reservoir simulation using TOUGH2 computational code was employed to assess natural geo-controlling structures for optimal productivity and predict future developments in the geothermal field. This study applied the analytical method to determine reservoir rock properties to construct a numerical model. The production and reinjection model confirmed declining pressure trends up to 19 bars after a period of 29 years when 1656 t/h mass is extracted while 42% water reinjection occurs. The extraction of 717.2 t/h from the new wells caused a further decline in production life to 13.48 years. These results are significant in determining suitable recharge rate, well location and depth interval for reinjection programs to mitigate pressure decline. This study suggested that hot and condensate water reinjection of 1530 t/h (73.62% of extracted fluid) at the south of Olkaria East field was required.

Chapter 7 discusses the compound rationale and conclusion of the dissertation. This chapter also shows the research challenges, achievements and recommendations.