RADON SOIL GEOCHEMICAL SURVEY AT ALLALLOBEDA GEOTHERMAL PROSPECT

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ABSTRACT

The Allallobeda geothermal field is one of the three geothermal fields located in the Tendaho graben and the other two are Dubti and Ayrobera geothermal fields. The Tendaho graben is located in a topographic depression in the Afar region (NE Ethiopia), some 600 km from the capital city Addis Ababa. Radon soil geochemical study was conducted in the Allallobeda geothermal field in an area of 1.8 km from east to west by 2.2 km from south to north. The area was gridded one hundred by one hundred meters and the radon measurement was taken in Bq/m3 at every one hundred meters by digging one meter deep hole where the radon probe goes in. Temperature was recorded at 50 cm and 100 cm depth of the hole. Northing, Easting, Elevation, Date and Time were recorded at every point of the surveyed area. The aim of this study is to locate the Radon Soil gas measurement mainly applied to detect buried or hidden faults to understand the permeable zone and to pinpoint favorable structural locations for geothermal exploratory drilling aimed at tapping fluids from the deep-sited geothermal resource. As a result, total of 350 measurements were recorded. An SPSS statistical soft ware was applied to evaluate the basic characteristics of the data. Invariant statistical and graphical methods that are histogram and cumulative frequency diagrams were used to study each variable independently and give a visual representation of the data distribution able to highlight the presence of multiple populations. Even though the data display negatively skewed distribution, yet it is well approximated by log normal distribution known as normal curve or bell shaped curve. As a result 49.86% of the data represent the background, where as 25.4% represent the anomaly and 24.7% of the data represent the low values. The radon soil geochemical survey has enabled to reveal the distribution of buried faults, joints or fractures. The investigation confirms that the anomalous values are concentrated in the North-North-East / South-South-West (NNE/SSW) and North-South (NS) direction of the studied area.

1. **INTRODUCTION**

Exploration of geothermal resources for electric power development started in 1969 under a joint Ethiopian Government - United Nations development program. The survey proved the existence of a high heat flow that could be harnessed for electric power generation, and identified numerous geothermal prospects (Fig.1). Tendaho was one of the selected prospect areas for further studies (UNDP, 1973). The Tendaho geothermal field is located in the NE part of Ethiopia, some 600Km from the capital Addis Ababa, and lies within Tendaho graben. Tendaho graben is a north-west trending structural trough in the Afar Region about 50 kilometers wide and more than 100 kilometers long from north-west to south-east. The graben floor, at about 480 meters a.s.l. is a barren, almost level plain known as Saha in the north-west. Dakin, Gouin et. al. 1968).

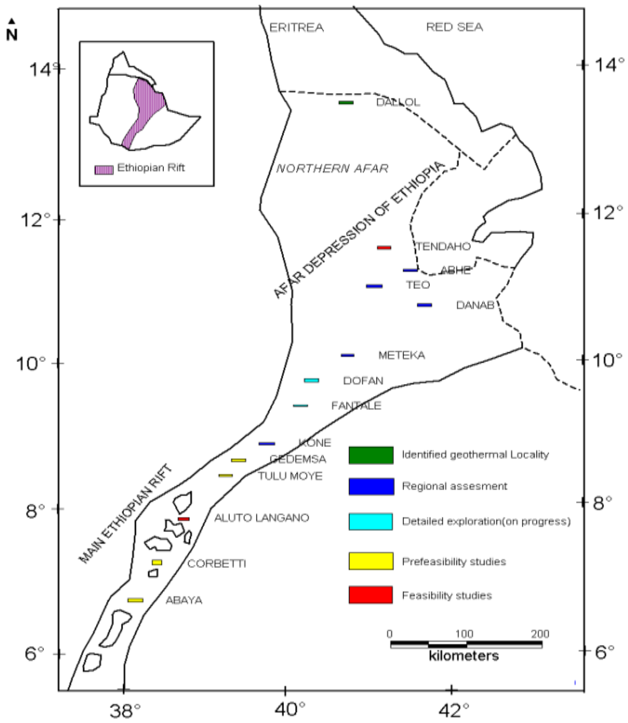

Figure 1: Location map of the geothermal prospect areas within the Ethiopian Rift

The graben and surrounding region has an arid climate. Occasional rain, usually as storms, falls mainly during summer (June to September). The Tendaho graben comprises the Dubti, Allallobeda and the Ayrobera geothermal systems. The lower course of the Awash river meanders through the graben and is used for irrigation of sugar cane at Tendaho, Dubti , Det Bahari and Asayita

The north-north-east trending faults are important. They are particularly well developed on fault blocks which bound Tendaho graben on the south-west and form Allallobeda Graben. Here, north-west fault are cut by those of north-north-east trend and vice versa, hence both fault systems must be considered recently active. Near to the south west of Allallobeda hydrothermal area, north-north-east faults displace graben filling sediments and are considered to be the youngest.

Studies have shown that radon measurements can be important in geological investigations. Measurements of radon in soil gas have been used to locate naturally heated ground water, which can often be a source of energy. Other applications include the location of faults, and the possible prediction of earthquakes and volcanic eruptions. Radon soil measurement was conducted at Allallobeda geothermal prospect as a geochemical technique to investigate hidden structures. So the measurement was conducted in a 100 meters by 100 meters gridded area see figure 2.

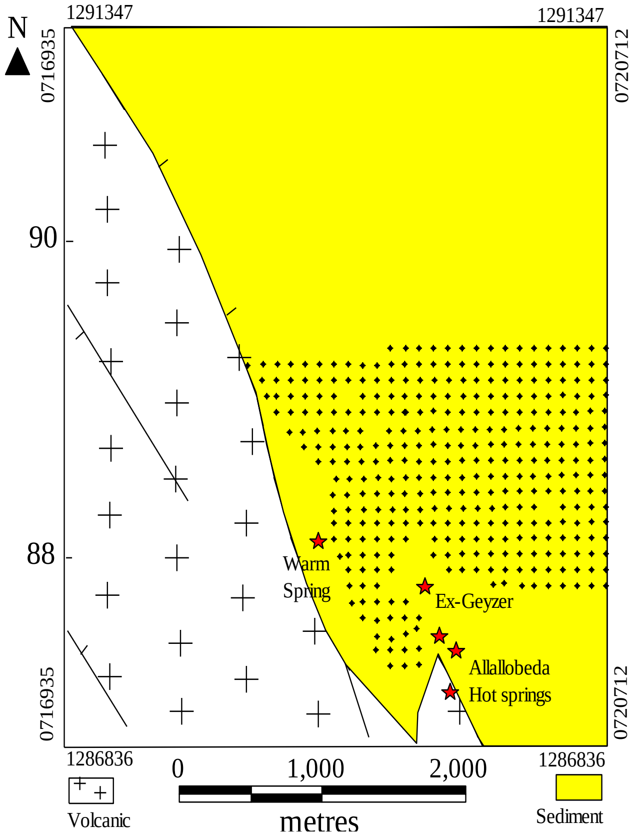

Figure 2: Geological Sketch map of Allallobeda area, together with station points of radon

1.1 Regional Geology

Tendaho Graben bounded by Loggia Fault on the west and Gamare fault on the east, is in the north-west part of the Afar Triangle (Tazieff, 1968) near the intersection of the three trends of the East African Rift System that is the Main Ethiopian (Lakes District), Red Sea, and Gulf of Aden Rifts. Hence within the Afar Triangle, major NW-SE, N-S, and NNE-SSW, and some E-W tectonic lines co-exist. In the Tendaho region north-west and north-north-east trending faults exist. The regional fault pattern shows that Tendaho graben is in the western-most of seven major grabens crossed by the Kombolcha-Aseb Highway. They formed predominantly by tensional faulting, but volcano-tectonic collapse may also have contributed to downfaulting of Tendaho graben, where the dominant north-west fault direction is expressed also in north-west alignments of volcanic centers within the graben.

The oldest sediment known in the Tendaho Graben occurs near Allallobeda interbeded with flood basalt believed to be of Pliocene/Pleistocene age. The sediment is bedded, coarse pumice tuff, containing rounded to sub-angular basalt cobbles, and is up to 30 meters thick. Flood basalt makes up the bulk of rocks which form the plateau and fault blocks bounding Tendaho Graben. The oldest looking basalt outcrops on the south-western flank of Tendaho Graben, and in a horst in the south of Allallobeda hot springs. The oldest rhyolites of the region are at Serdo and west of Det Bahari. At both localities the rhyolite is intensely faulted and overlain by flood basalts.

2. METHODOLOGY

For measuring the radon concentration in soil we used the **RAD7 Solid-State Detector machine**. The RAD7's internal sample cell is a 0.7 litter hemisphere, coated on the inside with an electrical conductor. A solid-state, ion implanted, planar, Silicon alpha detector is at the center of the hemisphere. The high voltage power circuit charges the inside conductor to a potential of 2000 to 2500 volts, relative to the detector, creating an electric field throughout the volume of the cell. The electric field propels positively charged particles on to the detector.

The radon-222 nucleus that decays within the cell leaves its transformed nucleus, polonium-218, as a positively charged ion. The electric field within the cell drives this positively charged ion to the detector, to which it sticks. When the short lived polonium-218 nucleus decays upon the detector's active surface, its alpha particle has a 50% probability of entering the detector and producing an electrical signal proportional in strength to the energy of the alpha particle. Subsequent decays of the same nucleus produce beta particles, which are not detected, or alpha particles of different energy. Different isotopes have different alpha energies, and produce different strength signals in the detector.

The RAD7 amplifies filters and sorts the signals according to their strength. In sniff mode, the RAD7 uses only the polonium-218 signal to determine radon concentration, and the polonium-216 signal to determine thoron concentration, ignoring the subsequent and longer lived radon daughters. In this way the RAD7 achieves fast response to changes in radon concentration, and fast recovery from high concentrations.

A group of personnel have participated in this operation that includes the geochemistry staff, Asfaw Teklu, Melese Mekonen and Weinshet Melese . The surveyors: Abebe Abera and Dress Tulu. Drivers and a number of daily labourers as well. Therefore for measuring the radon concentration, we look for a location where the soil is uniform and generally free of rocks, for this we are procedurally allowed to move 25 cm in either direction from the gridded point. We hammer the pilot rod into the ground first to a depth of 50 cm and we take temperature reading at this point. Then we hammer the pilot rod further to a depth of 100 cm. and we take the temperature reading. Before that we record the air temperature, Northing-Easting and elevation reading as well.

We hammer the radon probe to a depth of 100 cm and then we carefully connect the probe to the RAD7 machine via the $CaSO_4$ desiccant (light blue in colour). It is connected from the radon probe to the bottom of the desiccant and from the upper end of the desiccant to the RAD7 machine; this is to bring the relative humidity to 10 percent or less. If the relative humidity is more that 10% then the desiccant has to be changed. We put the RAD7 in start mode with the pump working continuously. It is believed that the RAD7 machine sniffs the radon concentration in a meter cube volume. We take the third and fourth readings and then we average the values. It is the average value that is used in constructing the contour. The radon concentration unit is in Becquerel per meter cube

Figure 3: Using the RAD7 machine radon measurement is being taken in one of the stations.

The photo above taken in the field shows that: 1) the cylindrical plastic container is the $CaSO_4$ desiccant it can be seen that the colour of the desiccant is three types, one is deep blue at the bottom, 2) violet colour in the middle and light blue colour in the upper part. This shows that the deep blue and the violet are exhausted but the upper part is still active. In the photo the open box is the RAD7 machine that reads the radon concentration. The red colour painted (wood) picket is the grid point put by the surveyors. Since the soil is hard and some rock fragments are also there, so that is the reason why the radon probe is put some 25 or 30 cm away from the picket.

3. STATISTICAL ANALYSES OF THE RADON DATA

An SPSS statistical soft ware was applied to evaluate the basic characteristics of the data, which are reported as summary statistics data tables a and b. Univariant statistical and graphical methods (i.e. histogram and cumulative frequency diagrams, see figures 4 and 5) were used to study each variable independently and give a visual representation of the data distribution able to highlight the presence of multiple populations. Probability plots describe the cumulative percent frequency distribution of the data and provide an easy way to model complex data sets comparing them to theoretically known distributions (e.g. normal distribution curve).

Even though the data display negatively skewed distribution but yet it is well approximated by the log normal distribution. On a logarithmic probability plots, the values of a single log normal distributed population describe a straight line. Appreciable overlap of the ranges of two populations results in a gentle sloping of the curve. Anyway abrupt changes in slope at both extremities of the probability distribution curve may reflect scarce representation of the data points which both low and high values rather than real inflection points.

In plotting the histogram the relative frequency was used as a Y axis and the log radon in Bq/m^3 was used as an X axis. From the diagram one can see that the histogram is negatively skewed but it has some how fitted the normal curve.

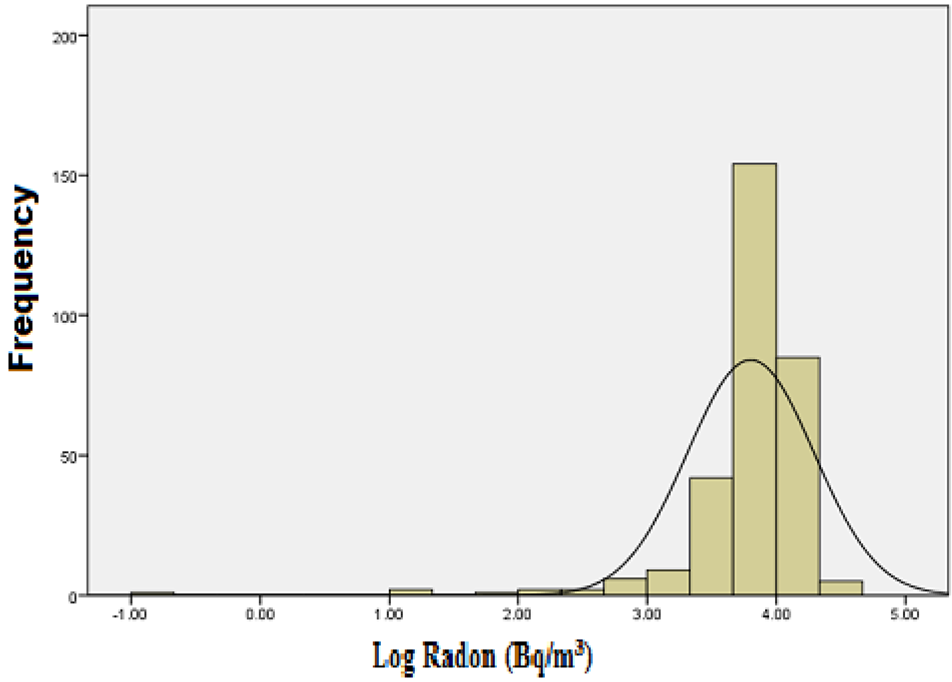

Figure 4: Histogram plot of radon data at Allallobeda, together with the normal curve fit.

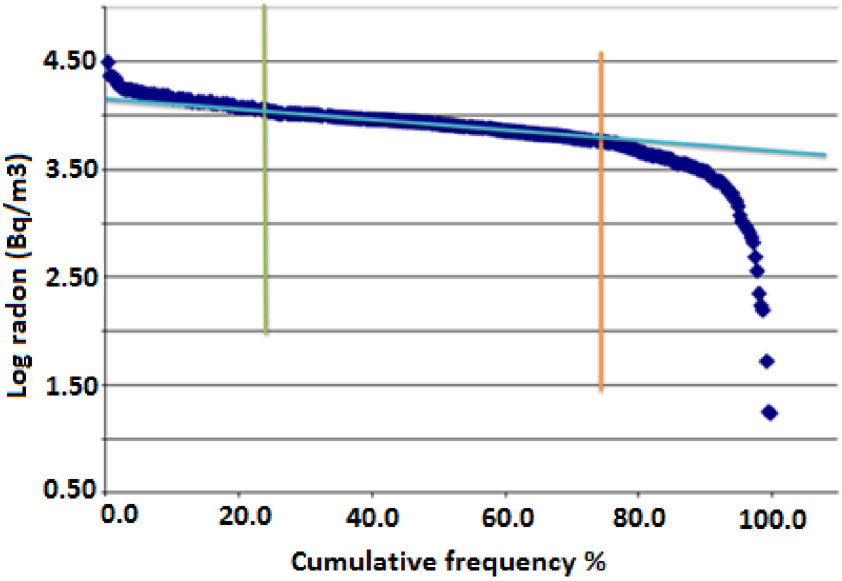

Figure 5: Probability plot of log transformed radon data and cumulative frequency percent.

In a probability plot figure 5 the log transformed radon data describes a curve with two inflection points at 25 and 75 cumulative percentiles, indicated in the figure 5 as green line and red line respectively. The points from the green line to the left that is up to the Y-axis corresponds to 25.4% of the data and represents the “Anomalous” radon data. The “Anomalous” radon data are related to circulation of hot fluids and possible heat transfer from deep structures such as fault, fracture or joint.

The points from the green line up to the red line represent the “Background” which is 49.86% of the data. The points from the red line to the right include the “Low” values of the measured radon data and are supposed to be 24.7% of the total data.

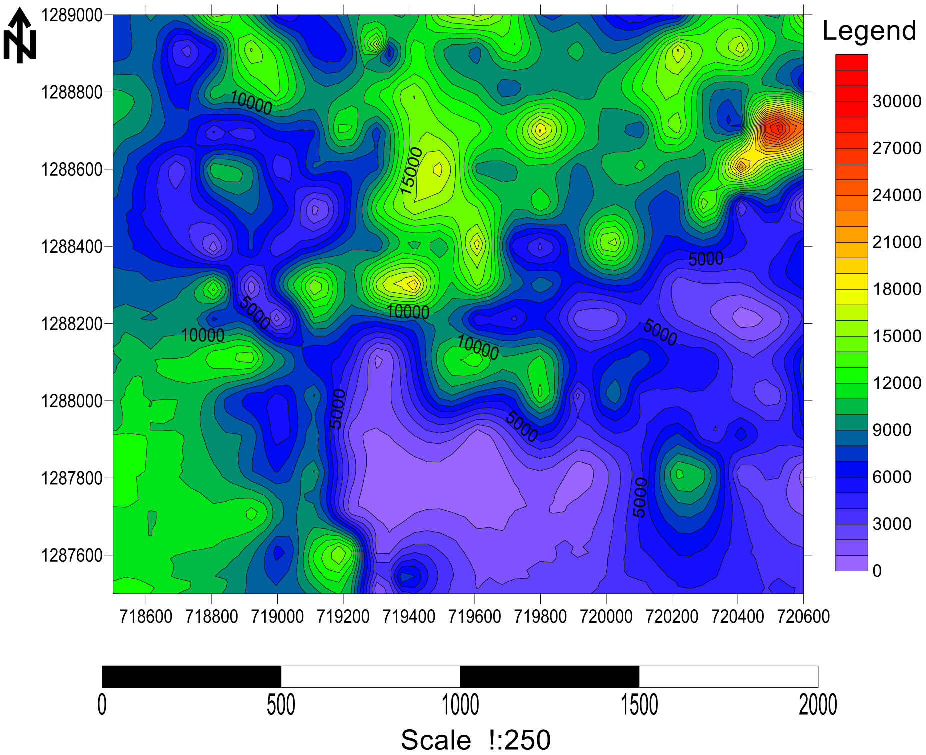

Figure 6: Contour map showing the radon concentration in (Bq/m^3) in soil of the surveyed area. Coordinates in UTM (WGD 84 - Adindan datum).

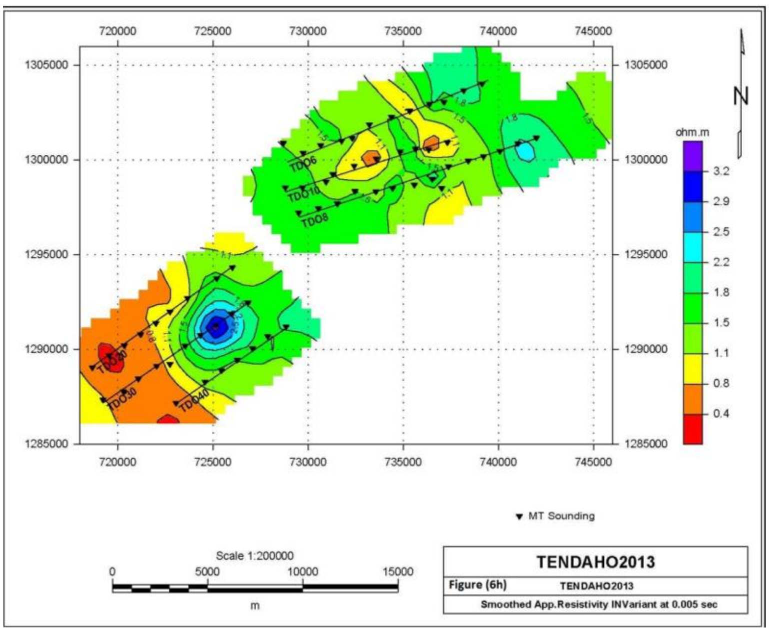

Figure 6b. Contour map of magnetotelluric study of geophysical survey. So we can see that it is similar to radon contour image showing that the structure is NNE/ SS

4. CONCLUSIONS

The study has enabled us to generate additional values in understanding the system better**.** The direction of the anomalous area is north-north east (**NNE**), south-south west (**SSW**) and north-south (**NS**) of the area under investigation. The background values are the values that most frequently recorded in the area of survey. The low anomaly values are mostly concentrated in the south east and North West of the area of interest.

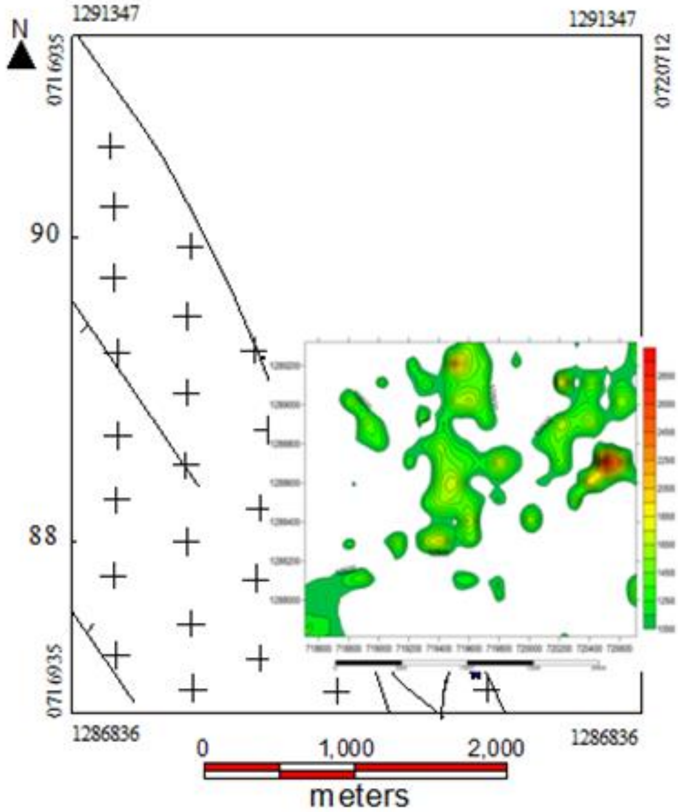

Figure 7: The anomalous contour of the surveyed area superimposed on the geological sketch map of Allallobeda geothermal prospect area.

5. RECOMMENDATION

We recommend that the survey has to continue in a better organized way to cover more area in the western and northern part of study area.

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