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Uganda Geothermal Energy Country Update

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ABSTRACT

Uganda presently has a total generating capacity of 317 MW, most of which is from large hydro. Peak demand is about 300 MW. The country's energy surplus is expected to be short term, with electricity demand growing by 7.4% per anuum. Despite its abundant hydro resources, the Ugandan government recognizes that it must diversify its energy resources. The present level of uncertainty regarding the future of large hydro power projects has caused the government to take a closer look at the country's geothermal potential. The government is especially interested in including village-scale geothermal power plants as part of its rural electrification program.

At present two geothermal prospects Katwe and Kibiro are being assessed in W-Uganda with support from the African Development Bank, Government of Iceland and World Bank. Katwe and Kibiro have subsurface temperatures of 160-200°C and above 200°C respectively and are considered as potential geothermal prospects. The temperatures have been inferred by geothermometry and mixing models. These temperatures are suitable for electric power production and direct use in industry and agriculture. The current geophysical surveys in the two areas are expected to be completed by mid 2005 marking the end of pre-feasibility studies in the two areas. Based on the results, a feasibility study will be carried out on one or both areas to fully assess the resource and its commercial viability. A pre-feasibility study in the third area, Buranga, is scheduled to start in early 2005 with support from the Germany Geological Survey (BGR). Its subsurface temperature is still unresolved being estimated at 120-150°C from solute geothermometry and as high as 200°C from isotope geothermometry. Uganda has other geothermal areas with subsurface temperatures in the range of 100-180°C from preliminary studies but further investigation is needed for a possibility of installing small scale geothermal plants for rural electrification.

The government of Uganda recognizes the lack of sufficient geothermal data to negotiate binding power purchase agreements (PPAs) with geothermal developers at the present time. Nevertheless, the government is interested in negotiating preliminary "non-financial PPAs" with private geothermal energy companies willing to partner with the Ministry of Energy and Mineral Development to obtain grant or "partial risk guarantee" funds for the feasibility study. This will require goods and services including: drilling and well completion (cementing and casing); reservoir assessment; water and mineral extraction (possible); well testing; environmental studies; project pre-feasibility studies and analysis; financing; power plant design; and machinery parts, maintenance and repair.

1. INTRODUCTION

Geothermal resources exploration in Uganda is still at the pre-feasibility phase with two of the three most promising prospects Katwe-Kikorongo (Katwe) and Kibiro under detailed surface analysis. The current studies in the two areas once completed will pave way to drilling of exploration wells and installation of the first pilot geothermal power plant in the country. The country is endowed with considerable hydropower resources with the potential capacity estimated to be in excess of 2,000 MW. Hydropower is the main source of Uganda's electricity supply with a total generating capacity of 317 MW of which 300 MW is from a single source on the River Nile; the Nalubale (formerly Owen Falls) and Kiira (Owen Falls extension) dams (Table 1). The rest is from small hydropower sources in W-Uganda namely Mubuku (15 MW) and Maziba (2 MW) located in Kasese and Kabale districts respectively. Further hydropower developments on the River Nile have raised socio-economic and environmental issues and therefore a need to diversify the energy sources. Alternatives being investigated are mainly renewable sources that include geothermal, biomass, wind, peat, mini and small hydro, and solar energy.

The country's energy consumption rate stands at about 5 million tones of oil equivalent per year (toe/year) of which approximately 93% is biomass (wood, charcoal and agricultural residues). The grid electricity access rate is very low: 6% for the whole country and about 2% for the rural areas. Electricity production is approximately 1,660GWh per year with a demand for power growing by 7.4% per anuum.

The Ministry of Energy and Mineral Development (MEMD) implements the national energy policy with two departments i.e. Energy Resources (ERD) and Geological Survey and Mines (DGSM). The DGSM is responsible for exploration and development of the geothermal resources while the ERD is responsible for energy policy, formulation, implementation and administration of energy laws. In 1997, the Government of Uganda formulated a comprehensive and detailed Strategic Plan for transforming the Uganda power sector into a financially viable electricity industry and enable it to supply reasonably priced and reliable power. As a result of the plan, an energy policy was enacted in 2002. The energy policy is implemented by the Uganda Electricity Act 1999. This Act provides for an independent Electricity Regulatory Authority (ERA), private sector participation in power generation and distribution with transmission remaining a government parastatal in the medium term.

This paper presents the current status of the geothermal exploration project, and planned exploration and development activities on the geothermal systems of Uganda.

2. GEOLOGY OVERVIEW

The geology of Uganda consists of an exposed pre-Cambrian basement dissected by the western branch of the East African Rift system in the western part of the country. The eastern branch, the Gregory Rift, passes through the central part of Kenya. The Western Rift starts to the north along the Sudan border, and then curves to the west, southwest along the border with the Democratic Republic of Congo, and south to Rwanda and Burundi. Spreading began at least 15 million years ago in Miocene time. The western rift is considered at an early stage in development, and is younger (late Miocene – Recent) than the more mature eastern branch (Morley et al., 1999). The region of the rift has a markedly higher heat flow than the surrounding Pre-Cambrian terrain. Two different en echelon strands are found in the Western Rift, separated by the Rwenzori Mountains, which rise from a base of less than 1000 m in the Rift to over 5000 m elevation. Within the rift valley there are thick layers of late Tertiary and Quaternary sediments; fresh water and saline crater lakes; volcanics; and plutonic bodies have been identified beneath L. Albert and L. Edward (EDICON, 1984). The three main geothermal areas of Uganda; Katwe, Buranga and Kibiro are all found in the Western Rift valley. Figure 1 presents the generalized geology of the Western Rift Valley in Uganda.

3. GEOTHERMAL POTENTIAL

The country's geothermal resources were estimated at about 450 MW (McNitt, 1982) in the Ugandan Rift System and no new estimates have been put forward since then. Geothermal energy cannot be left out of Uganda's energy plans for the following reasons: Hydro - electricity sites are more or less concentrated in one area (along the river Nile) resulting in long transmission distances and high energy losses; Uncertainty of continued availability of hydropower arising from climatic fluctuations and therefore need to diversify energy sources; Location of geothermal fields in isolated areas without grid connection; and it is environmentally benign energy source.

The major areas under study are Katwe, Buranga and Kibiro. They are all situated in the Albertine graben that runs along the border of Uganda with the Democratic Republic of Congo (DRC) (Figure 1). The Albertine graben is part of the western branch of the EARS commonly known as the Western Rift Valley. Katwe and Kibiro are now in the final stages of surface exploration, which will be followed by detailed surface mapping and exploratory drilling while Buranga is still at preliminary level. The three areas were chosen as priority areas because of their volcanic and tectonic features that are indicators of powerful heat sources and permeability. The other geothermal areas are located on the outskirts and/or close to the rift valley in SW, NW and NE-Uganda (Figure 2).

3.1 Katwe Geothermal Prospect

This prospect is located within the Katwe-Kikorongo Volcanic field, south of the Rwenzori massif and is bordered to the south by Lake Edward and Kazinga Channel water bodies (Figure 1). Its unique compositions of the volcanics as well as the salt deposits at Lake Katwe have attracted scientific attention since the early 20th Century. The volcanics, composed mainly of pyroclatics and utramafic xenoliths, are deposited on the extensive Pleistocene lacustrine and fluvial Kaiso beds and in some places directly on Pre-Cambrian rocks. The volcanic setting of this prospect gives indication of a powerful heat source. The prospect covers an area of about 200 km^2 and is characterized by a number of craters, some of which are crater lakes. The surface manifestations, hot springs with a maximum temperature of 70°C, are limited to Kitagata and Katwe craters and lava flows to two adjacent craters Kitagata and Kyemengo. Travertine cones (Tufa), which are indicators of extinct hot springs activity, are a common feature in the Lake Katwe crater. Lake Katwe is also characterized by an ancient salt industry utilizing the geothermal brine. The surface manifestations, the size of the volcanic field and the geological observations make this prospect attractive for geothermal exploration (Gislason et. al., 1994).

3.2 Buranga Geothermal Prospect

This prospect is located 52 km from Fort Portal along the Fort Portal - Bundibugyo road in Bundibugyo district. It is at the foot of the Rwenzori massif and localized by the major rift valley faults (Figure 1). The surface manifestations (Hot springs) emerge at the surface through, 'Epi - Kaiso' beds and 'Peneplain Gravels' (of Upper to Middle - Tertiary age), sediments which consists of boulder beds and unsorted scree overlying sands and clays. These sands and clays are described as Kaiso - Kisegi beds. They have been thrown against Pre-Cambrian migmatites and gneisses by the main fault, which strikes at 45˚ azimuth and dips at 60 - 65˚NW. The Buranga prospect is the only field in Uganda where geothermal prospecting has been initiated as a result of three boreholes drilled in the early 1950's although the project was abandoned (Brown, 1954). The three wells were not maintained and have since been blocked. This area has the most impressive geothermal surface manifestations of all the geothermal areas of Uganda and the whole of the Western branch of the EARS. A total of 37 hot springs have been located and mapped, with a maximum surface temperature of 98.3°C and the greatest flow rate of up to 10 - 15 l/s (Gislason et. al., 1994). The Buranga prospect has the highest natural flow, and the largest confirmed areal extent of the three study areas.

3.3 Kibiro Geothermal Prospect

This prospect is located on a small peninsula in Lake Albert under the eastern escarpment of the Rift Valley in Hoima district (Figure 1). The surface manifestations, hot springs, are less conspicuous than at Buranga although the geological setting is similar. The hot springs cover a small area, but a relatively high temperature gradient of 9˚C/100m in an oil well 1.5 km NE of the springs and sulphur deposits in the escarpment rocks at Kachuru 0.5 km SW of the springs gives hopes that the thermal area might be somewhat larger (Gislason per. communication). 15 hot or warm springs have been located and mapped with a maximum surface temperature of 86.4°C measured in one of the springs (Gislason et. al., 1994). The Kibiro prospect is also characterized by an ancient salt industry utilizing saline water, which percolates through the sediment. This industry has been in operation for the last 900 years (Connah et. al., 1990). The heat source has not been localized in Kibiro and Buranga but from the results of the aeromagnetic survey of 1983, magnetic anomalies were observed in the vicinity of the two areas. These were interpreted as magmatic intrusions and seem very likely to serve as a source of heat for the two areas (EDICON, 1984).

4. CURRENT UTILIZATION

The Uganda geothermal project is still at the surface exploration stage with no geothermal wells drilled yet and therefore the current utilization is from the fluids discharges from hot springs which are used locally and has not been quantified. The geothermal water is being used as a source of salt at Kibiro and Katwe. At Kibiro the geothermal water is concentrated using dry soil by capillary attraction, the impregnated soil is then scooped and the salt recovered by dissolution and evaporation to dryness. At Katwe, the method is different from that one at Kibiro, and is done by channeling the brine into concentration ponds from which the salt solidifies on the surface by natural evaporation during the dry weather. Most of the Uganda hot spring waters are currently used for spas and are believed to have curative powers for skin diseases and rheumatics. The only known in-house use of geothermal energy is at Kisiizi hospital situated in Rukungiri district, SW-Uganda, where hot water at a temperature of 32°C is tapped from a hot spring and used in hospital for bathing and other domestic uses. The hot water is also used for watering animals as a substitute for salt licks because of its high salt content. And lastly, hot springs are a tourist attraction.

5. RECENT STUDIES

Recent studies have concentrated on the three geothermal prospects of Katwe, Buranga and Kibiro under two projects, Geothermal Energy Exploration I (UGA/92/002) and Isotope Hydrology for exploring Geothermal Resources (UGA/8/003).

5.1 Geothermal Energy Exploration I

This project was carried between 1993 and 1994. It was funded by the Government of Uganda (GoU), United Nations Development Programme (UNDP), Organization of Petroleum Exporting Countries (OPEC), and Government of Iceland and was executed by the Department of Development Support and Management Services of United Nations (UNDDSMS) and implemented by the Geological Survey and Mines Department (GSMD) of the Ministry of Energy and Mineral Development (MEMD) of Uganda. The funds committed under this project amount to 0.577M USD (Table 8). The study employed geological and geochemical methods with the aim of selecting one of the geothermal areas for further surface geophysical analysis and exploratory drilling.

The results of this project indicate that the geothermal activity is clearly related to the tectonic and volcanic activity of the rift, which has higher heat flow than the surrounding Pre-Cambrian crust; their hydrothermal systems appear to be relatively old and rise from volcanic rocks rather than from the young overlying sediments; at Katwe, the size of the volcanic field, the high subsurface temperature of about 160-200°C, as well as various geological observations and proximity to the national grid make the prospect attractive for electricity production; while the Buranga prospect appears to have a significant volume of water at 120 -150°C and may be appropriate for electricity generation from a binary power plant, and drying of agricultural products; and Kibiro prospect has a relatively simple geologic structure and waters indicative of subsurface temperatures of above 200°C suitable for conventional electricity production (Armannsson, 1994; Gislason, 1994).

5.2 Isotope Hydrology for Exploring Geothermal Resources

This project was conceived as a follow-on to UGA/92/002 with the objective to upgrade the geochemical model by carrying out additional hydrological studies to delineate the origin of the geothermal fluids, residence time, source of salinity and recharge areas of the fields. This project was funded by the GoU with support from the International Atomic Energy Agency (IAEA). The total funds committed under this project amount to 0.15M USD (Table 8). This project started in 1999 and ended in 2002.

The results of UGA/8/003 indicate that the thermal waters show isotopic composition compatible with the local meteoric water line, confirming the meteoric origin of the water circulating in the geothermal systems; admixture of modern water close to the surface in Kibiro but not in Buranga and Katwe; $\delta^{18}O$ enrichment of about 1‰ observed in the hot springs at Kibiro and Katwe suggests high temperature water-rock interaction, old age, or low water/rock ratio and high carbonate in the subsurface rock additionally for Katwe; magmatic contributions of sulphate; source of recharge as from higher elevations in the nearby Rwenzori Mountains in the case of Katwe and Buranga, and Mukihani-Waisembe ridge for Kibiro; subsurface temperatures of 200°C, 100-140°C and 140°C for Buranga, Kibiro and Katwe predicted by sulfate-water oxygen isotope geothermometry (the lower temperature for Katwe and Kibiro are possibly due to mixing of the geothermal water with cooler water); reservoir rock types for Katwe are most likely Basalt (Leucites and Melilites) and Granitic xenoliths, Granitic gneisses for Buranga and Kibiro; and the major source of salinity as from water-rock interaction, but some magmatic input is also evident (Bahati, et. al., 2004).

6. PRESENT GEOTHERMAL PROGRAMS

The ongoing programs are focused on the pre-feasibility study of Katwe and Kibiro and detailed geochemical investigation of other areas located outside the rift valley.

6.1 Preliminary geophysical surveys in Katwe and Kibiro

The GoU with support from the African Development Bank (ADB) and the Government of Iceland carried out preliminary geophysical survey and additional geology in Katwe and Kibiro in 2003 and early 2004 respectively. In the Katwe area the surveys were part of the first phase of the study 'Uganda Alternative Energy Resources Assessment and Utilisation Study (UAERAUS)' with support from ADB while the Kibiro project was under an agreement between Uganda's Ministry of Energy and Mineral Development (MEMD) and the Icelandic International Development Agency (ICEIDA). The total funds committed under these projects amount to 0.6M USD (Table 8). The aim of the surveys was to delineate the spatial extent of the thermal anomalies and upgrade the existing geothermal models of the two areas with geophysical information to pre-feasibility status.

The results of the geophysical surveys indicated the existence of geothermal systems in the two areas which is supported by the low resistivity and high gravity anomalies. In both areas, the areal extent of the low resistivity proved larger than anticipated an indication that the anomaly is somewhat larger and extends beyond the surveyed area. The funds were not sufficient to complete the pre-feasibility study in the Katwe and Kibiro areas.

6.2 Completion of the pre-feasibility of Katwe and Kibiro and assessment of other areas.

The World Bank (WB) is currently assisting the GoU through MEMD in its quest to meet the ever-increasing demand of the market for electricity. One of the options under consideration is to harness geothermal energy for electricity production. A WB fact-finding mission visited

Uganda in March – April 2004 to evaluate the current situation of the geothermal projects in Uganda, and it was concluded that the pre-feasibility studies on Katwe and Kibiro areas be completed before a donors meeting, scheduled for June 2005. It was proposed that MEMD requests technical assistance from ICEIDA to complete the pre-feasibility study while the WB meets the local cost as well as equipment cost.

Following the proposal by the WB mission, the GoU has obtained support from the WB and ICEIDA and is carrying out additional geophysical and geological surveys in Katwe and Kibiro with the aim to define the areal extent and the boundaries of the major low resistivity and high gravity anomalies. The project will also drill 4-5 temperature gradient wells of between 100-200 m deep in each of the two areas. If good results are obtained, they will be used as a basis for siting deep exploration wells.

Preliminary investigation on other areas has been carried out by the DGSM (Bahati, 2003b). However, this was limited to areas in SW-Uganda and the investigation was not detailed enough to be used as a basis for ranking the areas. Detailed geochemical investigation of these areas and others located in the northern parts of the Rift Valley, the West Nile region, and NE-Uganda is part of this project. Their assessment would justify the continued focus of geothermal exploration on Katwe, Buranga and Kibiro areas. The cost of the project is 0.5 M USD.

7. FUTURE PROGRAMS

The results from the pre-feasibility study, once completed, will be used to source for funding for the feasibility study on one or two areas. Two projects, therefore, are proposed for continued geothermal exploration and development in Uganda.

7.1 Pre-feasibility study of Buranga

The GoU with support from the German Geological Survey (BGR) is to carry out detailed geological and geophysical surveys in Buranga. The project is scheduled to start early 2005 and will take will take 4-5 months to complete. The results of the surveys will update the geothermal model of Buranga to pre-feasibility status. This project is estimated to cost 0.2 M USD.

7.2 Geothermal Energy Exploration II

This project is proposed to carry out the feasibility study on the most promising area(s) once the pre-feasibility on the three areas is completed. The objective of the feasibility study is to upgrade the geothermal models and site boreholes in three areas; drilling at selected sites, in one or two areas; prepare technical and financial/investment plans for the installation of appropriately sized power plants and feasibility of direct use in industry and agriculture; and train Ugandans in geothermal resource testing, evaluation, project design, and financing. The current geothermal team comprises of seven people who have been involved in collection of surface exploration data but lack experience with feasibility studies (Table 7).

The Geothermal Energy Exploration II project is divided in two phases - A and B. Phase A will involve locating drill-sites within a selected area(s). This will include careful review of and second opinion on the previous results; further exploration narrowed down to the most promising anomalies in order to further sustain siting of exploratory wells; designing of exploratory wells and preparing of tender documents; and environmental impact assessment for drilling. Phase B will include exploratory drilling that will involve drilling of 2-3 wells, in a selected area(s), to discover a geothermal reservoir, prove sufficient production capacity for the initial generating plant; provide data for assessing the long–term production capacity; economically determine capital and operating costs for a generating plant; and compare the costs of generating power from other available sources. The possible economic uses of the resource for purposes other than power generation will be determined and the environmental impact of development assessed.

Funding for the Geothermal Exploration II project has not yet been effected since it will depend on the results of the pre-feasibility study and GoU’s commitment to developing its geothermal resources.

8. CONCLUSION

The current status of the geothermal models for Katwe, Buranga and Kibiro areas indicate the existence of geothermal reservoirs in the three areas. Their subsurface temperatures of approximately 200°C predicted by geochemistry; geological and hydrological characteristics provide evidence for the existence of exploitable geothermal resources. The on going geophysical and geological surveys once completed will delineate the special extent of the reservoirs and their boundaries. The geothermal models will be updated to pre-feasibility status and proposals put forward for the feasibility phase that will involve drilling 2-3 exploration wells in one or two areas. The feasibility phase is a very expensive undertaking and needs support from the GoU and its development partners. It’s only after the feasibility stage that the private sector will gain confidence to invest in geothermal development. Cascaded geothermal exploration on other areas should continue and if good results are obtain the possibility of installing small geothermal power plants for rural electrification needs to be investigated.

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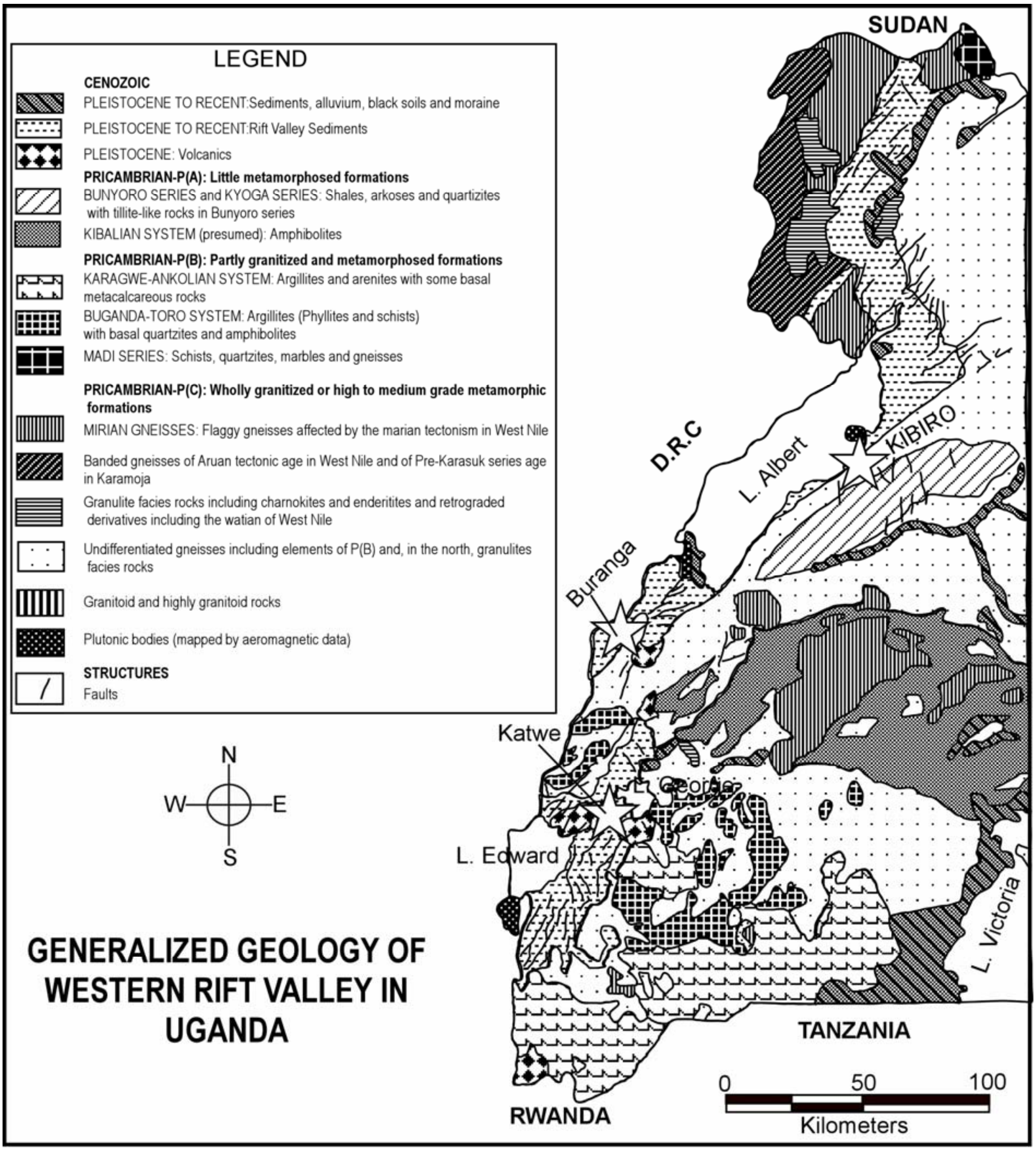

Figure 1: The geology of the Western Rift Valley in Uganda.

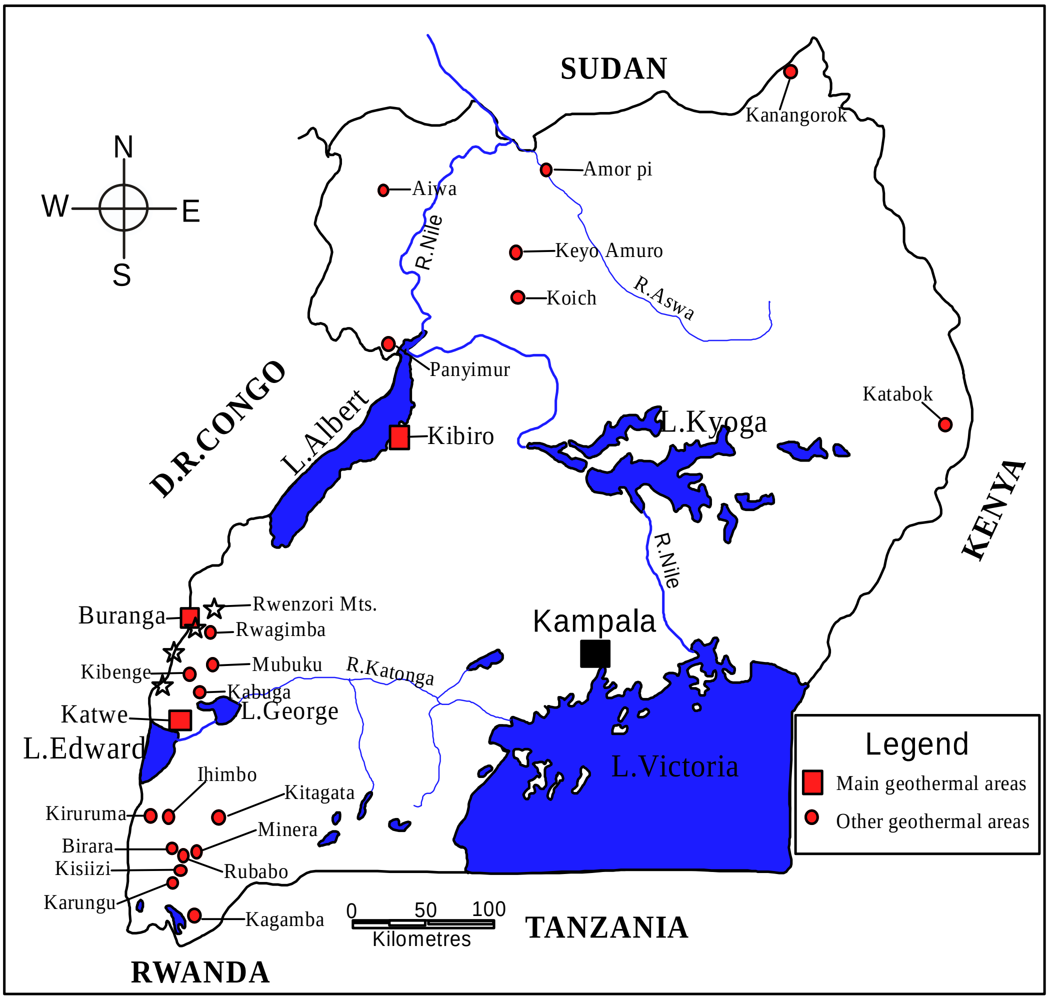

Figure 2: Uganda geothermal areas.

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY (Installed capacity)

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2004	-	-	8.0	4.8	317.0	1666.0	-	-	-	-	325.0	1671.0
Under construction in December 2004	-	-	0	0	85.0	446.8	-	-	-	-	85.0	446.8
Funds committed, but not yet under construction in December 2004	-	-	0	0	250.0	1314.0	-	-	-	-	250.0	1314.0
Total projected use by 2010	-	-	24	14.4	652.0	3307.2	-	-	-	-	676.0	3321.6

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	7	-	-	-	0	-
2001	7	-	-	-	2	-
2002	7	-	-	-	0	-
2003	9	-	-	-	2	-
2004	9	-	-	-	3	-
Total	39	-	-	-	7	-

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2004) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1990-1994	0.577	-	-	-	-	100
1995-1999	0.078	-	-	-	-	100
2000-2004	1.130	-	-	-	-	100