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Geology and Geothermal Resource Utilization Options in the Arus-Lake Bogoria Prospect, Northern Kenya Rift

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ABSTRACT

Arus-Lake Bogoria geothermal prospect is located in the northern sector of the Kenyan Rift. Geothermal phenomena in form of fumaroles, hot springs, steam jets, geysers, sulphur deposits and high geothermal gradient expressed by anomalously hot ground and anomalous groundwater manifest the area. Detailed surface exploration surveys carried out in the prospect indicate presence of low to intermediate temperature fracture controlled geothermal system(s) in the area.

These low to medium enthalpy resources can be utilized in direct uses and electric power generation using binary-cycle power plants. The direct use applications that can be realized in the area include tourism, spa pools, greenhouse heating, agricultural produce drying and industrial processes. The direct use application currently available in area is tourism and a spa pool at one of the tourist hotel. Advances in binary-cycle power and submersible pump technologies have made electric power generation in low enthalpy areas commercial.

Keywords: Kenya Rift, Geology, Geothermal, and Utilization.

1. INTRODUCTION

Arus-Lake Bogoria prospect is located within the Kenya Rift valley immediately south of Lake Baringo prospect and north of Menengai prospect (Figure 1). Geothermal phenomena namely fumaroles, hot springs, steam jets, geysers, sulphur deposits and altered grounds manifest the area. They occur mainly at the shores of Lake Bogoria and at Arus area. Detailed surface exploration in the prospect area was carried to determine the potential and propose how best the resource could be utilized.

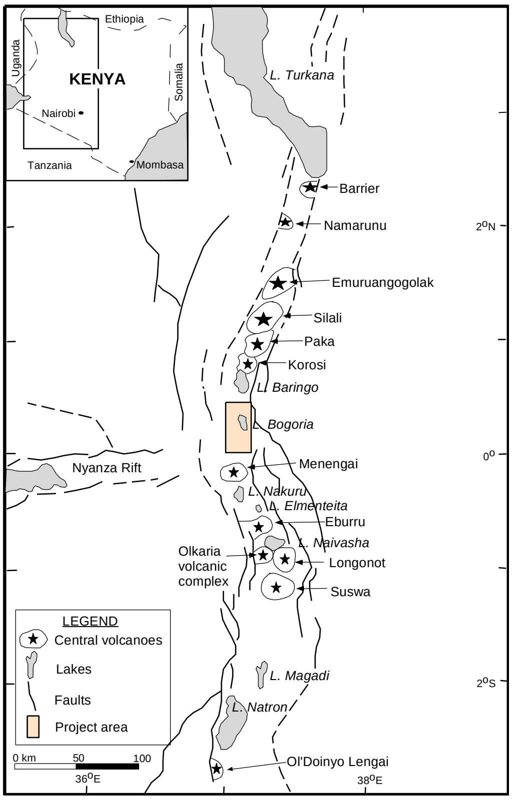

Figure 1: Map of the Kenya rift showing the showing the location of the Arus-Lake Bogoria prospect.

2. OBJECTIVES OF THE STUDY

The main objectives of the Arus-Lake Bogoria geothermal surface exploration project were to:

- Study volcanological evolution of the area with a view to understanding the possible heat sources for the geothermal system(s).

- Study structures essential for occurrence of the geothermal system(s).
- Determine the size and extent of the geothermal system, heat source and hydrogeological controls of the system(s).
- Determine whether the prospect is suitable for further exploration and if so, recommend site for exploration by drilling.
- Recommend how best the geothermal resource can be utilized.

3. PREVIOUS WORK

The first detailed geological mapping in this sector of the Kenya rift was done in the late 1960's by the Kenya Geological Survey. McCall (1967) described the geology of the Nakuru-Lake Hannington areas while Walsh (1969) and Jennings (1971) described the geology of the Eldama Ravine-Kabarnet area. In their work they gave detailed description of the volcanic rocks and the sediments and were able to draw up a fairly detailed history of the tectonism. They also gave a detailed description of the surface manifestations found in the area between Arus and Lake Bogoria. Glover (1972) colleted a large number of water and steam samples from Lake Bogoria area and concluded from his analytical data that a relatively large and homogeneous body of warm water lies under much of the area. Griffiths (1977) in his dissertation did a comparative trace element study of the volcanic products in the area

Geological work in the area with bias in geothermal exploration was carried out by Geotermica Italiana Srl (1987) in their Menengai-Lake Bogoria reconnaissance report, but dwelt mainly on Menengai caldera and did not discuss geological and structural set-up for development of the extensive anomalous geothermal manifestations in the Arus Lake Bogoria areas.

4. GEOLOGY

4.1 Regional Geological Setup

The Kenya Rift (Figure 1). is part eastern arm of the Great East African system that extends from the gulf of Eden in the north to Beira, Mozambique in the south. It is part of a continental divergent zone, a zone where spreading occurs resulting to the thinning of the crust hence eruption of lavas and associated volcanic activities.

The development of the Kenya Rift Valley started during early Miocene (14-23 Ma BP) with volcanism in Turkana followed by activity southwards. The faulting that accompanied rifting occurred in several stages starting with faulting on the western side accompanied by basaltic and phonolitic volcanism on the crust of uplift (Baker et al. 1987). Major faulting on both the eastern and the western flanks was accompanied by volcanic eruptions that resulted in the formation the graben structure about 5 million BP. This was followed by fissure eruptions in the axis of the rift to form flood lavas.

During the last 2 million years, volcanic activities become more intense within the axis of the rift. During this time, large shield volcanoes, most of which are geothermal prospects, developed in the axis of the rift. These Quaternary to Recent volcanoes include Suswa, Longonot, Olkaria, Eburru, Menengai, Korosi, Paka, Silali, Emuruangogolak, and Barrier Complex. Other geothermal prospects, of which Arus and Lake Bogoria prospects are, occur between these central volcanoes (Omenda et al., 2001).

3.1 Surface Geology of Arus Lake Bogoria

The upper Plio-Pleistocene volcanism of the rift floor in the area between Arus and Lake Bogoria is characterized by large volumes of evolved lavas that consist mostly of peralkaline trachyte, trachyphonolite and phonolite. Small outcrops of basaltic lavas occur in isolated areas within the prospect. The northern sector is, however, dominated by fluvial and alluvial deposits. The geological map showing all the outcrops encountered in the area is presented in Figure 3.

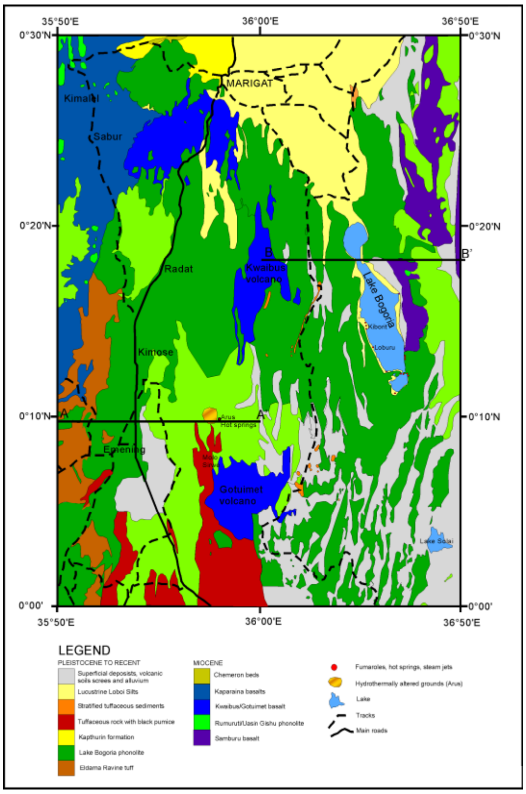

Figure 2: The geological map of the Arus-Lake Bogoria geothermal prospect

4.2 Structures in the Arus-Lake Bogoria prospect

The main structural features in the Arus and Lake Bogoria areas include; the eastern rift flank, the rift proper, NW, NNE and N-S trending faults and fractures and the Marigat and Loboi lineaments (Figure 3).

The most prominent of the NW trending faults is the line of Sattima-Aberdares and Marmanet Faults. Its complement to the north comprising the Lariak-North Arabel and other shorter minor faults forming a belt of discontinuous fractures. Progressively towards the northwest, both fault zones display an *en echelon* displacement to the west. The NNE trending faults form a dense swarm of 8-10 km, which correspond, generally to much of the eastern shoulder of the rift. In the north the margin of these NNE trending is clearly demarcated by Laikipia Monocline clearly defined by dip variations and the Loriki Escarpment (Figure 3). To the south interaction with faults trending N-S and NW-SE enhances the composite effect of sigmoidal elements, which contribute to the flexure in the rift structure south of Lake Bogoria. Faults trending N-S are fractures with a broadly meridional trend interact with the NNE trending faults in the eastern rift shoulder, but are the dominant structural elements of the rift floor, notably the grid-faulted platform west of Lake Bogoria and the fissure system. The same structures are aligned to the vents and the cinder cones of Korosi and Paka volcanoes further north of the prospect area.

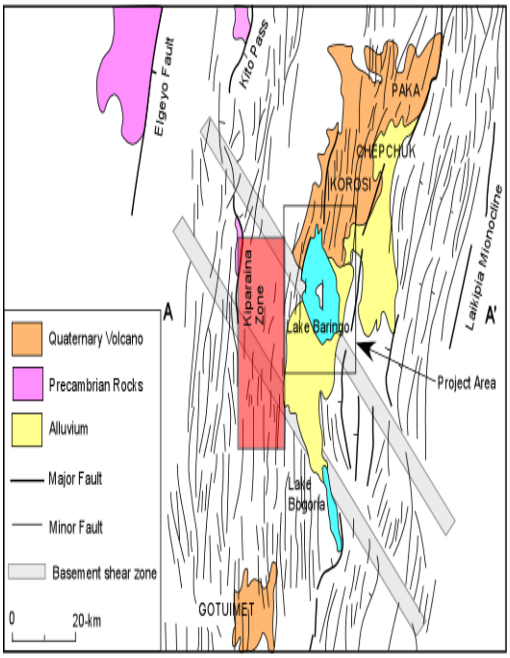

Figure 3: The structural map of the Arus-Lake Bogoria prospect.

Marigat lineament detected on special thematic mapping Landsat imagery is one of the minor swarm, which affects the Loboi Silts deposited between Lake Baringo and Lake Bogoria. The NW trending faults, which comprise the Sattima-Aberdares, and Marmanet Faults coincide with the major NW shear zones, which are considered to reflect reactivation of the Precambrian Mozambiquan belt formation. The important structures are the Ol Arabel and Loboi/Marmanet lineaments (Figure 3). The interaction between these faults and the NNE ones has created an intensely sheared/fractured zone (Box fault systems according to Hackman, 1988) to the northeast of Lake Bogoria at the Laikipia Escarpment. The shearing has resulted some of the Lake Bogoria phonolites develop fissility (slaty) texture, which trend in the same direction.

Recent faults affecting Loiminangge beds south east of Lake Baringo, slightly northeast of the prospect area where west facing scarps up to 6 m high displace pre-existing piedmont fans can be recognized. The Marigat lineament is also a very recent structure affecting the alluvial plains between Lake Baringo and Lake Bogoria (Loboi plains, suggest rejuvenation of buried Proterozoic structures in response to neotectonic regime. Continuation of tectonic activity in the prospect area has been demonstrated by the 28th January 1928 (Tillotson, 1938), Magnitude 7.1 earthquake with its epicenter at Lariak forest at the foot of Laikipia Escarpment (Figure 4). An elongate about 28 km curvilinear fissure appeared at the foot of the Laikipia Escarpment along the line of Marmanet Fault and at the Lake Bogoria Escarpment both opening up to 2.4 m and 0.6-0.8 m thick respectively.

5. GEOTHERMAL MANIFESTATIONS

The geothermal manifestations occurring in the prospect include fumaroles, hot and steaming grounds, anomalous boreholes, hot

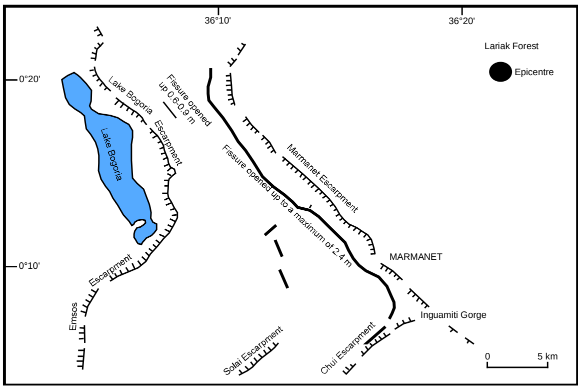

Figure 4: Fissure openings and the epicentre of the 28th January, 1928 earthquake

springs, steam jets, altered grounds, sulphur, calcite and travertine deposits and silica and quartz deposits in veins.

Most of the southern shores of Lake Bogoria (Figure 5) have geothermal manifestations consisting of hot springs, spouting springs (Plate 2) and hot grounds with temperatures in the range of 85-98°C. Several springs occur a few meters off shore and are characterized by bubbles under the water. Several weak geysers (spouting springs) occur at Kwaibeipei and Loburu where they spout hot water feebly after every few minutes (Figure 5). There are other numerous spouting hot springs in more or less continuous activity at Kwaibeipei and a few kilometers to the north occurring in a recognizable linear arrangement along fault lines. Most of the occurrences are characterized by bare ground (scarce vegetation).

Warm springs are common around Lake Bogoria and within the prospect. The most important ones include Emsos, Ndolaita and Loboi (Figure 5). The hot springs at Emsos are associated with the Emsos fault where they discharge at 37°C. The Ndolaita springs occur to the west of Lake Bogoria at Maji Moto where they bubble up in the rocky bed of the Ndolaita River at Maji Moto. The hot springs discharge at 38°C at the foot of a fault scarp. Northwest of Lake Bogoria, a series of hot springs at Loboi discharge through a series of pools of clear water (Plate 1) into the Loboi swamp.

Plate 1: Clear Loboi warm springs discharging into the Loboi swamp.

Plate 2: Hot spring at Loburu in the western edge of Lake Bogoria.

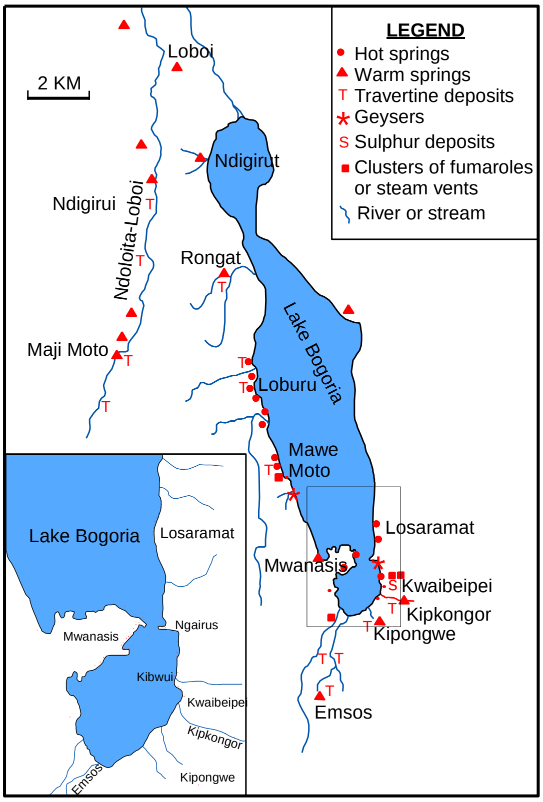

Figure 5: Geothermal manifestations in the area surrounding Lake Bogoria

6.0 GEOTHERMAL RESOURCE UTILIZATION

6.1 Current Utilization

Fault controlled geothermal systems exist in both Arus and Lake Bogoria geothermal prospects. The estimated geothermometry temperatures are low to medium (<248°C) Kizito et al 2006 and are ideal for direct uses and binary cycle electricity generation technologies.

The direct application currently available within the prospect area is a spa pool at Lake Bogoria Hotel (Plate 3). The water, which is at 38°C is channelled directly into the swimming pool at one end and flows out at the other end.

6.1 Proposed Utilization

Direct or non-electric utilization of geothermal energy refers to the immediate use of the heat energy rather than to its conversion to some other form such as electrical energy. The primary forms of direct use that can be harnessed in Arus and Lake Bogoria include swimming, bathing and balneology (therapeutic use), space heating and cooling, agriculture (mainly greenhouse heating and some animal husbandry), aquaculture (mainly fish pond), industrial processes, and heat pumps (for cooling). In general, the geothermal fluid temperatures required for direct heat use are lower than those for economic electric power generation.

Most of these direct use applications utilize geothermal fluids in the low to moderate temperatures and the reservoir can be exploited by conventional water wells drilling rigs. Advances in binary-cycle power and submersible pump technologies have made electric power generation from geothermal fields in low enthalpy fields with low temperature ranges of 50-150°C commercial. For these temperature ranges, shaft pumps installed on the wellhead would supply enough hot water to run a binary-cycle power plant.

Plate 3: Hot spring feeding into the spa pool at Lake Bogoria hotel.

7.0 CONCLUSIONS

1. There exist several low to intermediate temperature fault controlled geothermal systems in the Arus-Lake Bogoria prospect.

2. The heat sources in both the Arus-Lake Bogoria prospect are associated with the thinning of the crust and shallow intrusives.

3. The geothermal resource can be utilized both for electricity generation using binary and for direct uses.

4. Deep exploration wells to be drilled in the prospect to confirm the

characteristics and potential of the geothermal reservoirs.

7.0 ACKNOWLEDGEMENT

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