



# Contribution to the Geothermal Exploration of Eburru Field

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**Abstract:** With the increasing global demand for clean energy, the use of geothermal energy is expected to increase in the future. The East African countries, especially those crossed by the East African Rift System, have a significant potential in geothermal energy. This paper comes therefore to bring a contribution in the exploration of this clean energy in Africa especially in the region of Eburru in Kenya. Eburru is one of the geothermal fields in Kenya, with the estimated capacity of around 250Mwe. This paper presents the results and interpretations of the processing and the analysis of some geophysical survey data especially gravity, geochemical data and geological data acquired during our field survey. For the geology studies, a geological map showing structures trending in North-South direction and also several geothermal manifestations like fumaroles, hot ground and craters were mapped. From the geophysical studies, a heat source located at 1500 meters below masl and the reservoir is estimated between 1000 above masl to 1000 below masl. The cap rock of this prospect is between 1000 to 2000 meters above masl and the density increases from the West to the East of the prospect. The interpretation of the fluids geothermometers gave the calculated temperature between 255-270 Celsius degree. By combining and interpreting the different results obtained, we found that the Eburru, with the reservoir temperatures ranged between 255-270°C, has the potential to provide geothermal energy for various utilization.

**Keywords:** Geothermal Energy, Exploration, Eburru

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## 1. Introduction

The East African Rift System is endowed with a geothermal energy resource potential of about 20 GW that can be used for power generation and direct use application.

The geothermal field of Eburru is located in the great East African Rift System (EARS) which is a major tectonic structure stretching about 6100 km starting from the Red Sea in the north to Mozambique in the south. The Rift starts from a triple junction, evident in Ethiopia; at this point, two branches are in contact with the Red Sea and the Gulf of Eden while the third passes through Ethiopia to the south. [1, 2]

The East African Rift System (EARS) stretches through Eritrea, Ethiopia, Kenya, and all the way down to

Mozambique (Figure 1). The great Africa Rift system forms more or less a linear like zone where the continental plate is being pulled apart with the rifting between. A widened mantle plume probably began under east Africa creating the three arms which are: The East Africa Rift, The Gulf of Eden Rift and The Red Sea Rift. The heat flow from the asthenosphere along the rift zones led to volcanism and the formation of domes, as can be seen in Olkaria to the south of Eburru (Figure 1). The eastern branch is believed to be much older and is considered to have developed about 13-23 million years earlier than the western branch; this is supported by the discovery of preserved vertebrate fossils and volcanic ash which are believed to be about 23 million years old [1, 2].

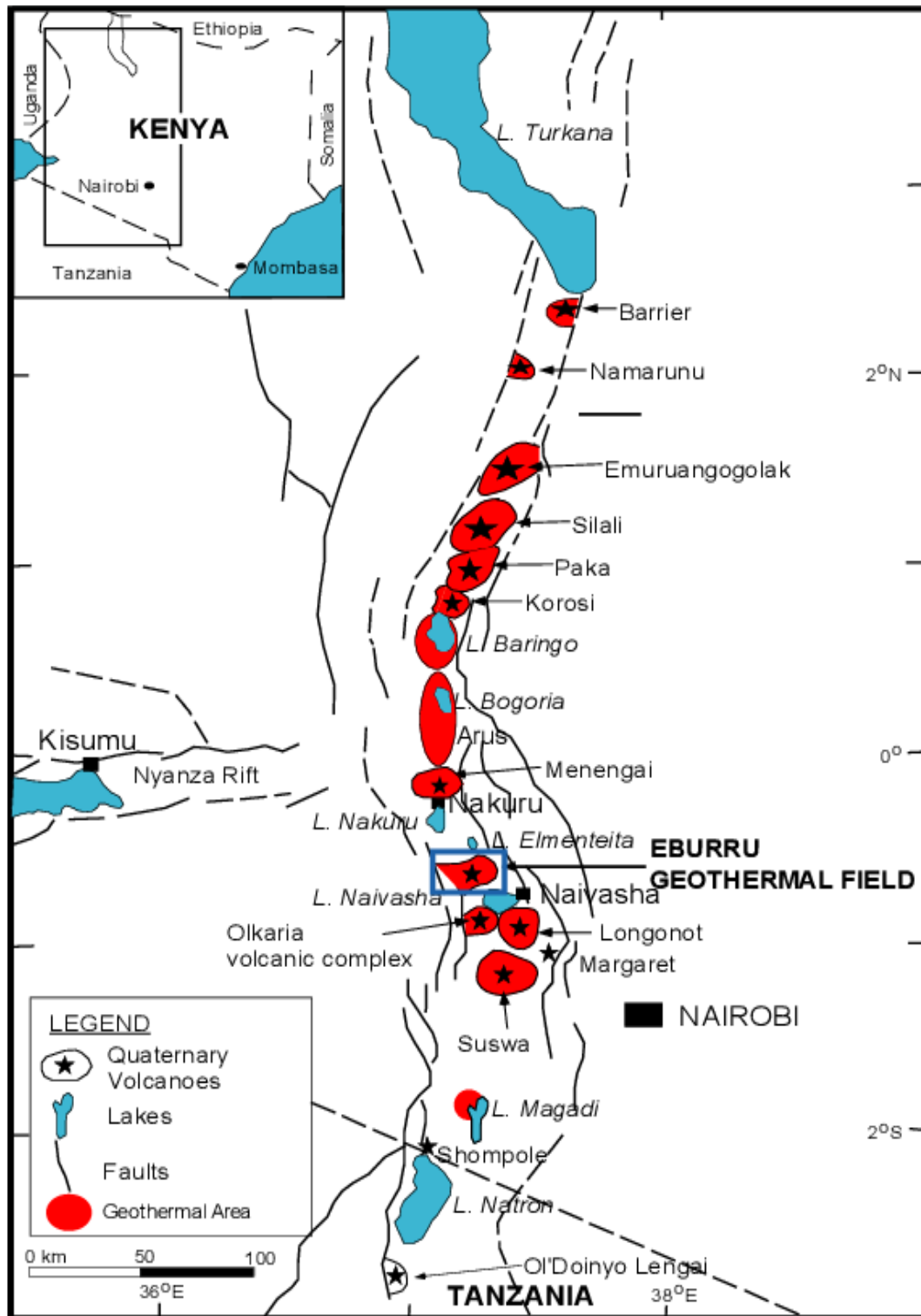


Figure 1. Map showing location of Eburru geothermal field [1].

## 2. Methodology

The methodology used to achieve this noble work was availed by Africa Geothermal Center of Excellence (AGCE) through resource materials including data sets derived from the field (geophysical, geochemical and geological survey) internet and previous work data. Programs and softwares such

as Golden Software Surfer 13, ArcGIS Desktop 10.1 and Microsoft Excel 13 were used to process and analyze the data acquired during the field survey (Geochemistry, Geophysics and Geology). After that, maps were produced for: surface temperature, Carbone dioxide distribution, Radon distribution and gravity (Complete Bouguer Anomaly). So we tried to do the interpretation by integrating all those data sets and maps produced.

### 3. Geology

#### 3.1. Volcanology and Geology of Eburru

Eburru is a complex volcanic located in the Kenya Rift. Eburru volcanic complex is made of two topographic highs in the west and the east. Each of these topographic entities is a ring structure. The west ring structure has an approximate diameter of 2 km. [2]

Other geologic structures in west Eburru are normal faults of age between 0.8 Ma and 0.4 Ma. This west side of Eburru are characterized by the presence of lineaments which are curved towards the axis of the Rift Valley. No geological map of the West Eburru because of pyroclastic events and vegetated forest.

The east ring structure has been referred to as caldera-like. Close examination of the satellite image and aerial photographs reveal the presence of a ring structure associated with eastern Eburru. Eburru hill, the second highest peak in the volcanic complex, is located on the northeast margin of the ring structure and rises to about 2600 masl [2].

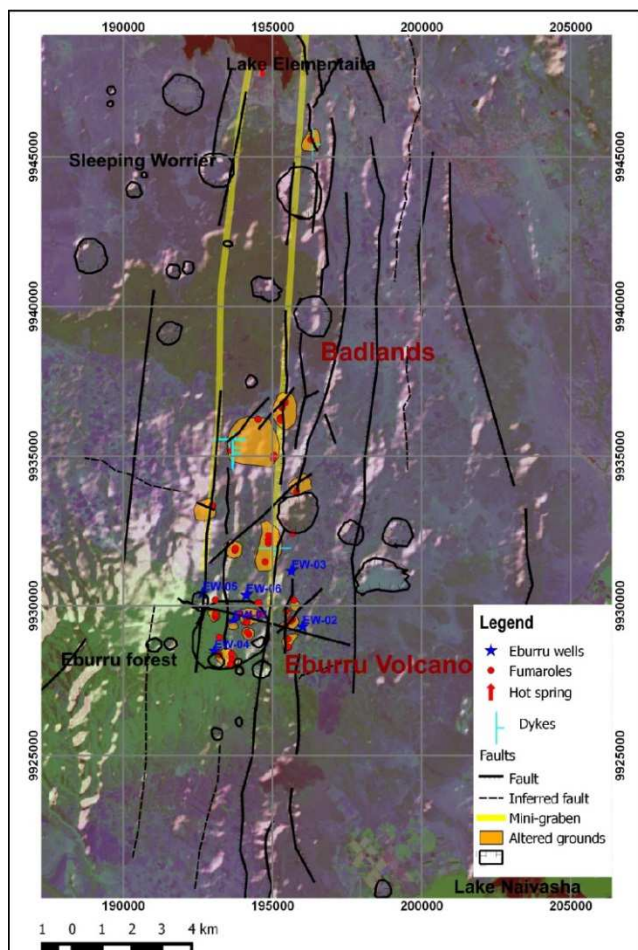


Figure 2. Map showing structural geology of Eburru [2].

#### 3.2. Stratigraphy of Eburru

The stratigraphic section of Eburru based on surface rock outcrops is separated into older and younger lava.

The oldest to the youngest section is composed of 1) older pantellerite, 2) older trachyte, 3) older basalts, 4) older pyroclastic sequence.

The younger sequences are 1) younger trachyte, 2) younger basaltic unit, 3) younger pyroclastic sequence, 4) younger pantelleritic unit. These younger sequences are between 0.4 Ma and 100 years old. [2]

The 0.8 Ma to 0.4 Ma faults offset the older lava and pyroclastic sequences. The estimated age for these lavas is between 1.2 Ma and 0.4 Ma. The younger sequences are 1) younger trachyte, which overlays the older pyroclastics and is not faulted and outcrops only in eastern Eburru, 2) younger basaltic unit, which is not faulted and caps the older basaltic unit, 3) younger pyroclastics sequence, which partially covers eastern and western Eburru and is not faulted, 4) younger pantelleritic unit, which in some locations seems to be contemporaneous with the pyroclastics, and in others overlays the pyroclastics. These younger sequences have an age between 0.4 Ma and 100 years. [2]

#### 3.3. Geological Structure of Eburru

In Eburru, several faults are identifiable. They date from 0.8 Ma to 0.4 Ma. [2]

#### 3.4. Eruptive Centres of Eburru

Eburru hill which culminates in 2600 meters. There are several craters. [2]

#### 3.5. Hydrothermal Activity

Fumerols associated with faults and crater (Velador et al.; 2003) Hot ground. The altered zones contain secondary minerals of kaolinite, smectite, native sulfur, and sinter which implies high heat flow from the source. [2]

Below about 1500masl for wells within the ring structure occurs epidote, garnet, calcite, biotite, illite, vermiculite and chlorite which indicates temperatures of more than 220°C.

Low temperature secondary minerals occur below 2000 masl. [2]

### 4. Geochemistry

Water and steam geothermometers are collectively termed chemical geothermometers. During the ascent of geothermal waters from a deep reservoir to the surface, they may cool by conductive heat loss as they travel through cooler rocks or by boiling because of decreasing hydrostatic head [5-15].

From the soil gas sampling, distribution maps of CO<sub>2</sub>, and Rn were produced. From the distribution maps the area in the southwest has high concentrations of Randon and Carbon dioxide. The presence of radon indicates the decay of magmatic material. These high concentrations of radon and carbon dioxide help to map out the heat source and the presence of fractures. In addition, these areas with high concentration of Radon and Carbondioxide also have high surface temperatures probably meaning presence of the heat source underneath. [3, 6-11]

#### 4.1. Radon Distribution

Table 1. Radon data.

| No. | Eastings | Northings | Rn-222 | No. | Eastings | Northings | Rn-222 | No. | Eastings | Northings | Rn-222 |
|-----|----------|-----------|--------|-----|----------|-----------|--------|-----|----------|-----------|--------|
| 1   | 198000   | 9930000   | 411    | 34  | 195850   | 9928700   | 427    | 67  | 196950   | 9927600   | 489    |
| 2   | 197750   | 9929950   | 718    | 35  | 195850   | 9929000   | 230    | 68  | 197250   | 9927600   | 340    |
| 3   | 197400   | 9929900   | 1764   | 36  | 195850   | 9929300   | 681    | 69  | 197550   | 9927600   | 223    |
| 4   | 197100   | 9929820   | 829    | 37  | 195850   | 9929650   | 594    | 70  | 197450   | 9930250   | 364    |
| 5   | 196850   | 9929820   | 1160   | 38  | 195850   | 9929950   | 290    | 71  | 197150   | 9930700   | 452    |
| 6   | 196350   | 9929800   | 681    | 39  | 195875   | 9930250   | 335    | 72  | 196800   | 9930165   | 722    |
| 7   | 196250   | 9929750   | 720    | 40  | 195850   | 9930575   | 620    | 73  | 196500   | 9930150   | 1100   |
| 8   | 195930   | 9929680   | 3562   | 41  | 196725   | 9937150   | 196    | 74  | 196200   | 9960100   | 931    |
| 9   | 195680   | 9929590   | 1583   | 42  | 196350   | 9936825   | 216    | 75  | 195900   | 9930075   | 1266   |
| 10  | 195400   | 9929450   | 63258  | 43  | 195875   | 9936800   | 300    | 76  | 195750   | 9930050   | 766    |
| 11  | 193000   | 9928550   | 60063  | 44  | 195375   | 9936775   | 700    | 77  | 195450   | 9930000   | 853    |
| 12  | 193550   | 9928750   | 1137   | 45  | 194450   | 9936400   | 670    | 78  | 195150   | 9930000   | 1091   |
| 13  | 193850   | 9928800   | 597    | 46  | 194400   | 9936700   | 1242   | 79  | 194850   | 9930000   | 321    |
| 14  | 194200   | 9928750   | 373    | 47  | 194050   | 9935850   | 1591   | 80  | 193000   | 9949000   | 100    |
| 15  | 194550   | 9928850   | 60     | 48  | 193550   | 9936050   | 254    | 81  | 194350   | 9946850   | 370    |
| 16  | 194750   | 9928850   | 183    | 49  | 193200   | 9936350   | 3000   | 82  | 196150   | 9944250   | 300    |
| 17  | 194990   | 9928950   | 854    | 50  | 192900   | 9936250   | 309    | 83  | 195300   | 9944500   | 580    |
| 18  | 195220   | 9929050   | 320    | 51  | 194750   | 9928450   | 319    | 84  | 195250   | 9943250   | 370    |
| 19  | 195510   | 9929150   | 1526   | 52  | 194750   | 9928450   | 2218   | 85  | 196200   | 9942500   | 280    |
| 20  | 195760   | 9929250   | 230    | 53  | 195050   | 9928475   | 398    | 86  | 196600   | 9942000   | 287    |
| 21  | 194950   | 9925950   | 126    | 54  | 195400   | 9928500   | 433    | 87  | 196500   | 9941300   | 140    |
| 22  | 194650   | 9926550   | 1025   | 55  | 195700   | 9928500   | 548    | 88  | 196200   | 9940100   | 380    |
| 23  | 194350   | 9928300   | 1628   | 56  | 196000   | 9928500   | 375    | 89  | 196250   | 9939100   | 418    |
| 24  | 194300   | 9928650   | 301    | 57  | 196300   | 9928500   | 102    | 90  | 192550   | 9930575   | 689    |
| 25  | 194300   | 9928950   | 104    | 58  | 196400   | 9928800   | 377    | 91  | 193000   | 9930600   | 870    |
| 26  | 194250   | 9929300   | 460    | 59  | 196700   | 9928750   | 281    | 92  | 193350   | 9930700   | 1832   |
| 27  | 194550   | 9929650   | 567    | 60  | 197000   | 9928750   | 683    | 93  | 193700   | 9930650   | 245    |
| 28  | 194450   | 9929900   | 1715   | 61  | 195150   | 9927350   | 1727   | 94  | 194000   | 9930650   | 261    |
| 29  | 194250   | 9930200   | 193    | 62  | 195450   | 9927450   | 18762  | 95  | 194200   | 9930650   | 393    |
| 30  | 194450   | 9930500   | 9237   | 63  | 195750   | 9927500   | 11016  | 96  | 194450   | 9930675   | 253    |
| 31  | 195900   | 9927800   | 503    | 64  | 196050   | 9927600   | 1685   | 97  | 194750   | 9930700   | 470    |
| 32  | 195900   | 9928100   | 488    | 65  | 196350   | 9927600   | 344    | 98  | 195050   | 9930750   | 890    |
| 33  | 195900   | 9928400   | 854    | 66  | 196650   | 9927600   | 393    | 99  | 196200   | 9930815   | 1266   |

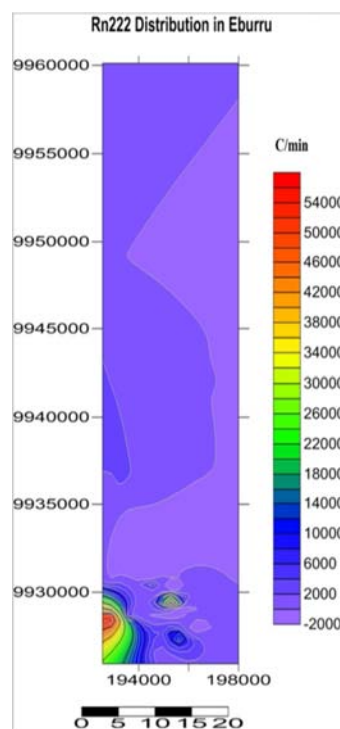


Figure 3. Map showing Radon distribution.

## 4.2. Carbon Dioxide Distribution

Table 2. Carbon dioxide sampling data.

| No. | Eastings | Northings | CO <sub>2</sub> (%) | No. | Eastings | Northings | CO <sub>2</sub> (%) | No. | Eastings | Northings | CO <sub>2</sub> (%) |
|-----|----------|-----------|---------------------|-----|----------|-----------|---------------------|-----|----------|-----------|---------------------|
| 1   | 198000   | 9930000   | 1,2                 | 34  | 195850   | 9928700   | 0,5                 | 67  | 196950   | 9927600   | 0,7                 |
| 2   | 197750   | 9929950   | 1,4                 | 35  | 195850   | 9929000   | 0,3                 | 68  | 197250   | 9927600   | 0,5                 |
| 3   | 197400   | 9929900   | 2,4                 | 36  | 195850   | 9929300   | 0,6                 | 69  | 197550   | 9927600   | 0,3                 |
| 4   | 197100   | 9929820   | 1,4                 | 37  | 195850   | 9929650   | 0,5                 | 70  | 197450   | 9930250   | 0,6                 |
| 5   | 196850   | 9929820   | 1,9                 | 38  | 195850   | 9929950   | 0,2                 | 71  | 197150   | 9930700   | 0,7                 |
| 6   | 196350   | 9929800   | 0,9                 | 39  | 195875   | 9930250   | 0,3                 | 72  | 196800   | 9930165   | 0,9                 |
| 7   | 196250   | 9929750   | 0,7                 | 40  | 195850   | 9930575   | 1,2                 | 73  | 196500   | 9930150   | 1,1                 |
| 8   | 195930   | 9929680   | 5,6                 | 41  | 196725   | 9937150   | 0,2                 | 74  | 196200   | 9960100   | 1                   |
| 9   | 195680   | 9929590   | 2,6                 | 42  | 196350   | 9936825   | 0,3                 | 75  | 195900   | 9930075   | 1,1                 |
| 10  | 195400   | 9929450   | 36,7                | 43  | 195875   | 9936800   | 0,4                 | 76  | 195750   | 9930050   | 0,4                 |
| 11  | 193000   | 9928550   | 25                  | 44  | 195375   | 9936775   | 0,8                 | 77  | 195450   | 9930000   | 0,6                 |
| 12  | 193550   | 9928750   | 1,8                 | 45  | 194450   | 9936400   | 0,9                 | 78  | 195150   | 9930000   | 0,8                 |
| 13  | 193850   | 9928800   | 0,6                 | 46  | 194400   | 9936700   | 1,1                 | 79  | 194850   | 9930000   | 0,5                 |
| 14  | 194200   | 9928750   | 0,7                 | 47  | 194050   | 9935850   | 1,3                 | 80  | 193000   | 9949000   | 0,2                 |
| 15  | 194550   | 9928850   | 0,2                 | 48  | 193550   | 9936050   | 0,4                 | 81  | 194350   | 9946850   | 0,5                 |
| 16  | 194750   | 9928850   | 0,5                 | 49  | 193200   | 9936350   | 2,7                 | 82  | 196150   | 9944250   | 0,4                 |
| 17  | 194990   | 9928950   | 0,9                 | 50  | 192900   | 9936250   | 0,4                 | 83  | 195300   | 9944500   | 0,6                 |
| 18  | 195220   | 9929050   | 0,4                 | 51  | 194750   | 9928450   | 0,5                 | 84  | 195250   | 9943250   | 0,7                 |
| 19  | 195510   | 9929150   | 1,6                 | 52  | 194750   | 9928450   | 1                   | 85  | 196200   | 9942500   | 0,4                 |
| 20  | 195760   | 9929250   | 0,6                 | 53  | 195050   | 9928475   | 0,6                 | 86  | 196600   | 9942000   | 1,8                 |
| 21  | 194950   | 9925950   | 0,3                 | 54  | 195400   | 9928500   | 0,8                 | 87  | 196500   | 9941300   | 0,8                 |
| 22  | 194650   | 9926550   | 0,8                 | 55  | 195700   | 9928500   | 0,7                 | 88  | 196200   | 9940100   | 0,6                 |
| 23  | 194350   | 9928300   | 1,8                 | 56  | 196000   | 9928500   | 0,6                 | 89  | 196250   | 9939100   | 0,7                 |
| 24  | 194300   | 9928650   | 0,6                 | 57  | 196300   | 9928500   | 0,2                 | 90  | 192550   | 9930575   | 0,7                 |
| 25  | 194300   | 9928950   | 0,3                 | 58  | 196400   | 9928800   | 0,5                 | 91  | 193000   | 9930600   | 1,2                 |
| 26  | 194250   | 9929300   | 0,9                 | 59  | 196700   | 9928750   | 0,3                 | 92  | 193350   | 9930700   | 2,1                 |
| 27  | 194550   | 9929650   | 1                   | 60  | 197000   | 9928750   | 0,7                 | 93  | 193700   | 9930650   | 0,3                 |
| 28  | 194450   | 9929900   | 1,5                 | 61  | 195150   | 9927350   | 1,8                 | 94  | 194000   | 9930650   | 0,3                 |
| 29  | 194250   | 9930200   | 0,2                 | 62  | 195450   | 9927450   | 13,2                | 95  | 194200   | 9930650   | 0,5                 |
| 30  | 194450   | 9930500   | 8,6                 | 63  | 195750   | 9927500   | 20,8                | 96  | 194450   | 9930675   | 0,4                 |
| 31  | 195900   | 9927800   | 0,6                 | 64  | 196050   | 9927600   | 1,5                 | 97  | 194750   | 9930700   | 0,8                 |
| 32  | 195900   | 9928100   | 0,7                 | 65  | 196350   | 9927600   | 0,5                 | 98  | 195050   | 9930750   | 1                   |
| 33  | 195900   | 9928400   | 0,8                 | 66  | 196650   | 9927600   | 0,4                 | 99  | 196200   | 9930815   | 1,3                 |

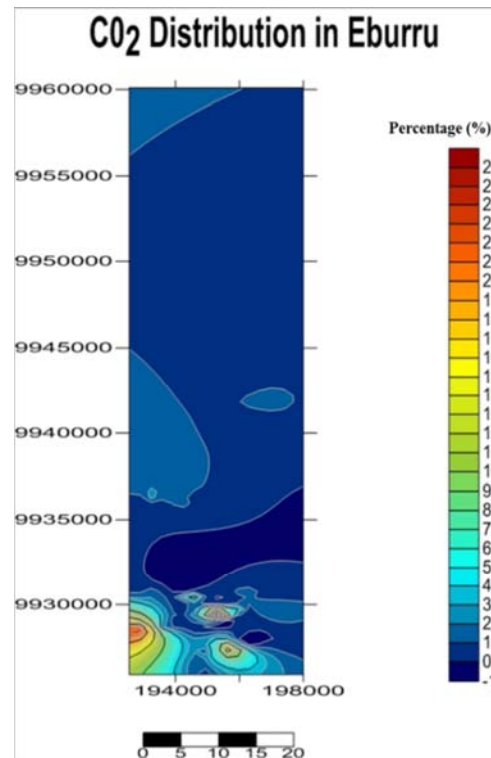


Figure 4. Map showing carbon dioxide distribution.



### 4.3. Surface Temperature Distribution

Table 3. Surface temperature data.

| No. | Eastings | Northings | Grnd temp | No. | Eastings | Northings | Grnd temp | No. | Eastings | Northings | Grnd temp |
|-----|----------|-----------|-----------|-----|----------|-----------|-----------|-----|----------|-----------|-----------|
| 1   | 198000   | 9930000   | 22,2      | 34  | 195850   | 9928700   | 22,1      | 67  | 196950   | 9927600   | 18,8      |
| 2   | 197750   | 9929950   | 15        | 35  | 195850   | 9929000   | 21,5      | 68  | 197250   | 9927600   | 23        |
| 3   | 197400   | 9929900   | 24,6      | 36  | 195850   | 9929300   | 21,2      | 69  | 197550   | 9927600   | 21,3      |
| 4   | 197100   | 9929820   | 26        | 37  | 195850   | 9929650   | 24,6      | 70  | 197450   | 9930250   | 20,7      |
| 5   | 196850   | 9929820   | 21,5      | 38  | 195850   | 9929950   | 22,2      | 71  | 197150   | 9930700   | 18,6      |
| 6   | 196350   | 9929800   | 22,5      | 39  | 195875   | 9930250   | 21,8      | 72  | 196800   | 9930165   | 20        |
| 7   | 196250   | 9929750   | 21,8      | 40  | 195850   | 9930575   | 20,5      | 73  | 196500   | 9930150   | 22,2      |
| 8   | 195930   | 9929680   | 25,9      | 41  | 196725   | 9937150   | 21,5      | 74  | 196200   | 9960100   | 20,2      |
| 9   | 195680   | 9929590   | 20,8      | 42  | 196350   | 9936825   | 21,6      | 75  | 195900   | 9930075   | 19,1      |
| 10  | 195400   | 9929450   | 41,4      | 43  | 195875   | 9936800   | 25        | 76  | 195750   | 9930050   | 21,5      |
| 11  | 193000   | 9928550   | 60,4      | 44  | 195375   | 9936775   | 30,3      | 77  | 195450   | 9930000   | 25,4      |
| 12  | 193550   | 9928750   | 19,4      | 45  | 194450   | 9936400   | 23,6      | 78  | 195150   | 9930000   | 13        |
| 13  | 193850   | 9928800   | 21,1      | 46  | 194400   | 9936700   | 34,4      | 79  | 194850   | 9930000   | 21,3      |
| 14  | 194200   | 9928750   | 21,1      | 47  | 194050   | 9935850   | 29        | 80  | 193000   | 9949000   | 39,7      |
| 15  | 194550   | 9928850   | 20,8      | 48  | 193550   | 9936050   | 24,2      | 81  | 194350   | 9946850   | 26,1      |
| 16  | 194750   | 9928850   | 20,9      | 49  | 193200   | 9936350   | 24,7      | 82  | 196150   | 9944250   | 26        |
| 17  | 194990   | 9928950   | 23,4      | 50  | 192900   | 9936250   | 22,8      | 83  | 195300   | 9944500   | 25,3      |
| 18  | 195220   | 9929050   | 23,5      | 51  | 194750   | 9928450   | 20,7      | 84  | 195250   | 9943250   | 31,9      |
| 19  | 195510   | 9929150   | 24,2      | 52  | 194750   | 9928450   | 17,7      | 85  | 196200   | 9942500   | 26,4      |
| 20  | 195760   | 9929250   | 22,2      | 53  | 195050   | 9928475   | 17,5      | 86  | 196600   | 9942000   | 21,5      |
| 21  | 194950   | 9925950   | 17,1      | 54  | 195400   | 9928500   | 21,7      | 87  | 196500   | 9941300   | 29,7      |
| 22  | 194650   | 9926550   | 22,9      | 55  | 195700   | 9928500   | 21        | 88  | 196200   | 9940100   | 26,8      |
| 23  | 194350   | 9928300   | 20,4      | 56  | 196000   | 9928500   | 24        | 89  | 196250   | 9939100   | 25,3      |
| 24  | 194300   | 9928650   | 21        | 57  | 196300   | 9928500   | 22,3      | 90  | 192550   | 9930575   | 19,6      |
| 25  | 194300   | 9928950   | 21,9      | 58  | 196400   | 9928800   | 21,1      | 91  | 193000   | 9930600   | 19,4      |
| 26  | 194250   | 9929300   | 20,4      | 59  | 196700   | 9928750   | 18,2      | 92  | 193350   | 9930700   | 22,1      |
| 27  | 194550   | 9929650   | 23,9      | 60  | 197000   | 9928750   | 18,6      | 93  | 193700   | 9930650   | 21,8      |
| 28  | 194450   | 9929900   | 23        | 61  | 195150   | 9927350   | 25        | 94  | 194000   | 9930650   | 27,6      |
| 29  | 194250   | 9930200   | 23,7      | 62  | 195450   | 9927450   | 87,8      | 95  | 194200   | 9930650   | 26,3      |
| 30  | 194450   | 9930500   | 35,6      | 63  | 195750   | 9927500   | 90,8      | 96  | 194450   | 9930675   | 20,2      |
| 31  | 195900   | 9927800   | 19,8      | 64  | 196050   | 9927600   | 18,9      | 97  | 194750   | 9930700   | 24,7      |
| 32  | 195900   | 9928100   | 18,7      | 65  | 196350   | 9927600   | 19,9      | 98  | 195050   | 9930750   | 30,1      |
| 33  | 195900   | 9928400   | 19,5      | 66  | 196650   | 9927600   | 18,1      | 99  | 196200   | 9930815   | 28,4      |

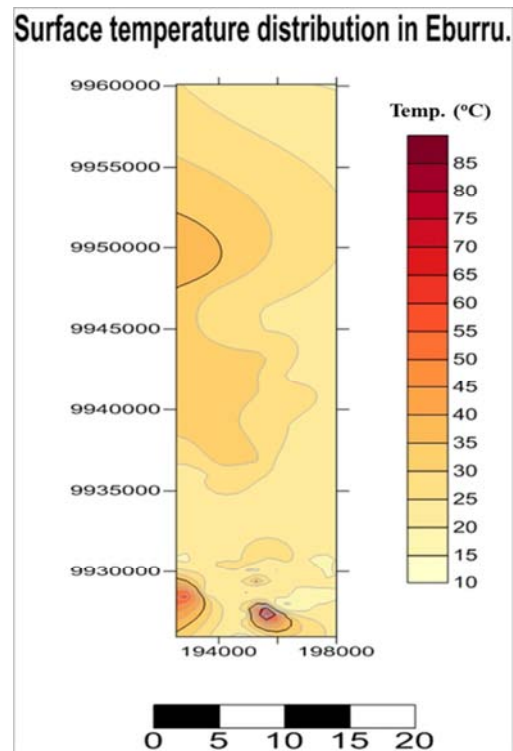


Figure 5. Map showing surface temperature distribution.

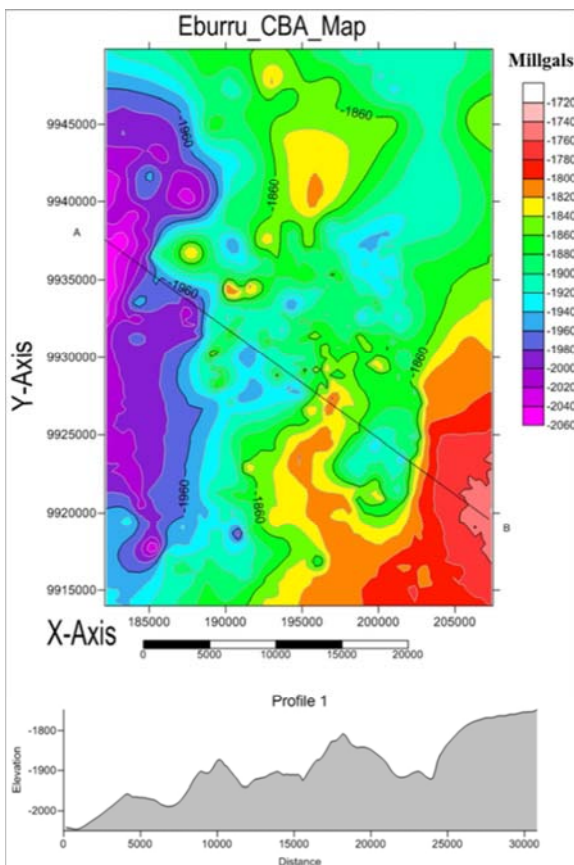
## 5. Geophysics (Gravity Surveys)

*Table 4. Complete bouguer Anomaly data.*

| No. | Easting | Northing | CBA     | No. | Easting | Northing | CBA     | No. | Easting | Northing | CBA     |
|-----|---------|----------|---------|-----|---------|----------|---------|-----|---------|----------|---------|
| 1   | 196310  | 9928500  | -1868,6 | 132 | 194700  | 9928800  | -1918,2 | 263 | 191300  | 9934400  | -1800,6 |
| 2   | 196060  | 9928510  | -1879,7 | 133 | 194660  | 9928800  | -1901,6 | 264 | 190900  | 9934200  | -1815,2 |
| 3   | 195815  | 9928400  | -1857,1 | 134 | 194600  | 9928700  | -1906,6 | 265 | 190400  | 9934100  | -1801,5 |
| 4   | 196290  | 9928910  | -1863,2 | 135 | 194600  | 9928600  | -1902,9 | 266 | 190400  | 9934200  | -1811,8 |
| 5   | 196255  | 9928855  | -1866,5 | 136 | 194700  | 9928400  | -1929   | 267 | 190000  | 9934300  | -1812,8 |
| 6   | 196130  | 9929055  | -1869,5 | 137 | 194735  | 9928310  | -1929,4 | 268 | 190000  | 9934500  | -1794,5 |
| 7   | 196110  | 9929200  | -1865,3 | 138 | 194800  | 9928255  | -1927,9 | 269 | 191100  | 9934600  | -1890,6 |
| 8   | 196135  | 9929455  | -1871,6 | 139 | 194910  | 9928200  | -1921,2 | 270 | 191100  | 9935600  | -1907,7 |
| 9   | 196320  | 9929700  | -1857,4 | 140 | 195000  | 9928030  | -1911,4 | 271 | 191100  | 9935700  | -1920,2 |
| 10  | 196355  | 9929800  | -1840,6 | 141 | 194900  | 9927760  | -1941,4 | 272 | 190700  | 9935800  | -1914,2 |
| 11  | 196425  | 9928600  | -1884,7 | 142 | 194800  | 9927600  | -1946,4 | 273 | 190700  | 9936000  | -1915,6 |
| 12  | 196310  | 9928500  | -1869,6 | 143 | 195900  | 9928400  | -1879   | 274 | 190600  | 9936400  | -1935,9 |
| 13  | 196600  | 9928800  | -1849,5 | 144 | 195900  | 9928200  | -1885,5 | 275 | 197800  | 9930500  | -1874,5 |
| 14  | 196700  | 9929000  | -1863,2 | 145 | 195700  | 9928200  | -1846,6 | 276 | 197900  | 9930300  | -1875,5 |
| 15  | 196700  | 9929100  | -1818,8 | 146 | 196000  | 9928200  | -1881,4 | 277 | 198200  | 9930060  | -1830,2 |
| 16  | 196700  | 9929200  | -1822,2 | 147 | 196100  | 9928100  | -1873,7 | 278 | 198400  | 9929800  | -1844,7 |
| 17  | 196700  | 9929400  | -1818,7 | 148 | 196300  | 9928200  | -1768,9 | 279 | 198900  | 9929300  | -1878,7 |
| 18  | 196900  | 9929800  | -1832,4 | 149 | 196600  | 9928100  | -1867,6 | 280 | 199300  | 9929100  | -1884,8 |
| 19  | 197200  | 9929700  | -1862,5 | 150 | 196300  | 9928000  | -1865,2 | 281 | 199600  | 9929900  | -1802,6 |
| 20  | 197400  | 9929800  | -1863,9 | 151 | 196700  | 9928000  | -1861,1 | 282 | 200100  | 9928800  | -1880,9 |
| 21  | 197500  | 9930255  | -1862,1 | 152 | 196060  | 9929500  | -1869,8 | 283 | 200600  | 9928000  | -1865,5 |
| 22  | 197500  | 9930800  | -1860,3 | 153 | 196000  | 9929290  | -1761   | 284 | 201100  | 9928600  | -1877,7 |
| 23  | 197400  | 9931000  | -1869   | 154 | 196000  | 9929000  | -1885,2 | 285 | 201500  | 9928400  | -1882,6 |
| 24  | 197300  | 9931200  | -1881,6 | 155 | 196055  | 9928940  | -1888,8 | 286 | 201800  | 9928200  | -1858,3 |
| 25  | 197100  | 9931500  | -1862   | 156 | 195900  | 9928900  | -1884,7 | 287 | 202100  | 9927800  | -1872   |
| 26  | 197055  | 9931700  | -1876,3 | 157 | 196100  | 9928700  | -1875,4 | 288 | 202300  | 9927600  | -1878,7 |
| 27  | 196900  | 9931900  | -1881,6 | 158 | 196255  | 9928600  | -1873   | 289 | 202500  | 9927000  | -1902,9 |
| 28  | 196755  | 9932155  | -1880,1 | 159 | 195700  | 9928600  | -1881,4 | 290 | 202100  | 9926400  | -1889,5 |
| 29  | 196655  | 9932400  | -1883,1 | 160 | 195700  | 9928600  | -1880,4 | 291 | 201900  | 9925400  | -1893,7 |
| 30  | 196555  | 9932600  | -1883,5 | 161 | 195800  | 9928800  | -1870,4 | 292 | 201700  | 9924300  | -1882,1 |
| 31  | 196800  | 9928900  | -1856   | 162 | 195700  | 9928800  | -1881,8 | 293 | 201400  | 9924800  | -1895,1 |
| 32  | 197100  | 9928900  | -1885,4 | 163 | 195300  | 9928900  | -1889,7 | 294 | 200800  | 9924000  | -1899,8 |
| 33  | 197400  | 9928900  | -1869,1 | 164 | 195200  | 9929100  | -1874,9 | 295 | 200200  | 9923700  | -1901,7 |
| 34  | 197600  | 9928800  | -1872,7 | 165 | 195400  | 9929100  | -1889,7 | 296 | 199800  | 9923300  | -1902,4 |
| 35  | 197800  | 9928800  | -1858,8 | 166 | 195455  | 9929040  | -1888,3 | 297 | 199500  | 9922800  | -1884,6 |
| 36  | 197900  | 9928800  | -1844,2 | 167 | 195500  | 9929300  | -1885,6 | 298 | 199300  | 9922400  | -1881,3 |
| 37  | 197900  | 9928900  | -1858,3 | 168 | 195500  | 9929400  | -1875,6 | 299 | 198100  | 9930700  | -1879,1 |
| 38  | 197700  | 9929200  | -1845,6 | 169 | 195400  | 9930100  | -1892,9 | 300 | 198300  | 9930900  | -1875   |
| 39  | 197700  | 9929400  | -1845,2 | 170 | 195100  | 9930100  | -1896,3 | 301 | 198600  | 9930900  | -1870,1 |
| 40  | 197600  | 9929500  | -1849,4 | 171 | 195000  | 9930000  | -1893,6 | 302 | 198600  | 9931300  | -1837,8 |
| 41  | 195100  | 9929200  | -1827,5 | 172 | 194900  | 9930100  | -1894,2 | 303 | 198300  | 9931200  | -1877   |
| 42  | 195200  | 9929400  | -1864   | 173 | 194800  | 9930300  | -1893   | 304 | 198300  | 9930500  | -1870,7 |
| 43  | 194900  | 9929500  | -1887,9 | 174 | 194700  | 9930400  | -1898,5 | 305 | 198600  | 9930500  | -1866,2 |
| 44  | 194700  | 9929500  | -1894   | 175 | 194800  | 9930300  | -1904,5 | 306 | 199000  | 9930500  | -1870,3 |
| 45  | 194200  | 9929500  | -1909   | 176 | 194700  | 9930200  | -1888,5 | 307 | 199300  | 9930600  | -1834,5 |
| 46  | 194100  | 9929400  | -1902,1 | 177 | 194600  | 9930055  | -1891,5 | 308 | 199700  | 9930900  | -1876,3 |
| 47  | 193800  | 9929600  | -1913   | 178 | 194500  | 9930000  | -1897,6 | 309 | 198700  | 9929700  | -1873,4 |
| 48  | 193700  | 9929200  | -1910,6 | 179 | 195000  | 9929600  | -1898,6 | 310 | 199200  | 9929600  | -1855   |
| 49  | 194600  | 9929900  | -1900   | 180 | 195200  | 9929900  | -1908,9 | 311 | 199500  | 9929900  | -1875,2 |
| 50  | 194455  | 9930100  | -1897   | 181 | 195300  | 9930100  | -1898,7 | 312 | 199800  | 9930100  | -1876,1 |
| 51  | 194100  | 9930300  | -1891,4 | 182 | 195300  | 9930200  | -1896,8 | 313 | 200100  | 9930600  | -1881,8 |
| 52  | 193800  | 9930400  | -1856,9 | 183 | 195200  | 9930000  | -1872,3 | 314 | 200500  | 9930600  | -1865,8 |
| 53  | 193700  | 9930600  | -1880,2 | 184 | 195400  | 9929800  | -1890,1 | 315 | 200500  | 9931100  | -1862,6 |
| 54  | 193500  | 9930800  | -1906   | 185 | 193600  | 9931300  | -1922,4 | 316 | 200700  | 9931400  | -1874   |
| 55  | 193400  | 9931000  | -1886,2 | 186 | 193500  | 9931200  | -1911,1 | 317 | 198900  | 9929700  | -1865   |
| 56  | 193300  | 9930700  | -1902,6 | 187 | 193500  | 9931100  | -1902,9 | 318 | 200700  | 9930600  | -1841   |
| 57  | 193100  | 9930700  | -1894,5 | 188 | 193500  | 9930900  | -1921   | 319 | 200900  | 9930500  | -1865,9 |
| 58  | 193100  | 9930900  | -1899,6 | 189 | 193600  | 9931900  | -1921,3 | 320 | 201200  | 9930400  | -1880,1 |
| 59  | 192900  | 9931000  | -1852,8 | 190 | 193500  | 9931900  | -1902,6 | 321 | 201500  | 9930300  | -1882,9 |
| 60  | 192900  | 9931200  | -1875,8 | 191 | 193500  | 9931800  | -1922   | 322 | 201900  | 9930200  | -1883,1 |
| 61  | 193000  | 9931355  | -1912,6 | 192 | 194600  | 9929600  | -1887,4 | 323 | 201800  | 9930500  | -1884,1 |
| 62  | 193155  | 9931510  | -1901,6 | 193 | 193600  | 9928800  | -1877,7 | 324 | 201700  | 9930700  | -1875,5 |
| 63  | 193255  | 9931620  | -1905,8 | 194 | 193400  | 9928800  | -1844,3 | 325 | 201700  | 9930000  | -1901,7 |
| 64  | 193400  | 9931700  | -1912,4 | 195 | 193200  | 9928600  | -1910,1 | 326 | 199500  | 9929500  | -1836,3 |

| No. | Easting | Northing | CBA     | No. | Easting | Northing | CBA     | No. | Easting | Northing | CBA     |
|-----|---------|----------|---------|-----|---------|----------|---------|-----|---------|----------|---------|
| 65  | 193500  | 9931700  | -1922,6 | 196 | 193100  | 9928500  | -1905,2 | 327 | 199800  | 9929300  | -1853,9 |
| 66  | 193600  | 9931700  | -1929,1 | 197 | 193700  | 9930300  | -1879,7 | 328 | 200055  | 9929200  | -1817,7 |
| 67  | 194400  | 9929900  | -1909,2 | 198 | 190700  | 9936900  | -1946,6 | 329 | 200500  | 9929000  | -1860,5 |
| 68  | 194300  | 9929900  | -1905,8 | 199 | 196500  | 9933100  | -1890,8 | 330 | 201000  | 9929000  | -1865,7 |
| 69  | 194100  | 9929800  | -1904,7 | 200 | 196600  | 9933500  | -1892,1 | 331 | 201100  | 9928900  | -1883,5 |
| 70  | 193900  | 9929800  | -1915,7 | 201 | 196400  | 9933700  | -1894   | 332 | 201300  | 9929000  | -1878   |
| 71  | 193700  | 9929600  | -1901,4 | 202 | 196300  | 9933800  | -1900,6 | 333 | 201600  | 9929100  | -1876,6 |
| 72  | 193800  | 9929900  | -1922,4 | 203 | 196200  | 9934000  | -1900,2 | 334 | 201800  | 9929200  | -1885,3 |
| 73  | 193900  | 9930100  | -1913,9 | 204 | 196000  | 9934200  | -1932,8 | 335 | 196755  | 9933020  | -1880,7 |
| 74  | 193700  | 9930300  | -1899,2 | 205 | 196500  | 9934700  | -1891,6 | 336 | 197000  | 9933100  | -1892,8 |
| 75  | 194400  | 9930300  | -1892,3 | 206 | 196800  | 9935000  | -1917,9 | 337 | 197400  | 9932900  | -1890,5 |
| 76  | 194400  | 9930400  | -1890,4 | 207 | 196800  | 9935700  | -1884,2 | 338 | 197800  | 9933100  | -1896   |
| 77  | 194300  | 9930500  | -1893,2 | 208 | 196700  | 9936100  | -1891,8 | 339 | 198100  | 9932700  | -1898,1 |
| 78  | 194200  | 9930600  | -1890,7 | 209 | 196600  | 9936500  | -1905,6 | 340 | 198300  | 9932400  | -1887,4 |
| 79  | 194100  | 9930700  | -1881,8 | 210 | 196100  | 9936700  | -1895,3 | 341 | 198300  | 9932200  | -1894,2 |
| 80  | 193900  | 9930900  | -1868   | 211 | 195700  | 9936700  | -1902,6 | 342 | 198100  | 9931900  | -1906,4 |
| 81  | 193700  | 9931100  | -1905,3 | 212 | 195200  | 9936700  | -1880   | 343 | 197800  | 9931600  | -1898,6 |
| 82  | 193700  | 9931400  | -1904,9 | 213 | 194800  | 9936500  | -1898,3 | 344 | 199100  | 9932300  | -1920   |
| 83  | 193700  | 9931500  | -1895,8 | 214 | 194600  | 9936100  | -1892,2 | 345 | 199100  | 9932300  | -1916,2 |
| 84  | 194000  | 9931600  | -1873,8 | 215 | 194600  | 9935600  | -1875,6 | 346 | 197600  | 9933200  | -1897   |
| 85  | 194300  | 9931500  | -1898,1 | 216 | 194200  | 9936100  | -1882,1 | 347 | 197800  | 9933400  | -1893   |
| 86  | 194200  | 9931300  | -1904,8 | 217 | 194800  | 9935800  | -1885,7 | 348 | 198200  | 9933900  | -1897,9 |
| 87  | 194200  | 9931200  | -1894   | 218 | 193800  | 9936000  | -1890   | 349 | 198600  | 9934000  | -1903   |
| 88  | 194200  | 9931100  | -1884,2 | 219 | 194500  | 9937900  | -1897,7 | 350 | 198700  | 9934300  | -1903,2 |
| 89  | 194400  | 9931000  | -1895,4 | 220 | 193000  | 9936200  | -1887,3 | 351 | 198100  | 9933700  | -1897,8 |
| 90  | 194700  | 9930800  | -1887,5 | 221 | 192700  | 9936100  | -1887,5 | 352 | 197600  | 9933500  | -1892,2 |
| 91  | 194300  | 9931700  | -1902   | 222 | 192400  | 9936400  | -1901,8 | 353 | 197300  | 9933700  | -1881,4 |
| 92  | 194300  | 9931800  | -1892,9 | 223 | 192300  | 9936300  | -1902,9 | 354 | 197100  | 9933700  | -1878,6 |
| 93  | 194600  | 9931075  | -1893,7 | 224 | 191900  | 9936400  | -1907,5 | 355 | 196600  | 9934100  | -1895,9 |
| 94  | 194255  | 9931020  | -1883,6 | 225 | 191500  | 9936600  | -1913,1 | 356 | 196800  | 9934600  | -1915,5 |
| 95  | 194875  | 9930855  | -1875,1 | 226 | 191200  | 9936600  | -1935   | 357 | 197000  | 9934500  | -1886,6 |
| 96  | 195000  | 9930990  | -1857,4 | 227 | 190800  | 9936800  | -1941,4 | 358 | 196800  | 9934600  | -1902,4 |
| 97  | 195055  | 9931100  | -1872   | 228 | 190500  | 9937300  | -1961,2 | 359 | 196900  | 9935300  | -1848,4 |
| 98  | 195100  | 9931170  | -1875,3 | 229 | 190400  | 9937500  | -1955,4 | 360 | 197100  | 9935200  | -1860,5 |
| 99  | 195200  | 9931255  | -1873,9 | 230 | 190200  | 9937600  | -1942,3 | 361 | 197500  | 9935200  | -1870,9 |
| 100 | 194800  | 9931200  | -1876,6 | 231 | 196600  | 9928200  | -1856,3 | 362 | 197800  | 9935200  | -1874,5 |
| 101 | 195655  | 9931180  | -1879,6 | 232 | 196800  | 9928300  | -1842,8 | 363 | 197700  | 9935500  | -1889,4 |
| 102 | 194755  | 9931300  | -1883,1 | 233 | 197000  | 9928310  | -1792,7 | 364 | 197600  | 9935800  | -1898,1 |
| 103 | 195755  | 9931255  | -1878,8 | 234 | 197200  | 9928320  | -1840,4 | 365 | 183020  | 9941500  | -2025,6 |
| 104 | 194800  | 9931530  | -1885,8 | 235 | 197400  | 9928325  | -1838,8 | 366 | 183340  | 9942010  | -2000,6 |
| 105 | 195700  | 9931420  | -1771,8 | 236 | 197490  | 9928370  | -1844,7 | 367 | 183330  | 9943100  | -2011,1 |
| 106 | 194800  | 9931700  | -1890,4 | 237 | 197700  | 9928410  | -1857,4 | 368 | 183330  | 9944255  | -1977,9 |
| 107 | 195655  | 9931560  | -1876,5 | 238 | 197760  | 9928500  | -1844   | 369 | 183330  | 9946030  | -1982,5 |
| 108 | 195460  | 9931540  | -1880,6 | 239 | 194600  | 9932000  | -1879,1 | 370 | 185220  | 9946060  | -1974,7 |
| 109 | 194700  | 9931900  | -1892,7 | 240 | 194600  | 9932200  | -1886,6 | 371 | 187490  | 9946510  | -1943,3 |
| 110 | 195466  | 9931740  | -1880   | 241 | 194900  | 9932200  | -1871,7 | 372 | 187610  | 9946720  | -1912,9 |
| 111 | 195500  | 9931870  | -1878,9 | 242 | 195100  | 9932200  | -1887,6 | 373 | 191360  | 9947030  | -1894,8 |
| 112 | 193300  | 9931800  | -1915,2 | 243 | 194400  | 9932100  | -1887,1 | 374 | 193755  | 9946810  | -1877,6 |
| 113 | 193300  | 9931900  | -1907,9 | 244 | 194300  | 9932010  | -1897,7 | 375 | 185760  | 9946255  | -1968,4 |
| 114 | 192700  | 9931800  | -1918   | 245 | 194300  | 9932100  | -1901,7 | 376 | 185770  | 9944730  | -1989,6 |
| 115 | 192500  | 9931800  | -1904,1 | 246 | 194300  | 9932300  | -1900   | 377 | 185740  | 9942790  | -2009,4 |
| 116 | 192600  | 9931700  | -1884,2 | 247 | 194200  | 9932300  | -1884,7 | 378 | 185090  | 9941755  | -1947,4 |
| 117 | 193100  | 9930700  | -1907,5 | 248 | 193900  | 9932700  | -1887,3 | 379 | 186840  | 9941940  | -2002,1 |
| 118 | 193000  | 9930600  | -1910,9 | 249 | 193810  | 9932800  | -1878,8 | 380 | 187510  | 9942000  | -2001   |
| 119 | 192700  | 9930500  | -1906   | 250 | 193800  | 9933100  | -1925,5 | 381 | 187500  | 9942610  | -1971,1 |
| 120 | 192500  | 9930600  | -1886,8 | 251 | 193810  | 9933300  | -1918,2 | 382 | 187520  | 9944870  | -1961   |
| 121 | 194000  | 9930600  | -1900,5 | 252 | 193300  | 9932000  | -1900,4 | 383 | 190420  | 9946740  | -1913,4 |
| 122 | 194000  | 9930500  | -1908,4 | 253 | 193100  | 9932200  | -1901,7 | 384 | 190410  | 9946710  | -1896   |
| 123 | 195100  | 9929300  | -1905,8 | 254 | 192830  | 9932200  | -1895,7 | 385 | 190455  | 9944990  | -1888,2 |
| 124 | 195100  | 9929200  | -1899,3 | 255 | 192900  | 9932700  | -1930,1 | 386 | 190500  | 9943600  | -1910,7 |
| 125 | 195000  | 9929300  | -1903   | 256 | 192800  | 9933000  | -1895,8 | 387 | 188760  | 9943240  | -1935,3 |
| 126 | 195000  | 9929255  | -1906,7 | 257 | 192600  | 9933500  | -1886,3 | 388 | 187340  | 9947710  | -1914,6 |
| 127 | 194980  | 9929120  | -1892,7 | 258 | 192300  | 9933700  | -1885,4 | 389 | 187500  | 9948560  | -1896,1 |
| 128 | 194500  | 9929130  | -1919,6 | 259 | 191800  | 9934000  | -1851,7 | 390 | 188540  | 9948580  | -1868   |
| 129 | 194855  | 9929100  | -1901,9 | 260 | 191700  | 9934000  | -1831,9 | 391 | 189210  | 9948610  | -1863,6 |
| 130 | 194800  | 9929080  | -1911,1 | 261 | 191600  | 9934300  | -1800,6 | 392 | 183420  | 9947255  | -1959   |
| 131 | 194755  | 9928900  | -1886,3 | 262 | 191400  | 9934400  | -1788,3 |     |         |          |         |





**Figure 6.** Gravity map showing the density of Eburru geothermal area, along cross-section A-B.

From the Complete Bouguer Anomaly (CBA) map, we can notice that the density increases from the West to the East. This high density in the East can be attributed to presence of intrusion (dykes, sills, etc.) or heat source. From the profile, we have three high density bodies. This shows the best drill target.

## 6. Conclusion and Recommendations

From the gravity analysis, along the section A-B, the density increases from the west to the east.

From the interpretation of the gas geothermometers the calculated temperature was 270°C, which almost confirms to the quartz geothermometer which gave the calculated temperature as 255°C.

We can conclude that the Eburru geothermal reservoir temperatures range between 255-270°C.

More Geological studies, geochemical studies and geophysical have to be carried out in Eburru geothermal prospect to know the actual potential of Eburru geothermal Field.

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