

## **Aluto and Bobessa Geothermal Prospect: Resource Identification Based On Structural Analysis, Geology, Geochemistry and Geophysics**

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### **ABSTRACT**

**Ethiopia**, one of the developing countries in Africa, is known for its famous big Rivers. Although Hydro is the major source of electricity at present, installed generating capacity is very low when compared to the estimated high potential.

The energy sector in Ethiopia can be generally categorized in to two major components: (i) traditional (biomass), and (ii) modern (such as electricity and petroleum). As more than 80 % of the country's population is engaged in the small-scale agricultural sector and live in rural areas, traditional energy sources represent the principal sources of energy in Ethiopia. The continuous economic growth has undoubtedly influenced the growth of energy demand. The current total installed electricity generation capacity has reached over 2,414 MW. The delivery of an adequate electricity service is essential. To fulfill the high growth rate of electricity demand which is recently 20 % / yr, it is planned to increase the generation capacity to over 25,000 MW by 2030. The aim is to address both domestic demands while exporting surplus power to neighboring countries and beyond. The need to expand the transmission and distribution system is also emphasized in order to deliver the energy generated to the consumer in an efficient and reliable manner. The growth plan further envisages increasing the customer base of the power utility from the current level of 2 million to 4 million and the universal electricity access rate from 45% to 75%.

Due to its location within the East African Rift (**EARS**) one of the hottest geothermal zones in the world, it is endowed with significant potential of geothermal energy resource. Despite its favourable location, Ethiopia has been slow in harnessing its potentially significant geothermal resource. The study area (Aluto Volcanic Centre and Bobessa) is situated in the Main Ethiopian Rift (MER). It is specifically situated on the southern end of the Aluto-Gedemsa Tectono-magmatic segment; this Quaternary age axial tectono-magmatic zone previously is known as the Wenji Fault Belt (**WFB**). A transverse fault structure of NW-SE orientation crosses the western horst. Hydrothermal manifestations in the area include thermal springs, weak fumaroles and hot grounds. The weak fumaroles and hot grounds are associated with heights on the southern and western flanks of Aluto Caldera and its summit area. Eight deep exploratory and appraisal wells were drilled in the study area from 1981-1985. After commissioning of 7.2 MW e with binary power plant from these wells, power generating activity stopped for many years due the decline of the steam originating from several geological problems and technical failures on the power plant. Recently, two additional deep appraisal

directional wells were drilled and development of a 5MW e single flash well head power plant is planned.

The objective of this project is to identify and correlate two areas (Aluto Caldera and Bobessa) geothermal reservoir heat source and local structural orientation. The final result of this study is believed to identify the heat source for the manifestations in Bobessa area. At the early stage of this research methodology, it is planned to gather the two areas geological, hydro geological, hydrological and structural data based on detail field investigation and analysis of geothermal manifestations and their orientation with the areas major lineaments. The next step to be emphasized is analysis of different data from drilled wells, such as temperature gradient, alteration, mineralogy of each rock unit and stratigraphic orientation. Fluid or gas chemistry and investigation of permeable zones using results of Electro Magnetic Survey. Reliable cat ion or gas geothermometry sampling and laboratory analysis is the planned approach for Bobessa with the absence of existing wells. In addition, chloride springs will be assed in Bobessa and other surrounding areas with the possibility of investigating any geothermal manifestations. It is expected that the final result of this research reveals the project areas geothermal system according to the classification. In order to reach at this point and achieve a precise result, the research has planned to gather geological and geochemical data which are located, in and out of Aluto caldera and different data from hot springs, fumaroles, and other geothermal manifestations in Bobessa area.

## **1. Introduction**

The research area, namely, Aluto Caldera and Bobessa are located in the Lakes District, Ethiopian Rift Valley, about 220km South of Addis Ababa City, It is accessible with 206 km asphalted road from Addis Ababa to Adami tulu Town and 14km all weathered road to the site (figure.1). Previous exploration activity was done in 1970 (Yehyse K. Et al 2002) and eight deep vertical wells were drilled during this period. After commissioning of 7.2 MW electric power with binary power plant from these wells, power generating activity stopped for many years due the decline of the steam originating from several geological problems and technical failures on the power plan. Recently two additional deep appraisal directional wells were drilled and development of a 5MW single flash well head power plant is planned. The two recently drilled directional wells (LA-9 and LA-10) are drilled to a depth of 1920m and 1952m respectively. Even though the first drilling plan was to reach a 2500m depth, but due to low efficiency of the rig, it could not reach the target. The government is under a procurement process to drill 22 wells to generate a total of 75 MW e at present from the two areas, which is expected to be completed up to June 2020 according to the agreement of the funding source or the World Bank.

Accordingly, the area's local structural orientation is expected to be geometrically deeper than all the drilled wells, more permeable zones can be reached with a future drilling plan by selecting modern drilling rigs and drilling personnel as well. The main objective of this project is to identify and correlate the two areas (Aluto Caldera and Bobessa) geothermal reservoir heat source and local structural orientation.

It is my assumption that some of the existing wells (figure.2), might not get the up flow steam from the same reservoir or there might be a ground water incursion that created from a secondary fracturing of the formation, due to the frequent process of local tectonic activity that cools the up flow and also there is an assumption that the three wells (LA-5, LA-7 and LA-8) might not intersect the major local

structures (Jawe and Bobessa lineaments NNE-SSW) (figure.3). From fluid chemistry result, fluid and gas temperature and lithological data analysis, wells which are found near to the periphery of Aluto caldera (LA-5, LA-7 and LA-8), and wells which are located around the caldera centre (LA-3, LA-4, LA-6, LA-9 and LA-10) shows some variation. Especially the two wells which are situated out of Aluto caldera (LA-1 and LA-2) might be in separate system based on the observation conducted in their physical parameters difference.

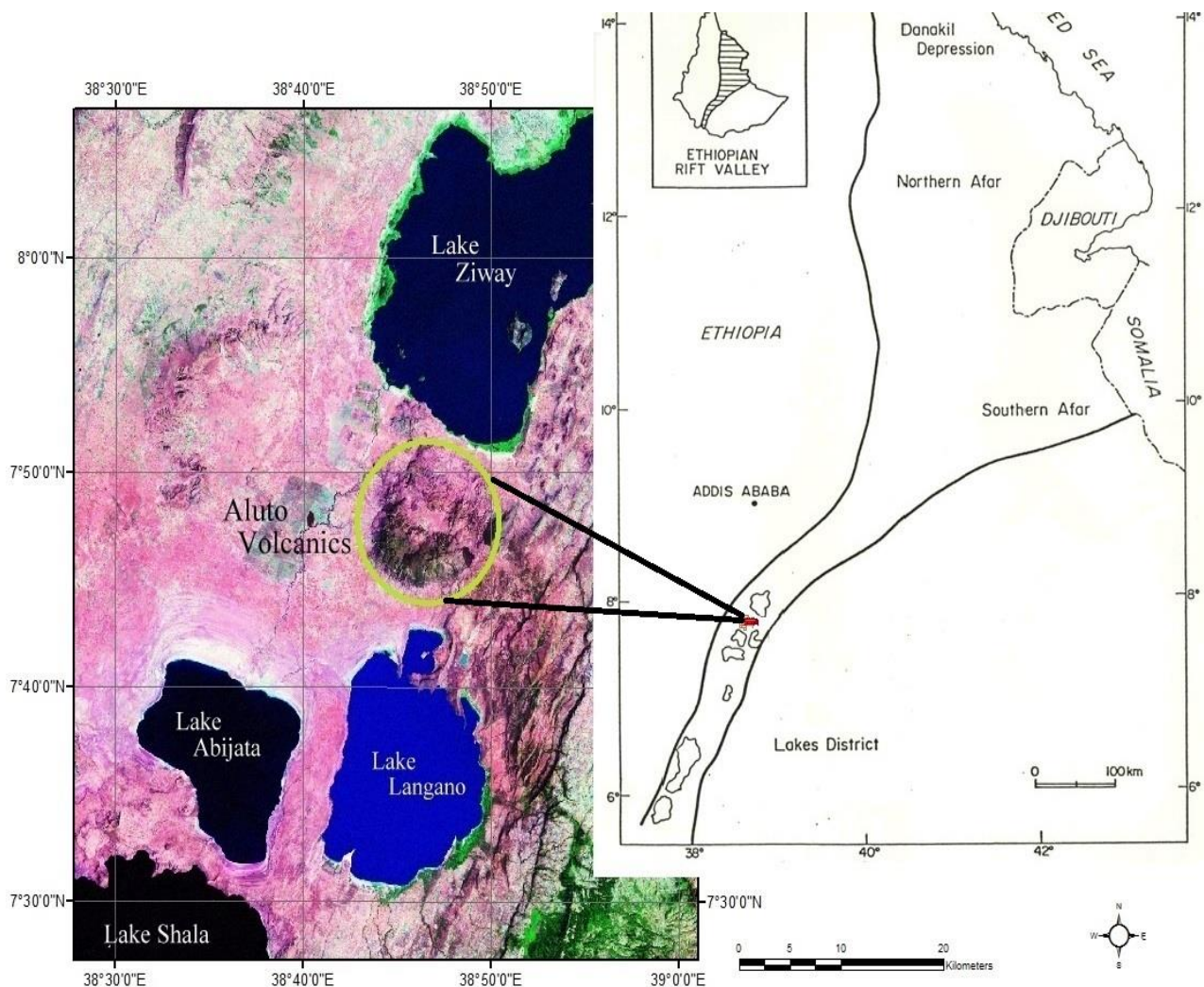


Fig-1. Location Map of Aluto Volcanic Complex: Source LA-9D Well Drilling Report, WJEC June, 2015

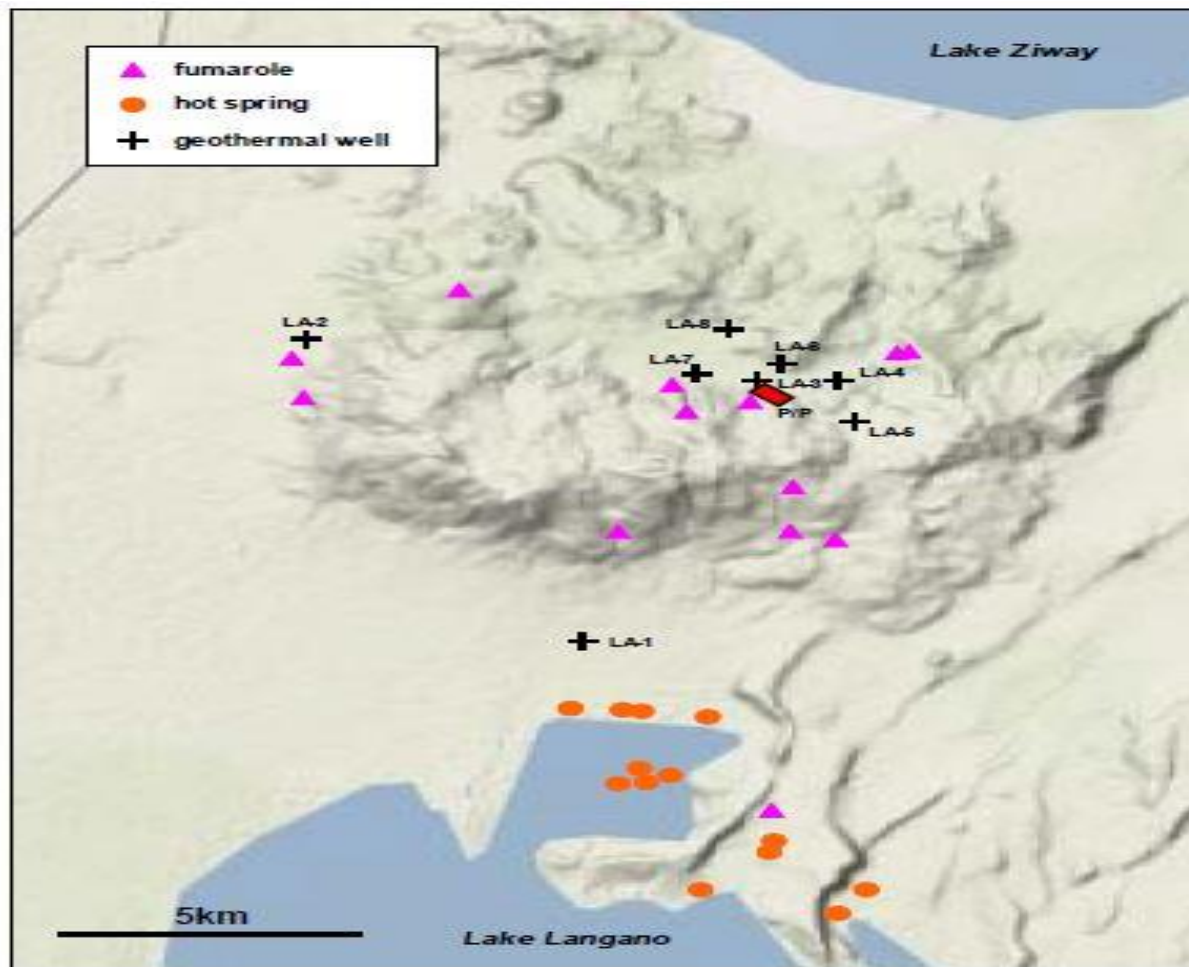


Fig-2. Aluto Caldera existing wells, Fumaroles, and Hot Springs.

## 2. Methodology

At the early stage of this research methodology, it is planned to gather the areas geological, hydrological, hydro geological and structural data based on field investigation of rock outcrops, assessment of surface water sources and geothermal manifestations. The second methodology approach is to gather previous available documents which provide relevant information for the study. The next step to be emphasised is analysis of different data from drilled wells, such as, temperature, alteration, geology, fluid or gas chemistry and correlation of smectite-illite clay alteration transition with resistivity data which is reliable for geophysical interpretation. Wells typical lithologies from previous studies will be analysed in order to correlate their mineralogy, thickness, alteration and chronology for structural interpretation. Thermal methods, which include:

- Mapping of thermal distribution at the surface (detailed geothermal surface mapping (GPS), soil temperature measurements in the uppermost one meter and 200m spacing).
- Soil diffuse degassing measurements aimed at identifying gas leakages that usually Mimic active faults and structures in Bobessa.
- Temperature measurement in 20-100m gradient wells in order to delineate regional or local gradient anomalies will be applied for the geothermal exploration.

Bobessa, where with the absence of existing wells will require reliable cation or gas geothermometry sampling and laboratory analysis in order to estimate the temperature the fluids in the reservoir (Gudmundsson and Arnórsson 2002). In addition, chloride springs will be assessed in the project area with no existing wells with 200m sampling interval using GPS, to identify if there is a deep fluid circulation system is found. A conceptual model cross-section of a 150-200 degree Celsius and 250-350 degree Celsius geothermal reservoir with isotherms, alteration zones and structure for the two systems geothermal reservoir interpretation.

According to ELC'S (Electro Consult) Conceptual Model Report Final Version, December 2016, lateral extent of the Bobessa prospect has assumed on the base of the result of the MT survey, several soundings (AT 38, 39, 46,47,55,56, 84, 89 and BO5) are characterized by the presence of a thin and shallow conductive unit, with resistivity lower than 6 ohm meter and electrostratigraphic sequence similar to the one recognized in the sounding case of well LA-3 which have a temperature of more than 300 Celsius.



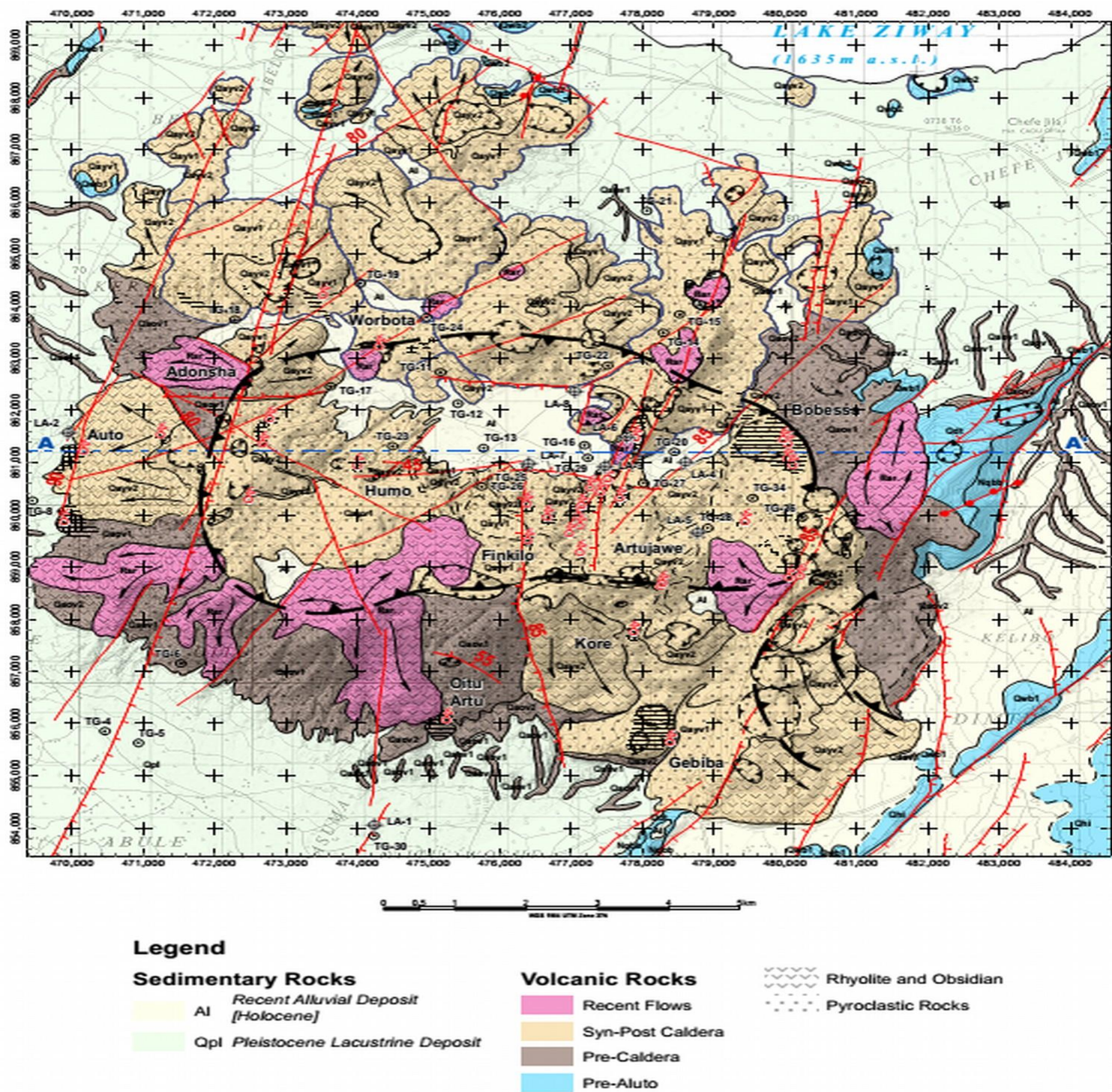


Fig-3. Geological Map of the Aluto Volcanic Complex and the surrounding area

### **3. Conclusion**

Rift oriented geothermal systems, like in the case of ‘‘ East African Rift ‘‘ are classified in to two types based on temperature; Low temperature which gets the heat source through deep circulation along fault and fracture system and High temperature which the deeply percolating meteoric water is heated in the vicinity active or cooling magma bodies (Jim Stimac Workshop on Geothermal Geology and the application of Leapfrog Geothermal Software to Conceptual Modelling, May2- May 14, 2016 Addis Ababa). It is expected that the final result of this research reveals the project areas (Aluto Caldera and Bobessa) geothermal system according to the classification. In order to reach at this point and achieve a result close to precision in general, the research has planned to gather geological and geochemical data from the wells which are located, in and out of Aluto Caldera and geothermometry data from hot springs, fumaroles, and other geothermal manifestations in Bobessa area. Analysis of the areas hydrological and hydro geological characteristics (such as recharge condition, ground water aquifer type, chemical composition, water table, rock permeability, and ground water flow direction) from existing data and the local community ground water wells to define and correlate the two areas geothermal system. In addition, it is planned to integrate the above result with existing geophysical data interpretations to prepare a Conceptual Model Cross Section with isotherms, alteration zones and structure for two system interpretation.

Finally, I believe that the result of this research will provide, as a source of alternatives for the planned 22 wells drilling site selection which is undergoing at present, and to minimise the problems encountered in the utilization process of the Aluto Caldera and Bobessa geothermal resource economically as well.

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