APPLICATION OF MAGNETOTELLURIC AND GRAVITY TECHNIQUES IN CHARACTERIZATION OF GEOTHERMAL RESOURCE IN EBURRU, KENYA

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論　文　名　：APPLICATION OF MAGNETOTELLURIC AND GRAVITY TECHNIQUES IN CHARACTERIZATION OF GEOTHERMAL RESOURCE IN EBURRU, KENYA
（ケニア・エブル地域の地熱資源の特性評価における地磁気地電流探査及び重力探査の適用）

区　　分　：　甲

論　文　内　容　の　要　旨

Eburru is a Quaternary volcano situated in the southern segment of Kenya Rift, an arm of the larger East Africa Rift System (EARS). It forms the highest topography within the entire Kenya Rift at an elevation of 2800 m, while Badlands lies lower to the North of Eburru massif towards Lake Elementaita. The geothermal potential in Eburru is indicated by surface manifestations such as fumaroles, hot springs and altered grounds, a series of faults and fracture network system with general N-S trends and minor E-W trending faults. Therefore, it is important to provide information on the physical properties of the Eburru geothermal system. This information would be vital in delineating the presence of its cap rock, reservoir, and heat source as well as geological structures that might be controlling the system. This study attempts to delineate the structures controlling the geothermal system, the extent of the geothermal resource, and estimate the geothermal power potential of the Eburru field.

This dissertation consists of 8 chapters, as follows:

Chapter 1: This chapter describes the background of the study, the general information about the geothermal status in Kenya as well as documented studies that were conducted by preceding researchers. The history and current state of geothermal development in Kenya, with a particular focus on the Eburru geothermal area, is provided. Likewise, a description of the structure of the thesis is also given.

Chapter 2: This chapter focuses on the various characteristics that define the Eburru geothermal area. The chapter gives a detailed review of the geology and tectonic setting of the area from both local and regional viewpoints. Then a description of the methodology used in the study of lineaments from Landsat images is presented. The description includes the extraction of lineaments from the satellite image, their analysis, and interpretation, and presentation of the results using the rose diagram.

Chapter 3: This chapter provides a detailed description of the gravity study. A comprehensive review of the gravity method, both theory and applications, is given. A Bouguer gravity map was created, which becomes the basic map for gravity interpretation. Since the complete Bouguer anomaly contained a superposition of regional and residual anomalies, a regional-residual separation was conducted in order to highlight the structures of interest for this study. The gravity data were analyzed using integrated gradient interpretation techniques for edge detection such as horizontal derivative and an improved normalized horizontal tilt angle. Interpretation of horizontal derivative and improved normalized horizontal tilt angle of gravity data indicated that the existence of high gradient anomalies characterizes the area. These anomalies could be associated with existing geothermal manifestations. 3-D gravity modeling of the complete Bouguer anomaly was conducted to determine the shape and depth of the geological structures controlling the geothermal system. This was guided by the fact that the integrated gradient interpretation techniques for edge detection can detect steep gradients and indicate the location of either faults or geological boundaries, but they cannot estimate their depth. The results from the 3-D modeling show a structure located on the south-west side of the study area, which might be the hydrothermal reservoir with a volume of about 3.0 km^3 and an average block density value of 2.45 g/cm^3.

Chapter 4: This chapter introduces the magnetotelluric (MT) method and explains how the method measures the subsurface resistivity structure from the earth's surface. The electrical properties of typical earth materials and the governing equations to calculate resistivity were compared and discussed in detail. The concept of distortion and static shift was explained, and some examples of soundings that suffered from these effects were shown as resistivity curves before and after corrective measures were applied.

Chapter 5: This chapter gives an introduction to MT instrumentation and a brief description of the MT data collection. Dimensionality analysis was carried out to determine if the data required a one, two, or three-dimensional modeling. The analyses revealed that 1-D and 2-D dimensionality effects were prominent at shallow depth. Also, 3-D characteristics were detected at deeper levels. For the 2-D case, directionality analysis was conducted to determine the geo-electric strike direction that was best for 2-D modeling. The dataset showed a consistent strike direction of 25°. The strike estimation of 25° was fairly consistent with the major N-S local fault system in the Eburru field and was taken as the regional strike direction.

Chapter 6: This chapter presents MT inversion modeling (1-D, 2-D, and 3-D) with a discussion of the various inversion parameters used, along with a description of the main resistivity features of the models. The 1-D models at each station imaged resistivity structures similar to the ones obtained in 2-D and 3-D models. Most of the geological structures in Eburru geothermal field trend in the north to south direction, and they are likely to control the movement of fluid in the geothermal field. Parallel profiles for 2-D analysis were selected to cut across these structures. Then vertical cross-sections were extracted from the final 3-D inversion model to compare with the 2-D inversion models. The two models recovered a topmost layer, which is relatively thin and resistive (> 80 Ωm) that lies between the depth of 200 m to 500 m spreading almost the entire area. Beneath this zone is a conductive zone (< 10 Ωm) within 1 km from the surface overlaying a relatively resistive layer (~ 35 Ωm) and a deep conductor (< 10 Ωm) extending from sea level to a depth of 2.5 km below sea level.

Chapter 7: This chapter brings together the results from geology, gravity, and magnetotelluric methods and presents an integrated interpretation. Based on these results, a conceptual model of the study area was developed. The conceptual model proposed is simple due to the small size of the geothermal field and the limited number of drilled wells, but it is in good agreement with available information. According to the proposed conceptual model, a possible geothermal reservoir for electrical power production is only around the three productive wells. An assessment of the potential for geothermal resources that can be used for conventional electric power production in the Eburru geothermal field was carried out. The result, from the probable geothermal resource, implies that the field could initially support a 13.1 MWe power plant for 25 years maximum, and a possible expansion to 24.7 MWe is subject to further delineation drilling and availability of field performance data. Nevertheless, the concluding results need to be corrected by further geoscientific investigations.

Chapter 8: This chapter concludes the thesis by providing a summary of the current findings regarding the information collected from the field and conclusions made in preceding chapters.