APPLICATION OF GEOPHYSICAL METHODS FOR THE EVALUATION OF THERMAL CENTERS AND THEIR STRUCTURAL CONTROLS IN BOKU, NAZARETH, MAIN ETHIOPIAN RIFT

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INTRODUCTION

The Boku thermal centres are located in the tectonically active axial part of the East African Rift system where the east and west rift margins are the narrowest. More specifically, in the part of the rift system known as the Main Ethiopian Rift (MER) where acidic and central volcanoes are erupted along NE-SW tectonic lines forming a region interspersed with fault scarps, volcanic scoria cones and collapsed segments (Figure 1). The topography is dominated by sunken strips of land between a series of normal faults forming part of the so called Wonji Fault Belt system.

The area is also characterised by high geothermal gradient and thermal anomaly associated with the acidic volcanic centres. Steam temperatures as high as 72 °C has been recorded at the currently active thermal centre, although the steam temperatures has also been observed to show variations within a given day. Studies conducted in the area earlier specially in Aluto volcanic centres, which are currently being developed for power generation, and adjoining areas within the rift have shown that pyroclastc deposits are the major thermal aquifers.

The main geological feature in the area, called the Boku caldera and its surroundings represent a typical example of central eruption from where peralkaline acidic and pyroclastic deposits have been erupted. The caldera shows rims of irregular geometry, indistinct at some places but well marked on the eastern side of the Boku. The prominent topographic high in the area is the Boku ridge which rises to an elevation of 1875 meters a.m.s.l. in the centre of the region.

In a few places in the area, manifestations of steam of very high temperatures from the ground have rendered the area to be usable as a traditional steam bath centre. The major area currently used for the purpose, the Boku, has a small scale infrastructure connected to Nazareth town by gravel road and serving the local population as a bath/healing centre.

Due to its geographic location connecting parts of Ethiopia between Addis Ababa and the large sections of the country in the east, Nazareth town is one of the fast growing urban centres of Ethiopia with future potential to be the centre of economic and industrial growth. It has recently shown large growth in population and has a future which will make it a trade and economic centre. The potential of the Boku to be involved in the future development of the

town both as a source of recreational and healing centre and in the future for the supply of hot water to the town and the surroundings is therefore apparent.

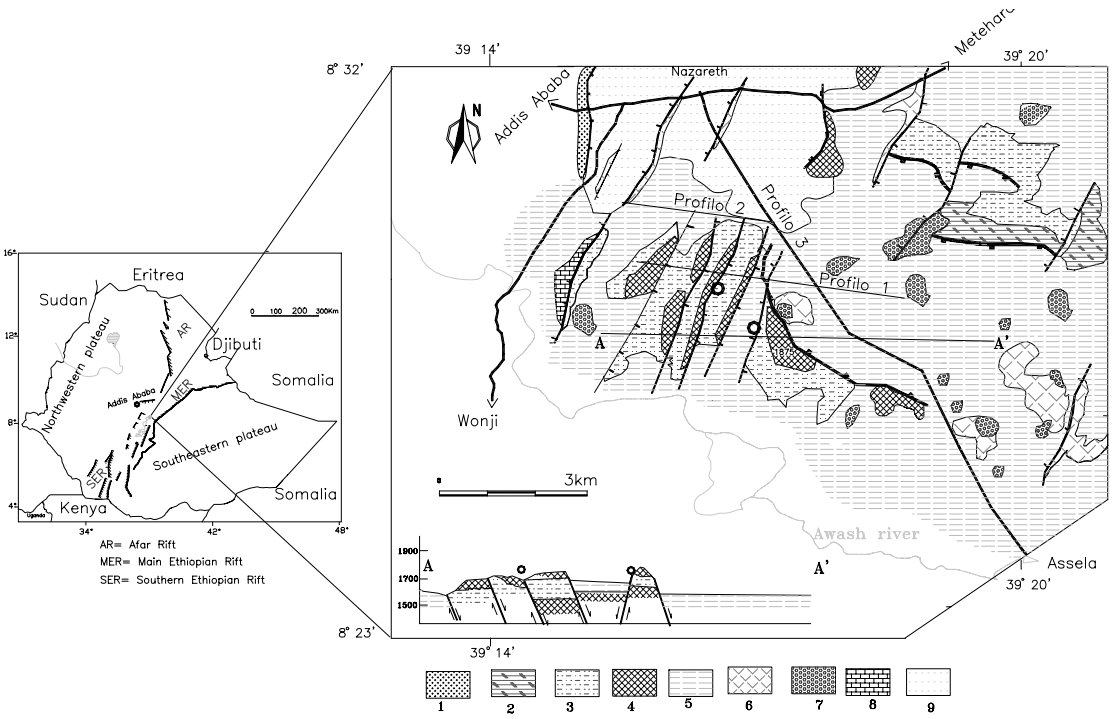

Fig.1 Geological map of Boku area (MER): 1= Rift floor ignimbrites, 2= Slightly welded tuffs 3= Pumice fall deposits, 4= Rhyolitic lava flows, 5= Unwelded tuffs 6= Basaltic lava flows, 7= Scoria, 8= Lacustrine deposits, 9= Alluvial deposits

Figure 1: Geological sketch map of the Boku area (Tamiru et al., 1997). The geophysical survey traverses are indicated.

In a series of field visits to the Boku and its adjoining areas, first geological and hydrogeological investigations and, choice of appropriate survey spacing and traverses based on the results of these surveys, were made. These were followed by geophysical investigations using a variety of techniques, designed to achieve the objectives set out in the project.

GEOPHYSICAL SURVEYS

The tasks assigned to geophysics in the project were broadly stated as:

1. to define the major underground structures which may act as conduits for the flow of superheated steam and heat to rise to the surface, and
2. to locate the thermal centres and define the depth to possible heat and water interaction zones.

In view of these objectives, various geophysical methods have been applied directed at both mapping zones of weakness and structural discontinuities, and zones of conductivity anomaly, their extent and depth below the surface. The major survey layouts for the geophysical surveys are given in Figure 1.

The major profiles 1 and 2, extending to lengths of 6 and 4.5 km respectively, have been laid out to start well within the caldera from which the heat source for the thermal manifestations

is believed to originate from and is passing over the current active thermal centre of Boku. Additional survey profile has been carried out, in addition to these profiles, along the main road from Nazareth town to Asella town.

As regard the temperature surveys, measurements were taken at 20 cm below the surface, right on the surface and a height of 20 cm above the surface. The ease with which measurements could be taken has made it possible to take random measurements over the survey area in addition to measurements taken at 50 m intervals along Profiles 1 and 2.

As mentioned in the introduction, the area under study is characterised by high temperature gradient and thermal anomaly.

Steam temperatures as high as 72 °C has been recorded at the currently active thermal centre, although this steam temperature has also been observed to show variations within a given day. From Figure 2 it is seen that the thermal anomalous regions are more or less aligned with the general fault trend of the area. V.E.S. soundings, I.P. Schulmberger and magnetic surveys (Tigistu et al., 2000), gravimetric and electromagnetic surveys (Ranieri, 2002) have been carried out along the same profiles (Figure 1).

The last of the geophysical methods applied over the survey area in the term of this project is the Time Domain Electromagnetic (TDEM) sounding survey. The equipment used for the survey was TEM-fast 48 of AEMR, the Netherlands. By combining both moderate (50 m) and large (200 m – 2 turns) loop dimensions it was planned to explore the survey area to maximum depths of 300 – 400 m. Both profiles 1 and 2 were used for the sounding with 8 loops on the first and 6 loops on the second profile. To increase the resolution of the upper layers the 50 loop size was used, while to recognize deep layers the 200 m loop size was used. All sounding were interpreted using 1D interpretation package. The "family" technique was then employed, to form vertical sections with high lateral resolution, one of which is reported in figure 3. As can be seen, there is a good correlation between the thermal anomalies, the general fault trend, and the conductivity and resistivity zones.

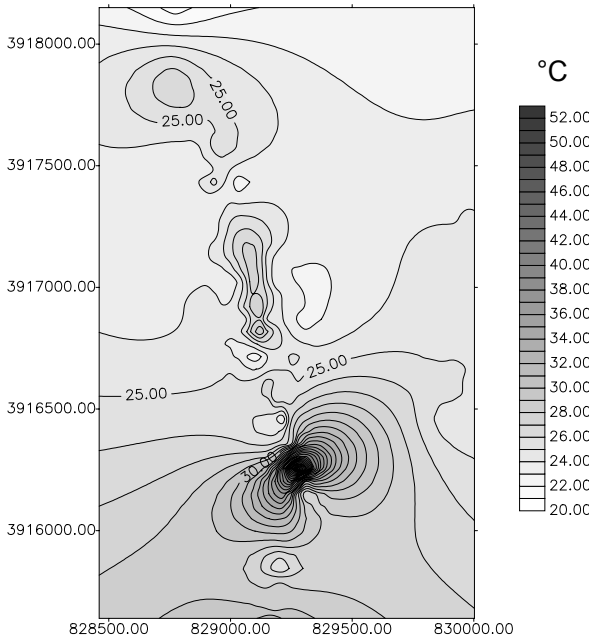

Figure 2. Boku thermal center (Nazareth, Ethiopia). Temperature plot along with data points at a depth of 20 cm beneath the surface.

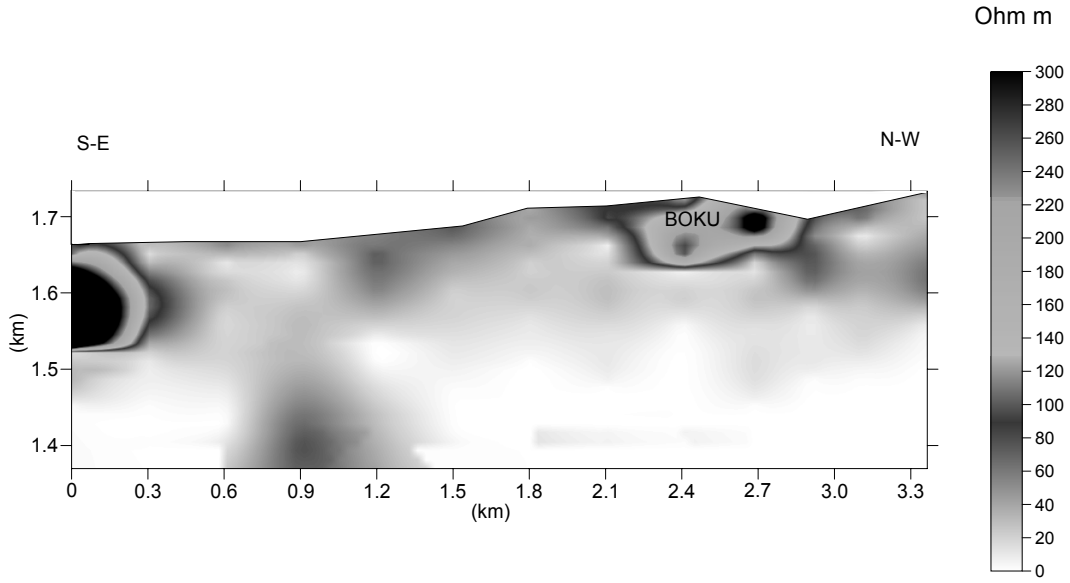

Figure 3. Boku thermal center (Nazareth, Ethiopia). Resistivity section, obtained by TDEM soundings.

CONCLUSION

Detailed geological and geophysical surveys have been carried out over the Boku thermal centres to elucidate the geothermal potential of the area for small scale development. Geophysical investigations suitable for mapping both structural features and subsurface geological situations have been employed. Through the combination of the methods it was possible to identify the major areas for the presence of high temperature anomalies and possible shallow aquifers for the utilisation of the steam potential of the area. Major structural units have been mapped by both the resistivity profiling and the magnetic methods. Regions of hydrothermal alteration have also been mapped from the results of the magnetic survey.

The TDEM survey, conducted at the last phase of the project has mapped, the low resistivity regimes in the subsurface and their general morphology. The combination of different loop sizes (from 50 m to 200 m) has enabled the mapping of the conductivity structure of the area to a depth of about 300 m, that is the depth estimated from theoretical computations based on surface temperature gradients.

With the combination of the methods, it was possible to map the regions of shallow aquifer system and the competent rock units around the active thermal centres.

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