Paper to be presented at *Workshop for Decision Makers on Geothermal Projects and Management,* organized by UNU-GTP and KengGen in Naivasha, Kenya, 14-18 November, 2005

OVERVIEW OF GEOTHERMAL RESOURCE UTILIZATION AND POTENTIAL IN EAST AFRICAN RIFT SYSTEM

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ABSTRACT

The Great East African Rift System (EARS) is one of the major tectonic structures of the earth that extends for about 6500 km from the Middle East (Dead Sea-Jordan Valley) in the North to Mozambique in the south. This system consists of three main arms: the Red Sea Rift; the Gulf of Aden Rift; and the East African Rift which develops through Eritrea, Ethiopia, Kenya, Tanzania, Zambia, Malawi and northern Mozambique floored by a thinned continental crust. The EARS is composed of two rift trends; the eastern and western branches. The western branch develops from Uganda throughout lake Tanganyika, where it joins the Eastern branch, following the border between Rwanda and Zaire. The western branch is, however, much less active in terms of volcanism although both branches are seismically and tectonically active today. The East African Rift is one of the most important zones of the world where the heat energy of the interior of the Earth escapes to the surface in the form of volcanic eruptions, earthquakes and the upward transport of heat by hot springs and natural vapor emanations (fumaroles). As a consequence, the EARS appears to possess a remarkable geothermal potential. The eastern branch, that forms the Ethiopian and Kenyan rifts, possesses, by far, the most extensive geothermal resource base in Africa and one of the most extensive in the world. Countries such as Djibouti, Uganda, Eritrea and other countries in southeastern Africa have lesser but still important resource bases. Using today's technologies, Eastern Africa has the potential to generate about 2,500-6500 MW of energy from geothermal power. East African Countries using, or having carried out research on, geothermal resources include: Djibouti, Eritrea, Ethiopia, Kenya, Tanzania, Uganda, and Zambia. Among these Kenya is the leading country in using geothermal energy for electricity production followed by Ethiopia. Kenya is generating a total of about 130 MWe of electricity using geothermal energy resources. In Ethiopia a geothermal pilot power plant with a total installed capacity of 7.2 MWe was built but is not operating due to technical problems. Countries such as Djibouti, Eritrea, Tanzania, Uganda and Zambia are at exploration stage. Other countries such as Rwanda, Malawi and the Malagasy Republic have, to date, not gone beyond the resource potential inventory work.

1. INTRODUCTION

The governments of East African Countries are committed to investigate and further develop geothermal energy in order to supplement and diversify energy sources. This commitment arises due to:

- Strong growth in electricity demand in the countries;
- Recent effects of drought
- Silting of hydropower resources; and
- Volatile nature of Petroleum prices.

The East African countries have similar energy production and consumption characteristics. Most of the rift valley countries in East Africa are dependent on fossil fuels as a primary energy source. They use traditional biomass fuels that represent the largest category of energy produced, ranging from 70-90% of total energy production. The high percentage of usage of combustible waste and biomass causes large areas of deforestation and contributes to environmental degradation. All East African countries import petroleum products mainly for transport and electricity production. Renewable energy sources (hydro, geothermal, solar, etc.) represent a small portion of total energy production, averaging 2% for hydropower and solar and geothermal production combined.

Hydropower is currently the predominant mode of electricity production in the region (70%), yet recent droughts and silting of reservoirs pose questions concerning the reliability of these resources (see Table 1). Thermal production (mainly diesel generation) is used in most countries and is the only source of power production in Eritrea and Djibouti. Volatile prices and high import costs make diesel based power production costly. Therefore, to decrease imports and save foreign currency and in the face of the increasingly recurring severe drought it is important for the region avoid relying solely on hydroelectricity and to make geothermal energy generation a complementary part of future development. Most of the East African countries with geothermal potential are turning to their own indigenous resources to help them meet their growing energy needs. Geothermal energy presents a clean and more environmentally friendly alternative to more traditional fuels.

Using today's technologies, Eastern Africa has the potential to generate 2500-6500 MW of energy from geothermal power (GEA, 1999) which if developed would represent from ¼ to ¾ of current worldwide production from geothermal sources (8,900 MW total installed capacity). Despite this potential, only Kenya now has active geothermal operations as part of the country's electricity generation infrastructure. The progress of development is affected by (a) lack of finance, and (b) lack of technical capabilities in some aspects of development.

To put this in an international perspective, approximately 8,900 MW of geothermal power is generated worldwide. Philippines produces over 1900 MWe and Indonesia produces about 589 MWe. Kenya and Ethiopia have a total installed capacity geothermal energy capacity of about 137 MWe. Since the early 1980's, Kenya has been increasing their total geothermal power generation from the initial 15 Mwe to 130 MWe at Olkaria near Naivasha. Of this total, KenGen generates 115 MWe, ORMAT (an IPP) generates 13 MWe from a pilot binary Plant and Oserian development company (a flower farm) generates 2 MWe. By 2019, Kenya plans to add a total of 576 MW of geothermal power.

Varying degrees of geothermal exploration and research have been undertaken in Djibouti, Eritrea, Uganda, Tanzania, Zambia and Malawi. The potential to use geothermal energy for grid-connected electrification is greatest in Kenya, Djibouti, Ethiopia, Uganda and Tanzania. In addition, all the countries have the potential to use geothermal energy for grid connected electrification. Government representatives from Ethiopia, Uganda, Tanzania and Eritrea have also expressed interest in using small-scale geothermal plants for rural electrification.

TABLE 1: Energy consumption in East African countries from all various energy sources

COUNTRY	THERMAL	HYDRO	GEOTHERMAL	WIND	TOTAL
Djibouti	85	-	-	-	85
Eritrea	130	-	-	-	130
Ethiopia	112	671	7	-	790
Kenya	346	584	130	1	1052
Tanzania	202	561	-	-	763
Uganda	-	300	-	-	300
Total	875	2116	137	1	3127
%	28%	68%	4%	0%	100%

This paper is a summary of literature review collected from various papers presented and/or published in various geothermal workshops and conferences and their proceedings. The paper also covers the main observations, strategies for development and upcoming projects.

2. THE EAST AFRICAN RIFT REGION

East African countries using, or having carried out research on, Geothermal Resources include: Djibouti, Eritrea, Ethiopia, Kenya, Malawi, Tanzania, Uganda and Zambia. Brief description of exploration and utilization of geothermal resources in each country is given below in alphabetical order.

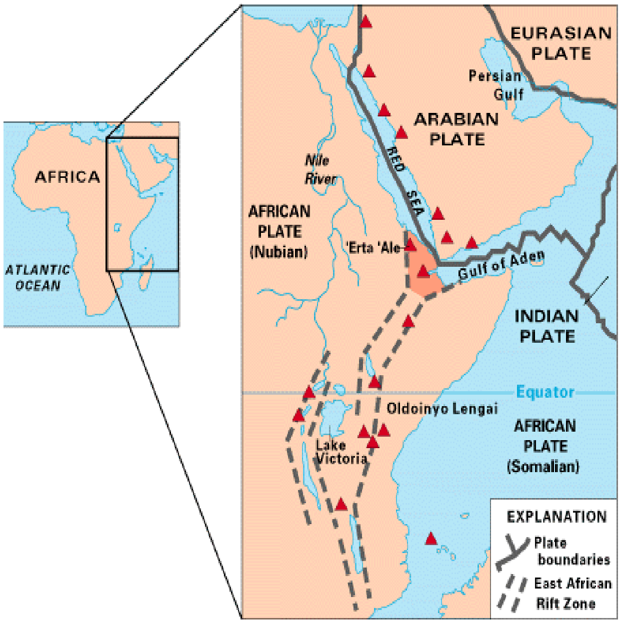

FIGURE 1: The Great East African Rift System

2.1 Djibouti

Djibouti lies at the junction of three active, major coastal spreading centers: (a) the Eastern Africa Rift zone; (b) The Gulf of Aden Rift; and (c) and the Red sea Rift (Figures 1 and 2). This structural junction is unique being the focal point of very high heat flux.

According to a recent study by the Geothermal Energy Association (GEA, 1999), the geothermal potential in Djibouti is between 230-860 MWe from a number of prospects including: (i) Lake Assal, (ii) Lake Abbe; (iii) Hanle; (iv) Gaggade: (v) Arta; (vi) Tadjourah; (vii) Obock; (viii) and Dorra (Figure 2).

Much effort has been expended in Djibouti since the 1970s, in view of the country being deficient of indigenous energy resources. Djibouti is entirely dependent upon imported petroleum supplies for its power generation needs (Table 1). The first concerted effort to assess and explore Djibouti's geothermal resources took place in the Assal area from 1970-83 and funded by French government. About six exploratory wells were drilled in the Assal geothermal fields. While a very high temperature system has been successfully located, problems related to high salinity of the discovered fluids, which is due to the close proximity of the field to the Gulf of Aden, has delayed resource development and exploitation.

FIGURE 2: Location of geothermal prospects in Djibouti

With the support of United States Trade and development Agency (USTDA), in 2000, an American privaate firm, Geothermal Development associates (GDA) completed a feasibility study for the development of a 30 MWe geothermal power plant in the Lake Assal region.

2.2 Eritrea

In 1973 the United Nations Development Programme (UNDP), identified a potentially significant exploitable geothermal resources in Eritrea. In 1995 with help of USGS, Eritrea identified the Alid geothermal prospect area for follow up detailed investigations. This area is located about 120km south of Massawa (Figure 3)

The Eastern lowlands of the country are of potential geothermal interest. First priority was given to the Alid Volcanic center for exploration as it has numerous manifestations in the form of hot springs and fumaroles. Detailed geological and geochemical investigations revealed a reservoir temperature of about 250°C (Michael 2005). It is possible that there could be other sites suitable for discovery of a high temperature resource.

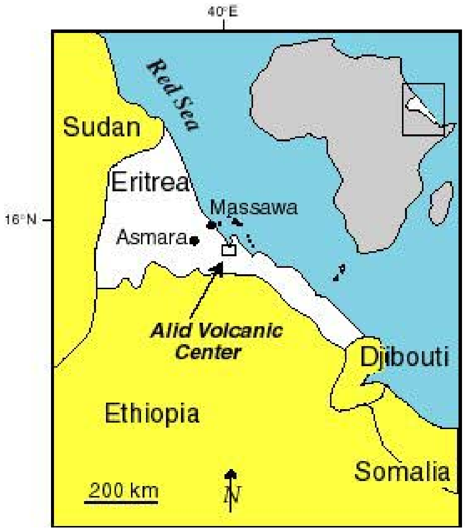

FIGURE 3: Location of Alid Volcanic center in Eritrea

2.3 Ethiopia

Ethiopia started a long-term geothermal exploration undertaking in 1969. Over the years a good inventory of the possible resource areas has been built up and a number of the more important sites have been explored in the Ethiopian Rift Valley (Figure 4). Of these areas, about sixteen are judged to have potential for high temperature steam suitable for electricity generation. A much larger number are capable of being developed for direct utilization of geothermal heat in agriculture, agro-industry etc.

Exploration work peaked during the early to mid-1980s when exploration drilling was carried out at the Aluto-Langano geothermal field (Lakes District). Eight deep exploratory wells were drilled to a maximum depth of about 2500 m, and four were found to be productive with a maximum geothermal reservoir temperature of about 350ºC.

During the early 1990s exploration drilling was also carried out at Tendaho (Northern Afar). Three deep (2100 m) and three shallow wells (500m) confirmed the existence of a high temperature (270ºC) reservoir. Currently discharge tests and geochemical monitoring work is in progress.

The Aluto-Langano geothermal field was handed over to the Ethiopian Electric Power Company (EEPCo) for development in the year 1996 but utilization was delayed until 1998. The first 7.2 MWe pilot power plant was built under a turnkey contract by an Israeli company ORMAT. This plant has faced operational

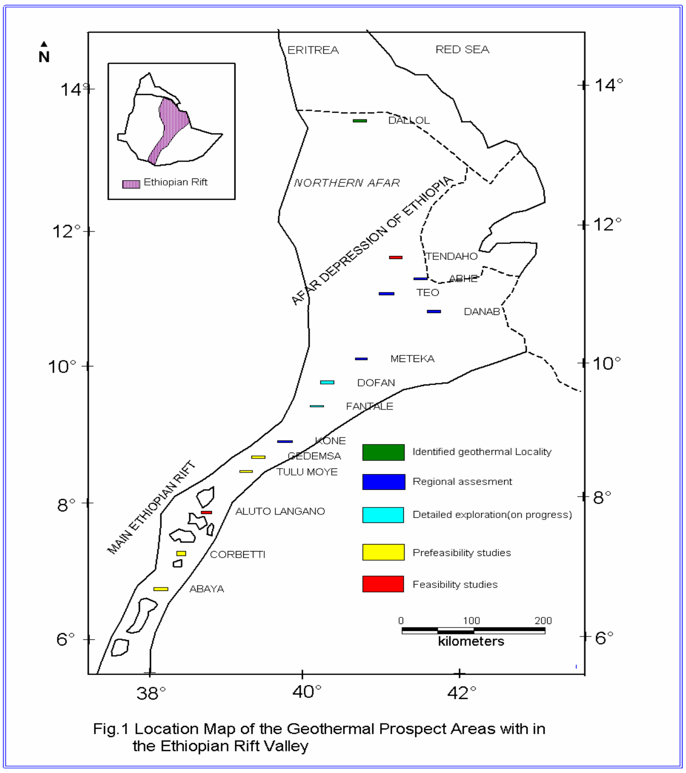

FIGURE 4: Location of geothermal prospect areas in Ethiopia

difficulties mainly due to technical limitations in appropriate field and plant management skills. With the rectification of these problems, the plant should run more reliably and provide experience that would be useful in the future exploitation of the country's extensive resources. This would suppliment power supply from hydro-resources and, diversify the energy supply structure.

In 2005, EEPCo sought international bids for problem identification and putting the plant back into operation. A number of companies submitted bids and Geothermal Development Associates, an American firm was awarded the contract. The work is to begin shortly.

Other geothermal prospect areas in the Ethiopian Rift Valley are at various stages of exploration that vary from reconnaissance to detailed geoscientific studies including drilling of temperature gradient (TG) wells. These include:

(i) Tulu-Moye and Corbetti : Detailed geoscientific including drilling of TG wells
(ii) Abaya and Dofan Fantale: Detailed geoscientific studies
(iii) Teo, Danab, Kone and others: Reconnaissance investigations.

During the three decades that the geothermal resources exploration work was carried out in Ethiopia, a good information base and degree of exploration capacity has been developed. This is especially in the human capacity and basic infrastructure development that will be critical in ensuring that future selected resources sites are advanced to the development phase much more rapidly than before.

2.4 Kenya

In the East African Rift region, Kenya was the first African country to tap geothermal energy for electric power generation. This has partly been due to its limited hydro resources and the success that it had in the staged geothermal development since 1982. Kenya's first electricity generating plant in Olkaria (Figure 5) has been operating for 24 years and has proven to be reliable and economical with a 98% availability and 100% load factor. This has encouraged Kenya to speed up its geothermal power development program. It now has an installed capacity of about 130 MWe. This has been achieved over a period of 50 years since exploration started in the 1950's. To date, a total of 105 wells have been drilled for exploration, production, monitoring and re-injection with depths varying from between 1000 and 2,600 m. The long term least-cost power development program foresees a total generating capacity of 2350 MW by the year 2019 of which about 576 MW will be from geothermal power plants. It is notable that in Kenya other than electricity production, geothermal water and carbon dioxide are used in an extensive complex of green houses for

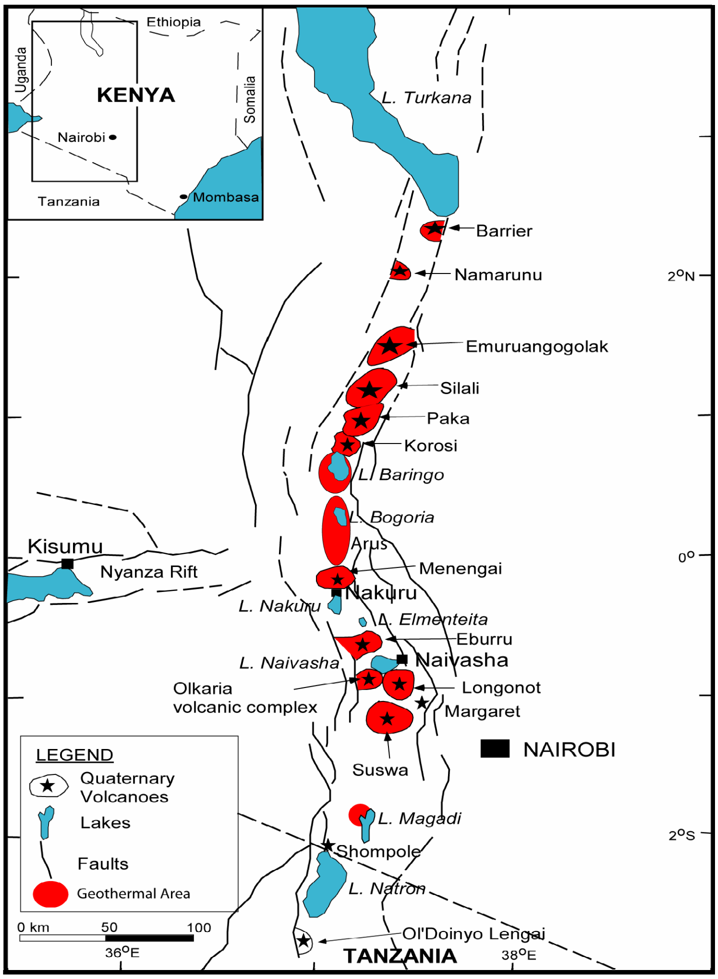

FIGURE 5: Location of geothermal prospects areas in the Kenyan rift

growing roses. Rose exports from that farm total US$300 million per year.

The most explored and developed field in Kenya is the Olkaria geothermal field that is divided into seven areas. The Olkaria I area has a 45 MWe power plant based on three 15 MWe units commissioned in 1981, 82 and 85 and Olkaria II area has a 70 MWe power plant commissioned in 2003. These two plants and areas are owned by KenGen. The Olkaria III area with a pilot 13Mwe plant is owned ORMAT (an IPP). Olkaria IV area (locally referred to as Domes) has three exploration wells drilled with temperature up to 350ºC. This area is now earmarked for appraisal and production drilling for a 70 Mwe power plant. Other geothermal areas such as Longonot, Suswa, Menengai etc. are at a various stages of exploration (Figure 5). The current estimated geothermal potential in Kenya is 3,000 Mwe.

In the process of these activities, Kenya has acquired considerable expertise in geothermal related earth sciences and engineering. It has also lead to a development of the institutional infrastructure that is necessary for geothermal resource exploration, development and utilization.

2.5 Tanzania

Geothermal exploration in Tanzania was carried out between 1976-79 by SWECO, a Swedish consulting group, in collaboration with Virkir-Orkint (Iceland), with financial support from the Swedish International Development Authority (SIDA). Reconnaissance studies for surface exploration were carried out in the north (near Arusha, Lake Natron, Lake Manyara and Maji Moto) and in the south (Mbeya region). Geothermal work in all locations in Tanzania is at the surface exploration stage.

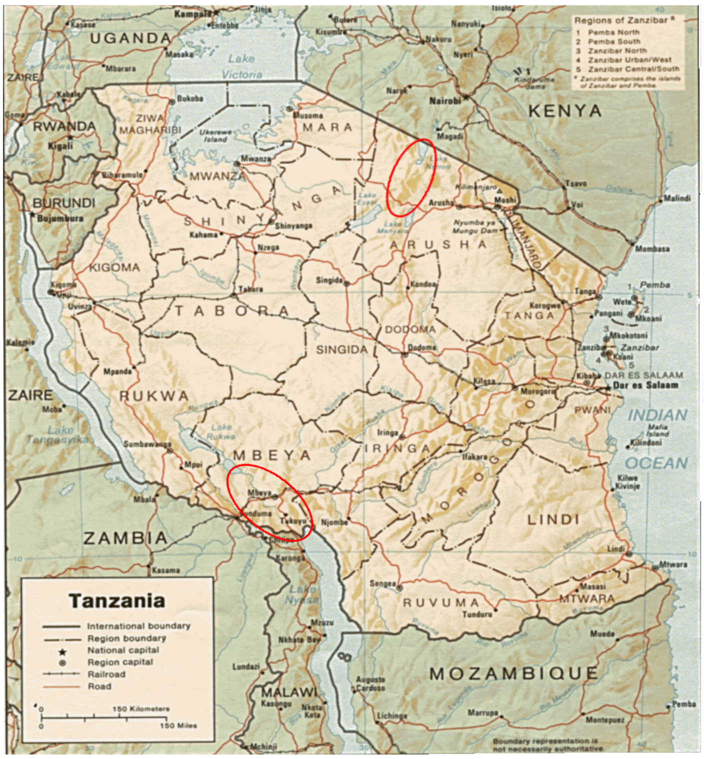

FIGURE 6: Geothermal prospect areas in Tanzania

Two potential target areas for geothermal exploration singled out so far are: (a) Arusha region near the Kenyan border in the North; and (b) Mbeya region between Lake Rukwa and Lake Nyasa in the southwest (Figure 6). Another potential area (Luhoi) was prospected during 1998-2002 by First Energy Company (a local firm). It conducted important project definition and reconnaissance evaluation work. This area is located 160 km south of Dar es Salaam. The work conducted so far indicates the existence of a geothermal reservoir with a temperature greater than 200°C.

2.6 Uganda

Reconnaissance survey has been carried out on geothermal areas of Uganda since 1935 when the first documentation of hot springs was made (Bahati and Joshua, 2002). Uganda recognizes the need to develop its geothermal resources to diversify its electricity generation, to support hydro and to improve electricity supply in the western part of the country. Recent geoscientific studies have focused on three geothermal systems of Buranga, Katwe and Kibiro (Figure 7), all located in the active belt in the western Rift valley along the border of Uganda and Democratic Republic of Congo**.** The African Development Bank with the Uganda Alternate Energy Resource Agency (UAERA) conducted research at Katwe. The Icelandic International Development Agency (ICEIDA) financed surface exploration survey (geological and geophysical) at Kibiro. ICEIDA also financed the finishing of the incomplete survey of UAERA study in the Katwe prospect. For this area, a contractor has been selected on the basis of international bids for drilling of temperature gradient wells in order to locate target areas for deep exploratory wells.

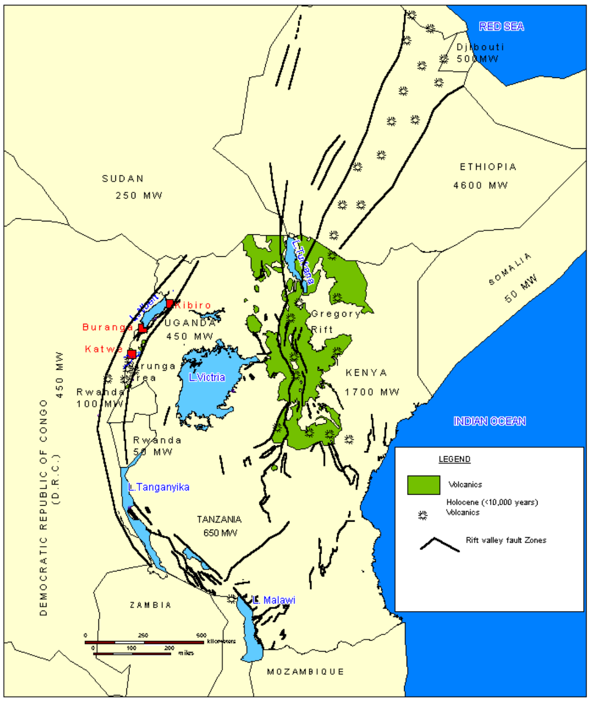

FIGURE 7: Geothermal prospects in Uganda

2.7 Zambia

Zambian Geological Survey (ZGS) has carried out reconnaissance survey on geothermal areas of Zambia since 1950's. In 1986, the ZGS together with an Italian Company studied various hot springs. As a result, development has been considered on two prospects (i) Kapisya and (ii) Chinyunyu projects (Figure 8).

The Italian government in 1987 funded a mini geothermal pilot power plant (200 KW) at Kapisya hot springs located in Sumbu National Park on the shores of Lake Tanganyika. The plant was installed on the basis of limited exploration work, and it never became operational. The government of Zambia is currently exploring options for refurbishing and commissioning the plant after being idle for 20 years.

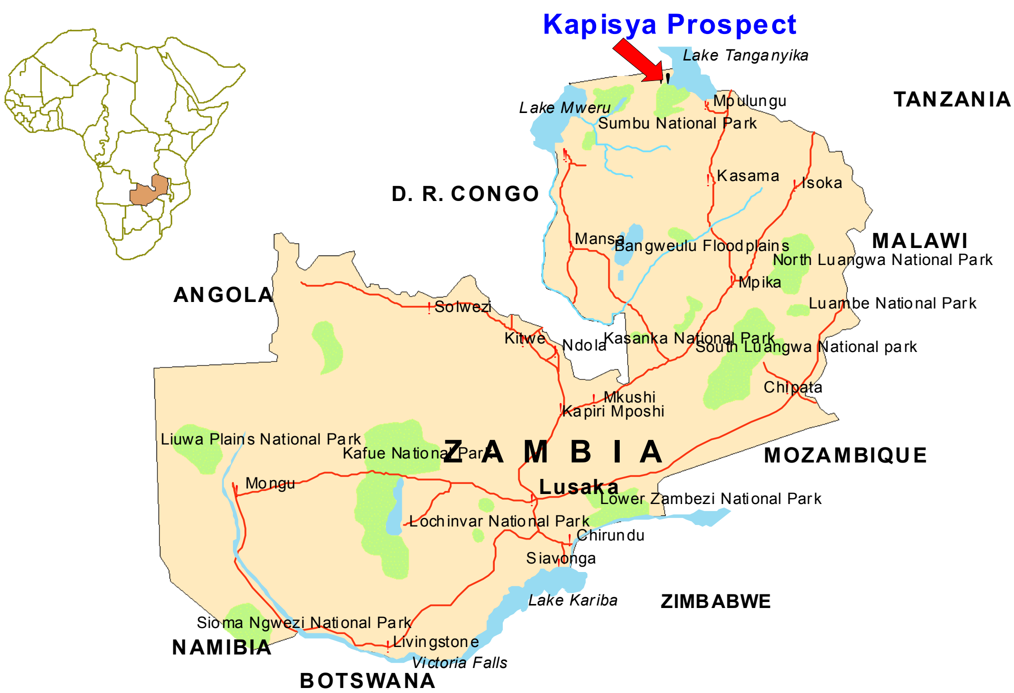

FIGURE 8: Map of Zambia showing location of Kapisya geothermal prospect

3. MAIN OBSERVATIONS

Exploration and utilization of geothermal energy resources in the East African region for the last three decades has indicated that:

- The region has a large untapped geothermal resource potential ;
- The resource is an indigenous, reliable, environmentally clean and economically viable, renewable energy resource;
- Development of geothermal resource is constrained by (i) the risks that are associated with resource exploration and development; (ii)the financial risks that are associated with investment in power development projects ; and (iii) lack of appropriate investment and institutional settings in many East African countries;
- Diversified use of energy augments energy supply from hydro power plants and improves the generation mix. It avoids vulnerability to drought and oil price fluctuations.

4. STRATEGIES FOR DEVELOPMENT

In order to promote the geothermal resource exploration and utilization each government of the East African countries has a plan to:

- Establish long-term conducive policies and incentives that attract private investment.
- Set up a Regional Network of Geothermal agencies to ensure the promotion and use of geothermal expertise in the East Africa Region.
- Establish a Risk Guarantee fund for exploratory and appraisal drilling of projects
- Look for Private Sector participation and financing from developers , investors, equipment suppliers and development banks.
- Look for loans and grants from International Organizations to finance the projects for further exploration and development.

5. UPCOMING PROJECTS

Towards the objectives of faster exploration and development of geothermal resources in the region, multi and bi-lateral efforts are being made.

Among these, the African Rift Geothermal Energy Development Facility (ARGeo) Project is a critical component. The objective of the project is to promote geothermal resource utilization by removing the risks related to resource exploration and development and by reducing the cost of power development project implementation. The ARGeo Project is planned to deliver a package consisting of financial and technical inputs as a means of realizing that promotion. Policy support will aim in cultivating the recognition that the resource is reliable and indigenous with respect to other sources of power. Utilization of the resource in direct uses such as agriculture, horticulture, aquaculture and industry will be promoted.

The project's implementing agency is the United Nations Environmental Programme (UNEP). Its executing agencies are Kreditanstalt fur Wiederaufbau (KfW) and African Development Bank (ADB). Projects will be executed in collaboration with a network of national institutions in the region. Other institutions that are involved in development financing will also contribute resources, including the Global Environment Fund (GEF).

Countries targeted by the project are Djibouti, Eritrea, Ethiopia, Kenya, Tanzania and Uganda. Institutional capacities that already exist in these countries will form a network that will be the main instrument for project implementation and capacity building.

ARGeo implementation will be preceded by an initial project development stage which will identify the most suitable resource areas for support, survey of the already existing human, institutional and infrastructure capacities in the region and assist with the creation of the collaborative institutional aims to support, initially 3 to 4 investment projects, in the subject countries. A total of US$ 250 million will be allocated to implement the project.

REFERENCES

Business Council For Sustainable Energy (2003): Market assessment report. *East African Geothermal "Market Acceleration" Conferenc, April 2003, Nairobi, Kenya*.

Bahati, G., and Joshua, T., (2002): *Geothermal energy in Uganda*. Geological Survey of Uganda.

Geothermal Energy Association, (1999): *Geothermal Energy, the Potential for clean power from the earth.*

Michael, A., (2005): Country update on geothermal energy in Eritrea. *Proceedings of the World Geothermal Congress, WGC 2005, Antalya, Turkey.*

Mwangi, M., (2005): Country update on geothermal energy in Kenya. *Proceedings of the World Geothermal Congress, WGC 2005, Antalya, Turkey.*

Teklemariam, M., and Beyene, K., (2005): Country update on geothermal energy in Ethiopia. *Proceedings of the World Geothermal Congress, WGC 2005, Antalya, Turkey.*

UNDP, (1973): *Geology, geochemistry and hydrology of the East Africa Rift System within Ethiopia*. United Nations, New York, DDSF/ON/116.