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Mapping of Olkaria Intrusives by Integration of Geologic and Geophysical Techniques

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Keywords

Olkaria geothermal field, gravity, intrusion, rocks, anomaly, modelling.

ABSTRACT

Olkaria geothermal field under KenGen's concession area is divided into 7 fields for easier resource management. These are Olkaria East, Central, Southeast, Northeast, Southwest, Northwest and Domes fields. Olkaria West field is under Orpower 4. The area under study occupies parts of Olkaria East and Southeast fields. It is bounded by coordinates 196000E & 200500E and 9900000N & 9903000N covering an area of approximately 15km^2.

The surface is partially covered by rhyolitic lava flows (Ololbutot lava flow) and pyroclastics, the former being the younger unit. Several wells have been drilled in this area and the subsurface geology studied from drill cuttings obtained. The main lithological units are pyroclastics, rhyolites, tuffs, basalts, trachytes, syenitic and granitic intrusions. These intrusions are of importance in this study.

Gravity survey has also been conducted and the gravity anomalies studied and compared with the subsurface rocks obtained during drilling for and correlation in their respective densities. It is evident that gravity is influenced by the rock's porosity, saturation, mineralogy etc. The different rock units encountered therefore have different densities which can be determined by gravity measurements. For example, the densities of deep-seated rocks like intrusives generally have higher densities than the near-surface and loosely-consolidated rocks. This is because the intrusive rocks like granites are usually compact and have less porosity as compared to pyroclastics and shallow tuffs.

From the total 118 gravity points collected and analysed, it can be seen in the Bouguer anomaly map that the regions where the continuous intrusions were encountered at a shallower depth had slightly higher density values as compared to areas where the intrusions were not encountered.

1. Introduction

The area described in this paper covers an area of about 15km2 and includes part of Olkaria East and Olkaria South East fields. The Olkaria South east field is still in the early stages of exploitation with about 20 geothermal wells drilled whereas East field is almost fully developed. Geological data used in this study was collected during drilling of the wells and modelled to give a geological model. Gravity data was collected, analyzed and the final Bouguer anomaly plotted on a contour map.

The two datasets were then compared and interpreted and forms the basis of this study.

2. Geological Setting

(Omenda, 2000) Divided the GOVC rock types into six major categories; the Proterozoic basement formation, pre-Mau volcanics, Mau tuffs, plateau trachytes, Olkaria basalt and upper Olkaria volcanics. The pre Mau volcanics, comprising of basalts and ignimbrites of unknown thickness is underlain by Mau tuffs. The latter are absent to the east of Olkaria Hill due to the high dipping angle fault passing through the Olkaria Hill. The surface geology in Olkaria geothermal field is dominated by rhyolitic lava flows and pyroclastics. The youngest lava flow in Olkaria is the Oloolbutot lava flow which erupted 180 ±50 yrs BP.

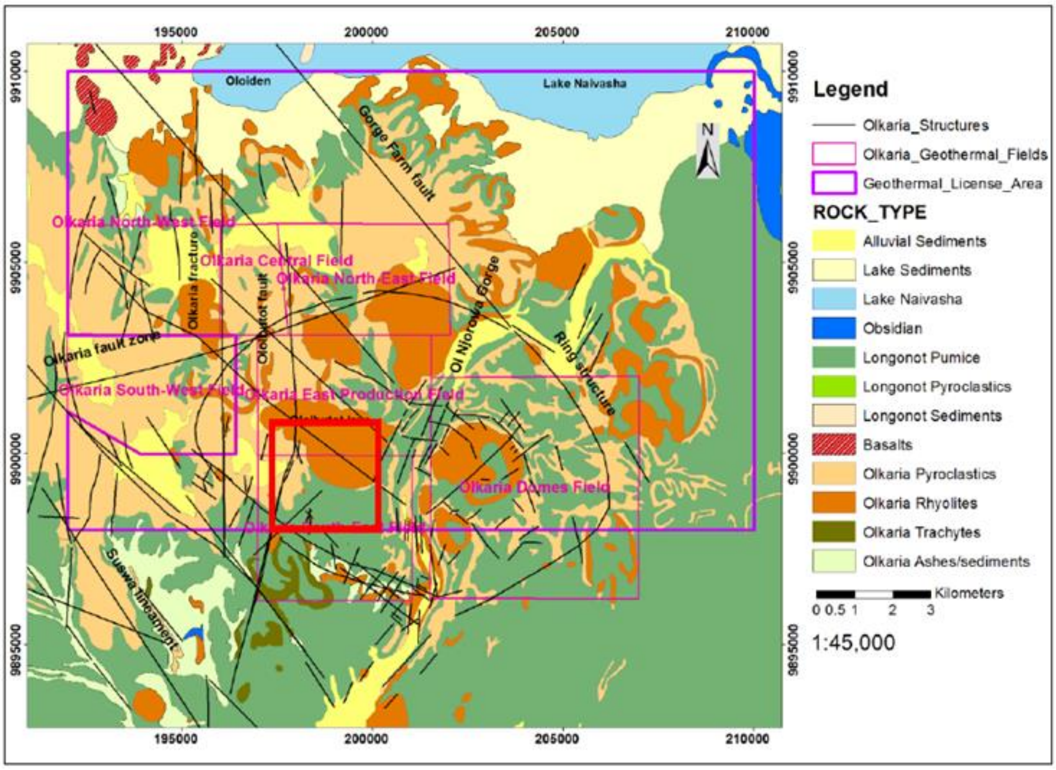

Figure 1: Map showing the surface geology and the structures in the Greater Olkaria geothermal area. (Study area in red). (Munyiri, 2016)

3. Methodology

3.1 The Gravity Method

Acceleration due to gravity is directly proportional to the earth's mass and inversely proportional to the square of the radius of the earth. The Bouguer gravity anomaly is the end-product of gravity data correction. The Bouguer anomaly correlates with the lateral variations in density of the crustal rocks (Rivas, 2009). This means that a high density feature in a low density medium should give higher Bouguer anomaly values and vice versa (Rivas, 2009). Take an example of granitic and syenitic intrusions emplaced in a trachytic formation as is the case in Olkaria. These intrusions in are crystalline, more compact and relatively fresh as compared to trachytes which form the bulk of the reservoir rocks. The trachytes, being the main reservoir rocks, are more porous than the intrusions and have been subjected to fracturing and hydrothermal alteration. These conditions affect their (Trachytes) densities and for these reasons we expect to observe higher Bouguer anomaly values where the intrusions are shallowest or where they were encountered during drilling.

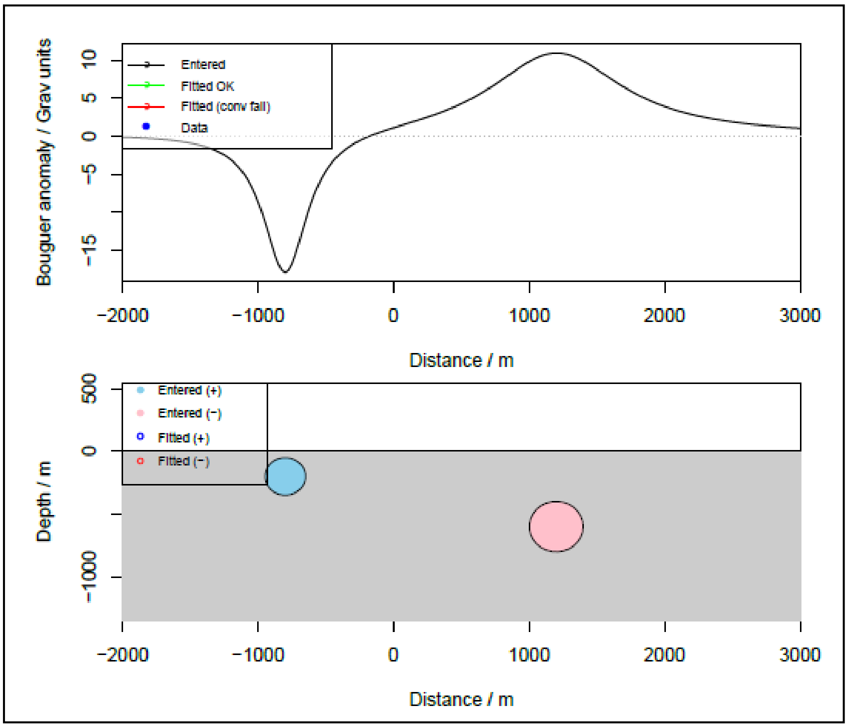

Figure 2: The lower panel shows a cross-section through the ground. The circles represent denser (right) and less dense (left) regions. The upper panel shows the gravity that might be measured at the surface. (Pumphrey, 2014)

3.2 3D Geological modelling

Rock samples were collected from every well during drilling and subjected to a number of tests to describe their properties. The first test was observation under a binocular microscope. This was done to identify the physical properties of the rock i.e. colour, texture, mineralogy, alteration intensity etc. Thin sections of the rock cuttings were also analyzed on a petrographic microscope to confirm the rock type and identify the alteration minerals that could not be identified under a binocular microscope. The geological data, i.e. the rock types were modelled using a software (RockWorks 16) to produce geological models as shown in figure 4. Figure 3 below shows the wells studied and their respective trajectories.

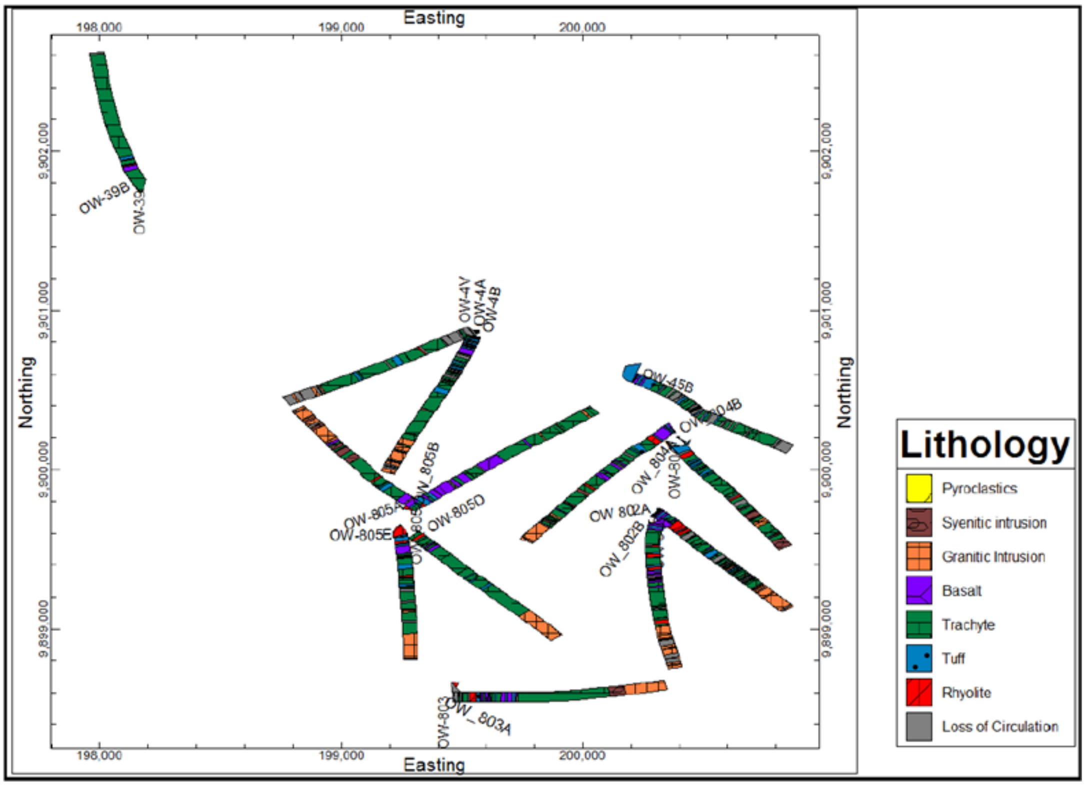

Figure 3: Map showing the location of the wells and their respective trajectories.

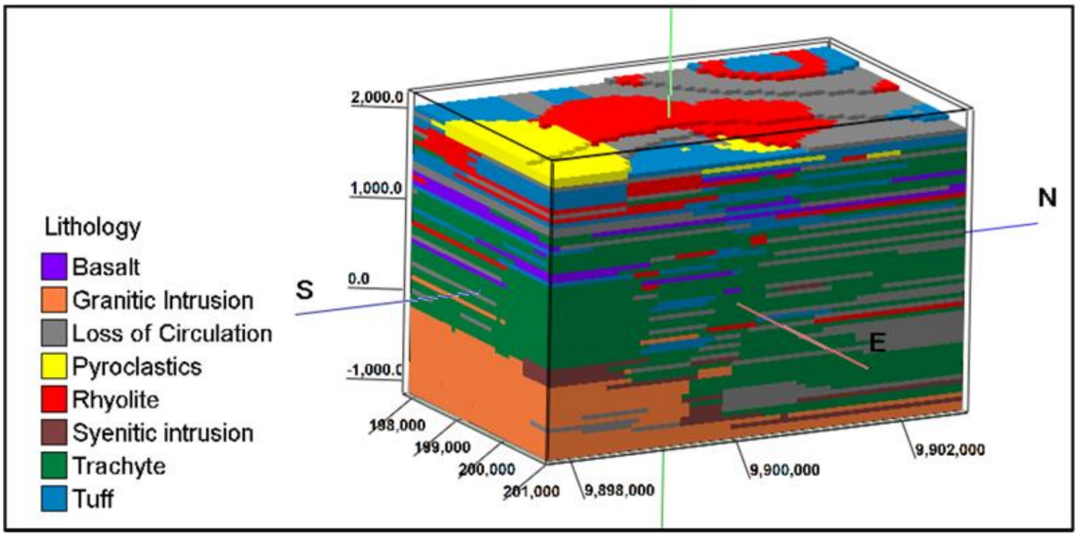

Figure 4: 3D solid geological model of study area.

4. Data Analysis and Results

4.1. Geology

The 3D geological model was built by modelling the rock types encountered during drilling of geothermal wells. The general stratigraphic sequence observed from shallowest formation to the deepest is

Pyroclastics
Rhyolite
Tuff

Basalt
Trachyte
Intrusions

The common intrusions encountered are granitic and syenitic types. In areas covered by the Oloolbutot lava flow, the rhyolite lavas are younger than the pyroclastics and therefore are encountered before the pyroclastics. A second layer of rhyolite lava is found beneath the pyroclastics. Tuffs occur intercalated with basalts and trachytes but the trachytes form the bulk of the reservoir rocks. The intrusions occur as dykes and sills. However, no detailed study has been done to ascertain the extent of the intrusion but preliminary studies indicate a granitic intrusion of batholithic dimensions. These rock layers are represented in the simplified stratigraphic column below.

	Pyroclastics
	Rhyolite
	Tuff
	Basalt
	Trachyte
	Syenitic Intrusion
	Granitic Intrusion

Table 1: Simplified stratigraphic column.

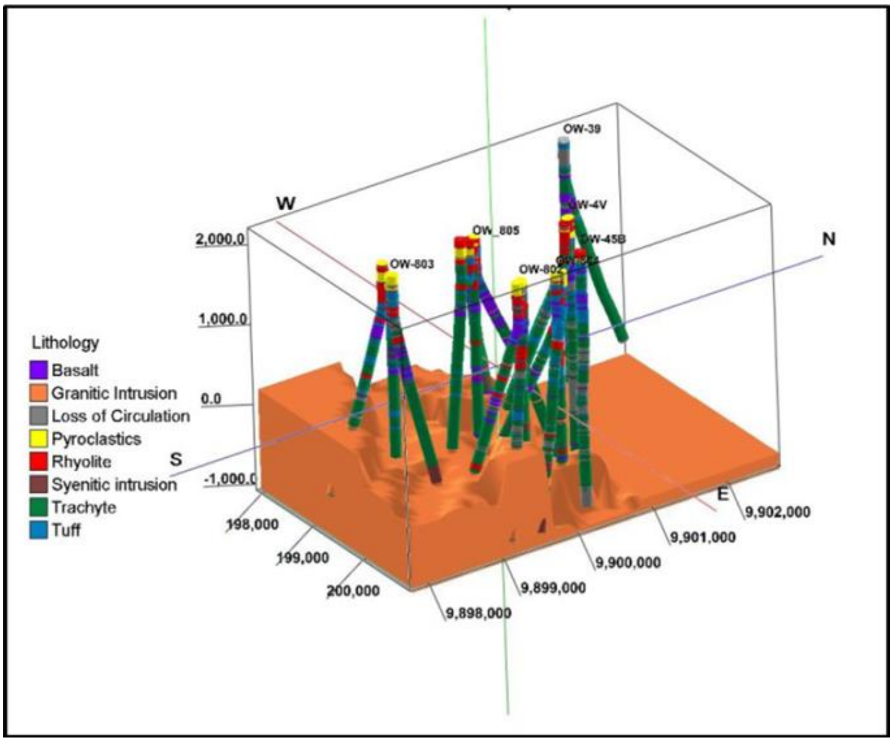

Figure 5: Geological model showing the granitic intrusion and 3D striplogs of the geothermal wells.

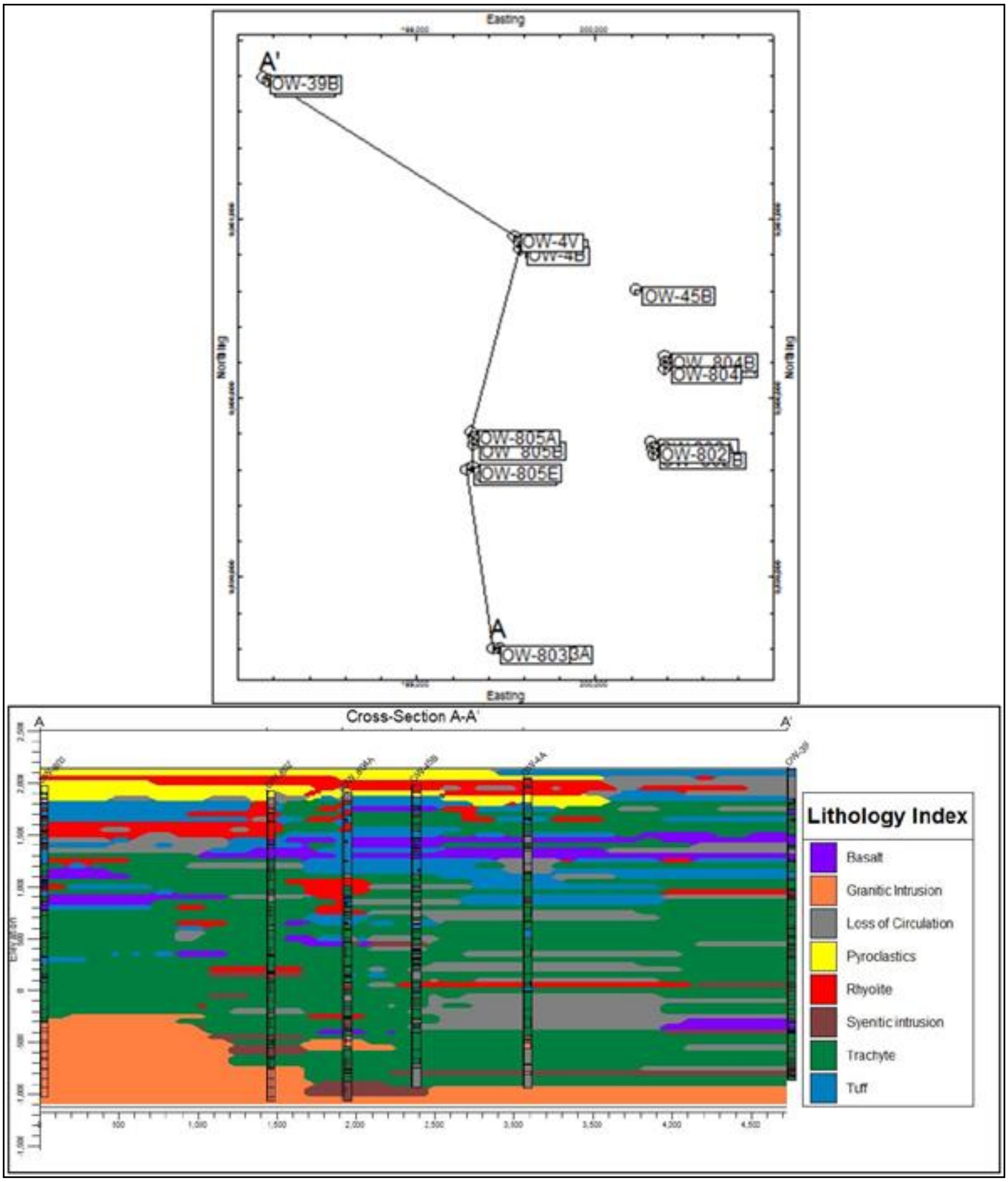

Figure 6: Cross section A-A' through wells 39-4-805-803.

The cross section above shows the granitic intrusion was encountered at relatively shallower depths towards the South at well 803 and appears at deeper levels towards the north at wells 4 and 39.

4.2. Gravity

A total of 118 gravity points were used for this particular study. The figure below shows the location of the data points.

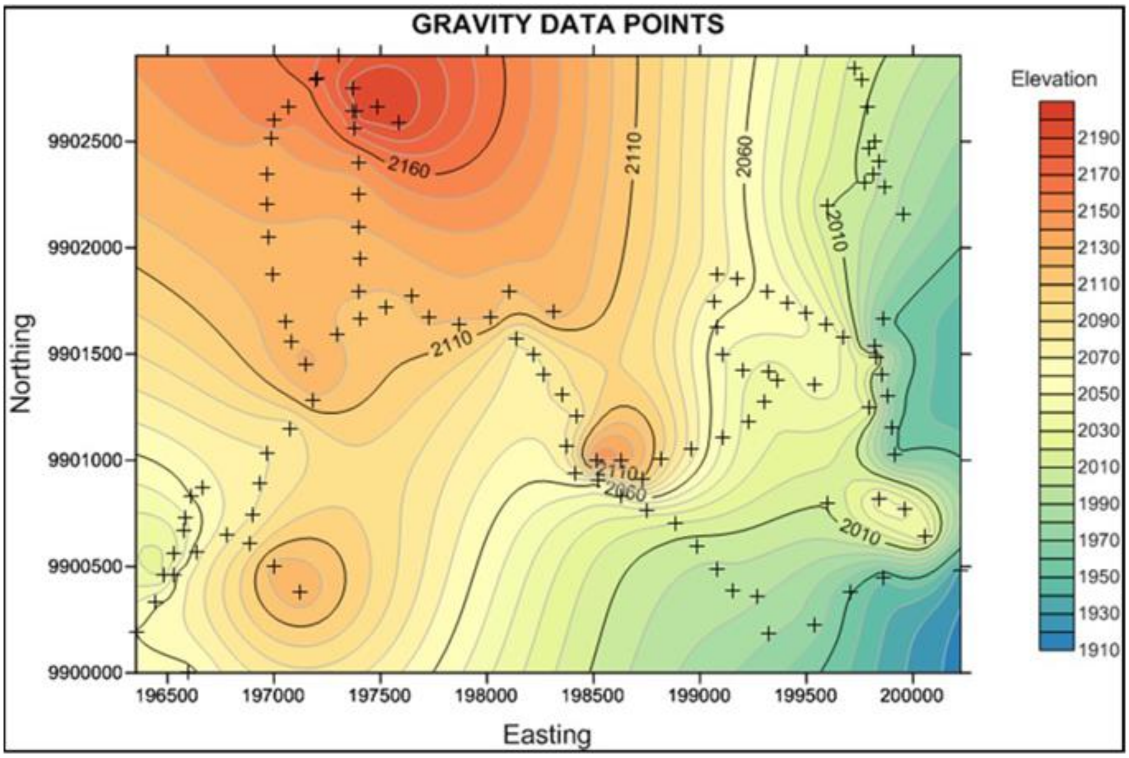

Figure 7: Map showing the location of gravity data points.

Generally, the area shows a largely negative Bouguer anomaly. The negative lows reach a minimum of -1883mGal while the gravity highs reach a maximum of -1733mGal. The highs are concentrated on the Western part of the study area. This area is centred over the locations where the granitic intrusion was shallowest.

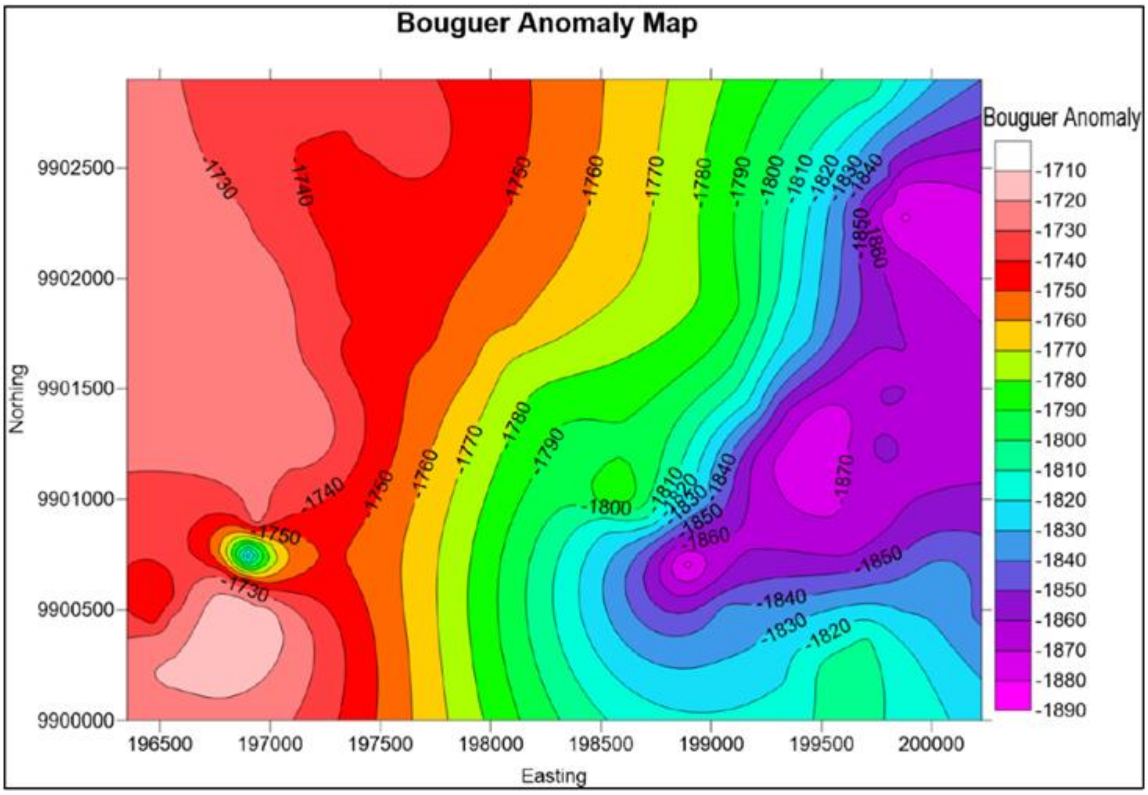

Figure 8: Bouguer anomaly map

Granitic and syenitic intrusions in Olkaria are crystalline, more compact and relatively fresh as compared to trachytes which form the bulk of the reservoir rocks. The trachytes, being the main reservoir rocks, are more porous than the intrusions and have been subjected to fracturing and hydrothermal alteration. These conditions affect their (Trachytes) densities and for these reasons we observe higher Bouguer anomaly values towards the western side of the map where the intrusions were encountered during drilling.

5. Discussions, Conclusions And Recommendations

From this study it is evident that the geology based model is consistent with geophysical data. The Bouguer anomaly is generally centred over the areas where the granitic and syenitic intrusions were shallowest. Gravity variations are as a result of the different lithological units which have different densities. The intrusions are compact, massive and denser than the other lava rocks which are relatively more porous. These porous rocks include the Tuffs and trachytes. The lava rocks also occur as thin intercalations.

It is recommended that more gravity surveys be conducted to the western side of the study area to determine the extent of this feature. 3D gravity modelling should also be undertaken in order to get a more defined geometry of the intrusion to guide in future siting of geothermal wells. It has been proven that these intrusions provide heat to the geothermal reservoir and therefore defining its geometry goes a long way in making informed decisions in siting and drilling of geothermal wells.

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