EFFECTS OF HYDROTHERMAL ALTERATION ON PETROPHYSICS AND GEOCHEMICAL MOBILITY IN RESERVOIR ROCKS OF OLKARIA NORTHEAST GEOTHERMAL FIELD, KENYA

MICHAEL MUSAU MWANIA

A Thesis Project Submitted in Partial Fulfillment for the Award of the Degree of Master of Science in Geothermal Technology, Geothermal Training and Research Institute, Dedan Kimathi University of Technology

DECEMBER, 2017

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DECLARATION

This Master's Thesis is my original work and has not been presented in any university/institution for a degree or for consideration of any certification.

Signature………………………………………Date…28/11/2017……………………………………

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SUPERVISOR'S DECLARATION

This research Thesis has been submitted for examination with/for our/my approval as University Supervisor(s).

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ABSTRACT

Characterization of reservoir geometry for any geothermal field under both exploitation and exploration provide rationale for optimal utilization programs. In spite Olkaria field being subject of extensive research in the last three decades, reservoir geometry under the influence of hydrothermal alteration remain relatively elusive and often creates uncertainties in optimal well siting. Within the Olkaria Northeast field, reservoir rocks are majorly typified by trachytes and rhyolitic intercalations. This research aims at characterising reservoir geometry through evaluation of the variability of petrophysical properties; porosity, relative permeability and lithological characteristics, and the type geochemical mobility taking place during hydrothermal alteration. To accomplish this, three wells; OW-706, OW-717 and OW-725 located in the Northeast field were selected based on the petrogenetic provenance and spatial attributes relative to major structural lineaments. In order to evaluate the petrophysical variability, gravimetric method alongside with optical methods were used. The optical methods employed use of Binocular and Petrographic microscopes to characterise lithological facies and inter-crystal matrix permeability. Fracture controlled permeability was also invoked indirectly from temperature distribution. On geochemical dispersion, XRF technique was used to evaluate chemical composition of reservoir rocks. The results were plotted on Hanker diagrams for empirical comparison of protolith and subsurface samples from selected elements for bulk chemistry; K_2O, Al_2O_3, CaO, Fe_2O_3, SiO_2, and trace elements Nb, Y, Rb, Zr, Ba. The results of medial facies were further integrated in a three-dimensional model in order to predict reservoir morphology.

Results of analysis reveal trachytes and rhyolites as major reservoir rocks were dearth of primary porosity and matrix-permeability was found to be controlled by pore-network evolution and differential hydrothermal alteration. The results indicated that, the average porosity values from optical methods are in orders of 2.48%, 1.56 and 3% in well OW-725, OW-717 and OW-706 respectively. Similar results from gravimetric measurements indicated marginal range of values from 9.05%, 9.42% and 11.6% in OW-717, OW-725 and OW-706 respectively, the difference essentially attributed to micro-porosity of the inter-crystal matrix. Markedly, dissolution of primary Alkali feldspars alongside replacement of secondary mineral were observed to be major processes controlling pore evolvement and subsequent matrix permeability. The greater variability was found to be augmented by fracture and lithological contact permeability largely controlling bulk fluid movement, a phenomena that was also evident from elevated temperature

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distribution patterns. Inconformity with petrophysical variability, empirical trends from geochemical mobility predicated bulk elemental transfers during hydrothermal alteration, where major oxides; K_2O and Al_2O_3 exhibited significant depletion trends from protolith samples while CaO and Fe_2O_3 displayed marginal enrichment on subsurface samples. There were no major variations on trace elements mobility apart from Y and Ba which indicated possible minimal enrichment in well OW-706.

The findings of this research concludes that, the reservoir pore-geometry of Olkaria Northeast field is more evolved along the NW-SE fault and less propagated to the eastern periphery of the field. The wider variability was attributed to the influence of predominant structural controls which augment vertical fracture-permeability while lateral permeability was well pronounced along lithological contacts. Remarkably, the pervasive fluid-rock interaction at the lithological contacts and fracture-fault permeability induces etch-pitting ultimately leading to pore-network evolvement and subsequent development of matrix permeability. Based on the predicted facies model in Olkaria Northeast sector, optimal siting of make-up wells should aim at targeting NW-SE fault inferred to be possible upwelling zone, while re-injection wells should be sited to the eastern periphery of the field adjacent to the Gorge farm fault inferred to be possible conduit for cooler meteoric fluids.