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GEOTHERMAL EXPLORATION IN UGANDA STATUS REPORT

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ABSTRACT

One of the greatest challenges of the 21st century is the production of sufficient energy to power the economies of both the developed and developing world. Declining reserves of fossil fuel, increased demand and environmental constraints will challenge human ingenuity in providing alternative sources of energy like geothermal.

Uganda is located in a geological setting of tectonically active rift system and characterized by recent volcanism. This is ideal geology for geothermal resources and evidence of geothermal resources include hot springs, warm springs, gaseous emission, travertine, hydrothermally altered rocks, mineral precipitates and thermophyllic grass. Preliminary surveys for geothermal resources in Uganda dates way back in 1920 when Geological Survey of Uganda was established. Three holes were drilled around Buranga in 1954 after preliminary geophysical surveying. However, serious exploration efforts were undertaken between 1993-1994 funded by United Nations Development Programme (UNDP), Iceland Government, OPEC and Government of Uganda. The International Atomic Energy Agency (IAEA) funded a programme "Isotope hydrology for exploring geothermal resources" from 1999-2002. IAEA also funded another programme from 2005-2006.

African Development Bank (ADB) and Government of Uganda funded a renewable energy project which included geological and geophysical surveying in Katwe from 2004 to 2005. In 2004, Iceland International Development Agency (ICEIDA) together with Government of Uganda funded geophysical surveys (TEM, gravity and magnetics), geochemical surveying and geological mapping in Kibiro and Katwe. Thermal Gradient Holes were drilled on the indicated anomalies in both Katwe and Kibiro in 2007 funded by World Bank Power 4 and ICEIDA. Reconnaissance survey of other geothermal sites all over Uganda was undertaken funded by ICEIDA and World Bank Power 4. Between 2005 and 2007, BGR carried out geophysical surveys, geochemical surveys, geological mapping of Buranga geothermal resource site. Between 2010 and 2011, IAEA funded another programme RAF/8/047 for exploring geothermal resources using isotope hydrology.

The timeline for geothermal exploration has stretched longer than expected. Breakthrough technology and techniques, finances and policy (Government strong will) are needed to develop Uganda's geothermal resources. The Government of

Uganda has committed public funds and manpower under the Uganda Geothermal Resources Development Project (1199). Under this programme geophysical surveys, geochemical surveys, geological mapping and environment baseline surveys have been undertaken in Kibiro, Katwe-Kikorongo, Panyimur and Buranga. Preliminary results indicate that these systems are larger than previously known. Under the Sustainable Management of Mineral Resources Project (SMMRP) airborne magnetic data was acquired and this has been processed, analyzed and interpreted to aid geothermal exploration. Airborne radiometric data is also being used to locate high heat producing granites important in geothermal industry. Japan International Cooperation Agency (JICA) is funding a preliminary survey of other geothermal sites in South and South West. JICA Studies included geochemical surveys, remote sensing (Landsat, Aster and SRTM) and environment studies. Not-technical data relevant to geothermal industry was also collected like nearness to the national grid, conservation area, accessibility, etc.

During the last Regional Integration Project Summit held in Kigali, Rwanda on October 26-28, 2013, the Heads Of State directed that an MoU between the Governments of Uganda, Rwanda and Kenya for exploration and development of geothermal resources be finalised and signed before the next Summit. This is yet to be signed and will fast track geothermal development in the region.

Uganda government has submitted a project proposal to African Rift Geothermal Development Facility ARGeo-UNEP for technical assistance to undertake surface studies at Kibiro Geothermal Resource Site.

The Ministry of Energy and Mineral Development has been restructured and a Department of Geothermal Resources will be created. The Department awaits a certificate of financial implication from Ministry of Finance, Planning and Economic Development. Human capital development is on-going and procuring survey equipment (Magneto-telluric, TEM, Gravity Meter, and Magnetometer) has been initiated to create a standalone state-run institution to steer and fast track geothermal development in Uganda.

The Government sought Private Sector Funding and granted 10 geothermal exploration licences to private sector investors. Due to high risks and costs associated with geothermal exploration, it is difficult to attract funds from private sector investors and most of them have not fulfilled their working obligations. Government has opted for public sector funding, undertaking exploration and de-risk its geothermal prospects.

Uganda is at the exploration stage of geothermal development aiming at test drilling in the near future. Geophysical methods so far applied have been structural in nature. A combined MT / TEM surveys planned in the near future will aid in locating conductive reservoir and image the sub-surfaces to locate reservoir.

Existence of geothermal resources is not enough for successful development. It is only a prerequisite. Geothermal development needs nation’s comprehensive development ability such as technology, finance and policy and a strong will from the Government.

1. INTRODUCTION

One of the greatest challenges of the 21st century is the production of sufficient energy to power the economies of both the developed and developing world. Declining reserves of fossil fuel, increased demand and environmental constraints will challenge human ingenuity in providing alternative sources of energy like geothermal.

Uganda is located in a geological setting of tectonically active rift system and characterized by recent volcanism. This is ideal geology for geothermal resources and evidence of geothermal resources include hot springs, warm springs, gaseous emission, travertine, hydrothermally altered rocks, mineral precipitates and thermophyllic grass (Figure 1). Preliminary surveys for geothermal resources in Uganda dates way back in 1920 when Geological Survey of Uganda was established.

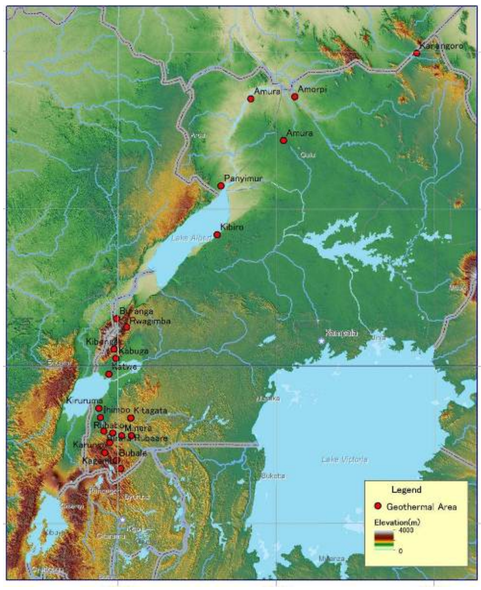


FIGURE 1: Location of geothermal resource sites in Uganda (Source: West Jec)

The existence of geothermal resources in not enough for its successful development. It is only a prerequisite. Geothermal development needs nation's comprehensive development ability such as technology, finance and policy (Government Strong Will).

Geothermal exploration and development is an acknowledged high-risk investment. Due to high risks and costs associated with geothermal exploration, it often difficult to attract sufficient funds from private sector equity investors. Therefore, the public sector has to play an important role in financing exploration. Government has to de-risk investment in the geothermal industry. Historically, governments have undertaken the earliest phase of geothermal exploration in those countries that now have established geothermal industries. Examples include Kenya (KenGen), Ethiopia, Costa Rica.

This successful business model can apply in Uganda. The timeline for geothermal exploration in Uganda has stretched too far and strategies have to be applied involving breakthrough techniques and technology to fast track geothermal development. There is need to put in place a stand-alone state institution to steer geothermal development, a policy, legal and regulatory framework.

There are seven recognised phase of developing geothermal projects; preliminary survey, exploration, test drilling, project review and planning, field development, power plant construction, commissioning and operation. Uganda is on the second phase of project development and the timeline has stretched too far. Historically, many large (50 MW or larger) geothermal projects have taken close to 10 years to develop.

2. GEOTHERMAL EXPLORATION HISTORY IN UGANDA

2.1 Geothermal projects in Uganda

Geothermal energy is hardly playing any role in the Uganda's energy mix despite its potential to do so, with a huge geothermal resource potential. Several exploration efforts have been undertaken in Uganda but drill targets have not been located.

In 1885, Emin Pasha an explorer described Kibiro hot springs issuing up the escarpment. E.J. Wayland (1920, 1921, and 1935) described hot springs in Uganda. Others included Simons (1921), A.J. Stevens (1948), Brown (1954), McConnell and Brown, (1954), C.G Dixon (1967), W.H. Morton (1967), D.V Sharma (1972). In 1954 four exploration wells were drilled in Buranga (Figure 2).

2.1.1 Geothermal Energy Exploration Programme phase 1 (1993-1994)

This was the first serious geothermal exploration carried out on the three highly ranked prospects. The project was funded by the Government of Uganda, United Nations Development Programme (UNDP), Organization of Petroleum Exporting Countries (OPEC), and Government of Iceland. It was implemented by DGSM and executed by Department of Development Support and Management Services of United Nations (UNDDSMS). Work included geological, geochemical and isotopic surveys, in Kibiro, Katwe-Kikorongo and Buranga. The results warranted more field investigations to up-grade the working model to a pre-feasibility status.

FIGURE 2: An old well drilled in Buranga in 1954

2.1.2 Isotope Hydrology for Exploring Geothermal Resources phase-1 (1999-2003)

IAEA together with MEMD funded this project with the aim of refining the conceptual working models of Kibiro, Buranga and Katwe-Kikrongo prospects, using isotopes. This was a follow up of the UNDP-ICEIDA project of 1993-1994.

2.1.3 Katwe-Kikorongo Prospect Exploration (2003)

ADB funded geothermal investigations were carried out in Katwe-Kikorongo in 2003, under the "Uganda Alternative Energy Resource Assessment and Utilisation Study (UAERAUS). This was to upgrade the working model of Katwe-Kikorongo to pre-feasibility status. The heaping up of volcanic materials around Kyamatumu-Lake Kitagata axis resulted in topographic heights (1250 m above sea level), possibly with a higher precipitation than the surrounding and a relatively high water table diverting the flow outwards. Such a high relief zone can have a relatively high groundwater table and an outward directed hydraulic gradient favouring the flow of hot fluids (through faults and permeable strata) to topographically lower areas like Katwe (895 m), Kikorongo (925 m), Kasenyi (895 m), Mahega (925 m) and Nyamunuka (884 m). This correlates well with earlier interpretation of having these outward areas as outflow of this system.

Travertine deposits typically precipitate from CO_2 rich thermal fluids, which are cooling at *marginal* and *shallow* subsurface zones. This possibly could cause to tentatively believe that *Lake Katwe, Lake Kikorongo, Lake Kasenyi* and *Lake Nyamunuka* where travertine deposits occur, represent out flow or marginal zones of this geothermal system. This would mean tentatively that the *up-flow zone* should be traced from around Lake Kitagata-Kyemengo-Kyamatumu area, assuming this is a single geothermal system. Such a high hilly zone can have a relatively high groundwater table and an *outward directed hydraulic gradient* favouring the flow of hot fluids (through faults and permeable strata) to topographically lower areas like Katwe (895 m), Kikorongo (925 m) and Nyamunuka (884 m). This correlates well with earlier interpretation of having these outward areas as outflow of this system. The spring around Kitagata gives a subsurface temperature above 200°C, which is quite impressive.

2.1.4 Kibiro Prospect Exploration (2004)

Kibiro prospect investigations were carried out by ICEIDA experts and DGSM counter parts with the aim of advancing the geothermal pre-feasibility survey initiated by DGSM. This work included geophysical studies (TEM, gravity and magnetic survey), geochemical surveys and geological mapping (Figure 3). Geothermal investigations identified some open geophysical anomalies. These open-ended anomalies warranted further work to close them.

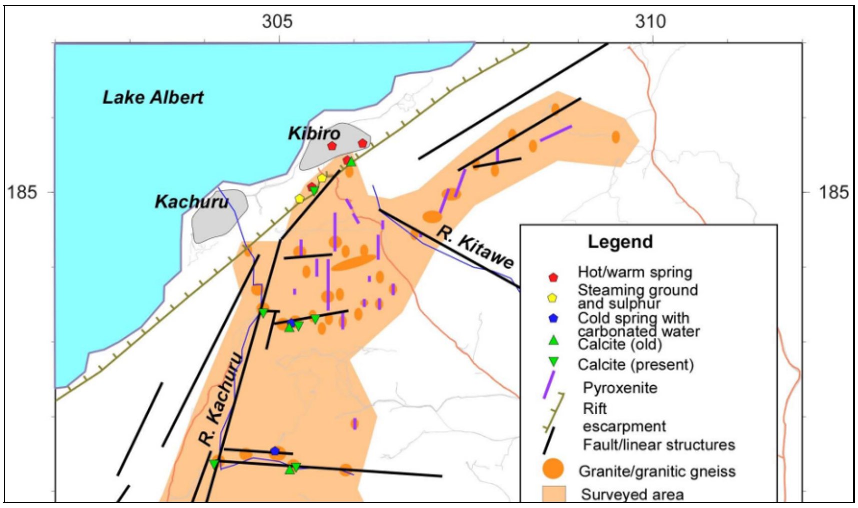


FIGURE 3: Geology map of Kibiro (ISOR)

A total of 70 TEM soundings were collected (Figures 4-8). A low resistivity anomaly was located in the sediments and a low resistivity trench was traced into the crystalline basement rocks. Magnetic surveys did not indicate any evidence of buried intrusive body. Anomalies were related to bedrock topography and do not reveal any structure. Similarly gravity surveys did not reveal any distinct density variation.

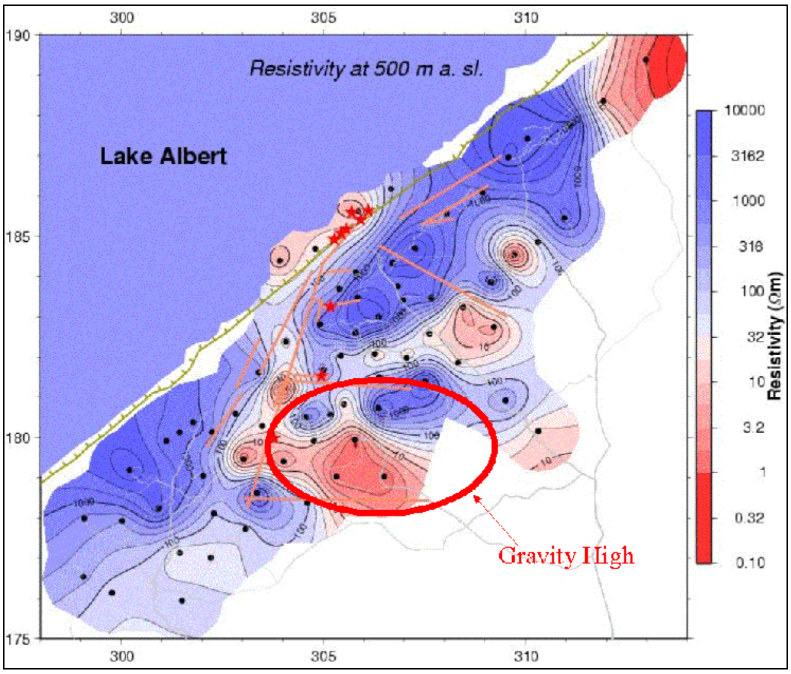


FIGURE 4: Kibiro resistivity maps (ISOR)

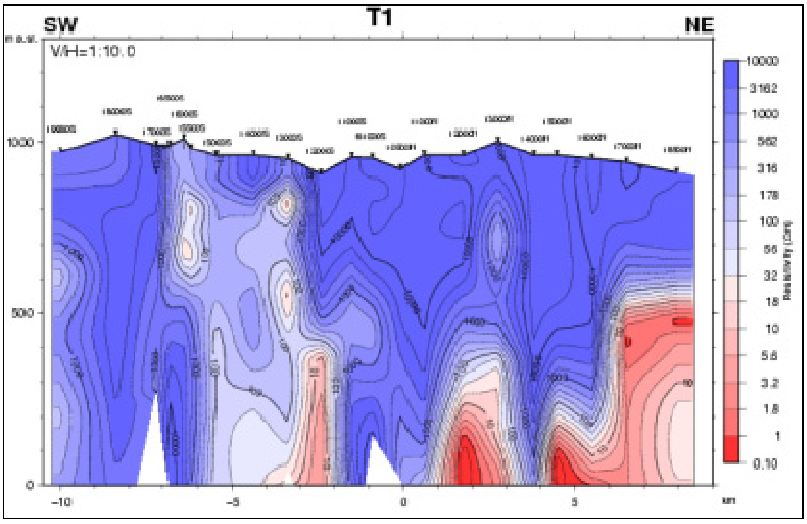


FIGURE 5: Kibiro resistivity maps (ISOR)

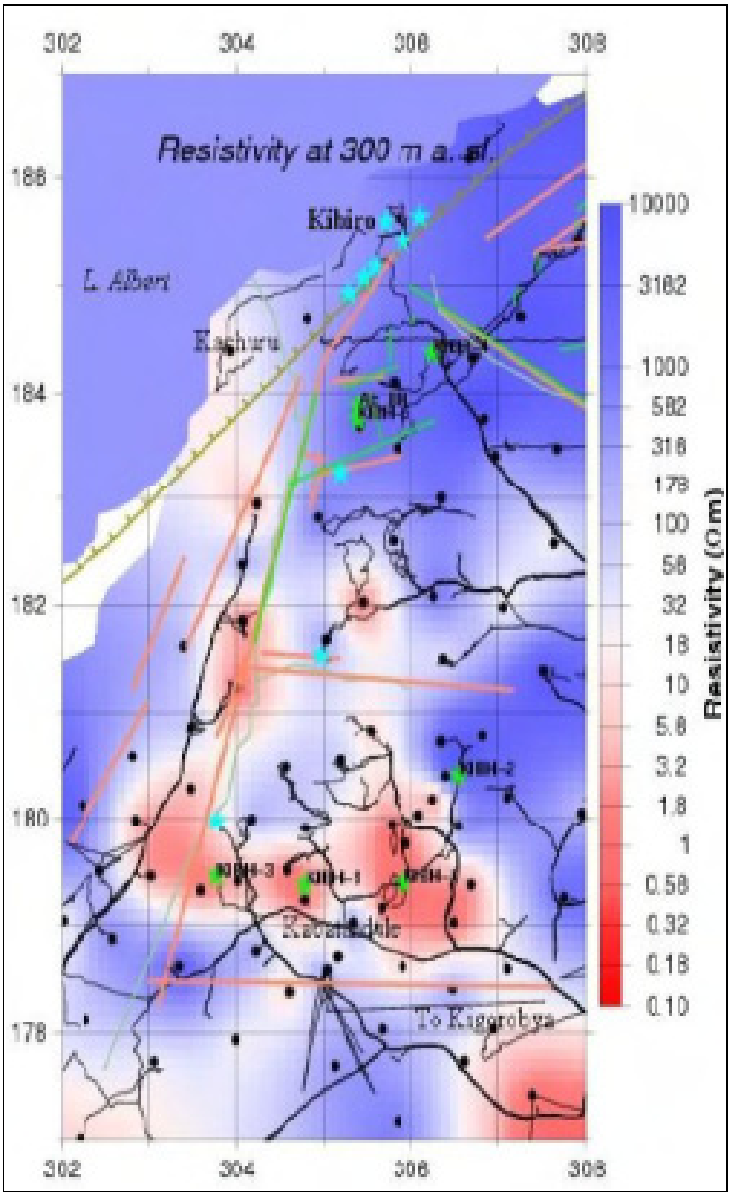


FIGURE 6: Kibiro resistivity maps (ISOR)

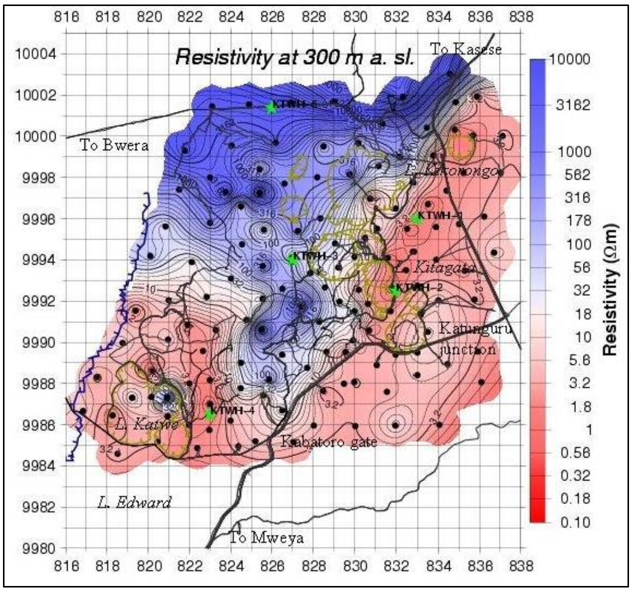


FIGURE 7: Katwe resistivity map (ISOR)

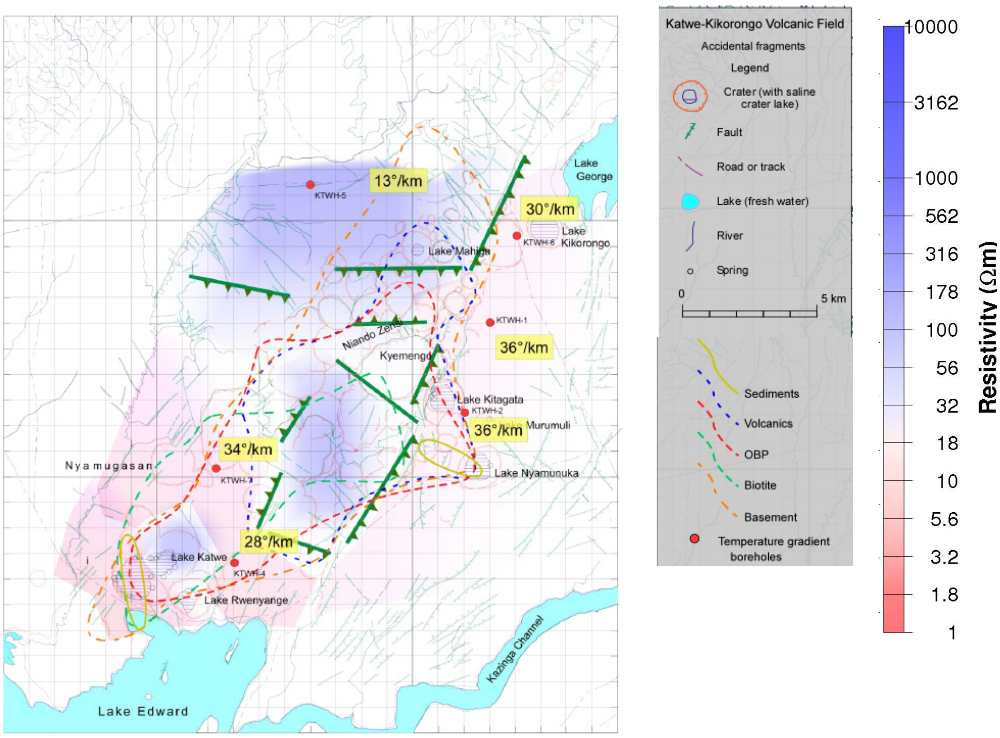


FIGURE 8: Thermal gradient map of Katwe (ISOR)

Low resistivity anomalies were subjected to drilling (thermal gradient holes) but the results were not encouraging.

2.1.5 Geotherm Project

Germany Federal Institute for Geosciences and Natural Resources (BGR) together with Ministry of Energy and Mineral Development carried out geothermal exploration in Buranga starting in 2003. The

GEOTHERM programme, was aimed at promoting the utilization of geothermal energy in developing countries. Studies included geochemical and geophysical surveys (TEM, and Schulmberger sounding). Seismometers (for micro-earthquakes) were installed in Buranga to aid in mapping active geological structures and rock types (Figure 9). A buried magma body was indicated beneath Rwenzori Mountains and the several micro earthquakes could be related to magma plumbing / diking (Figure 10). The geothermal system is recharged from the ice / glaciers from top of Rwenzori Mountain since waters from here have the same Deterium values as the hot springs. All springs around the Rwenzori are correlated pointing to a common origin.

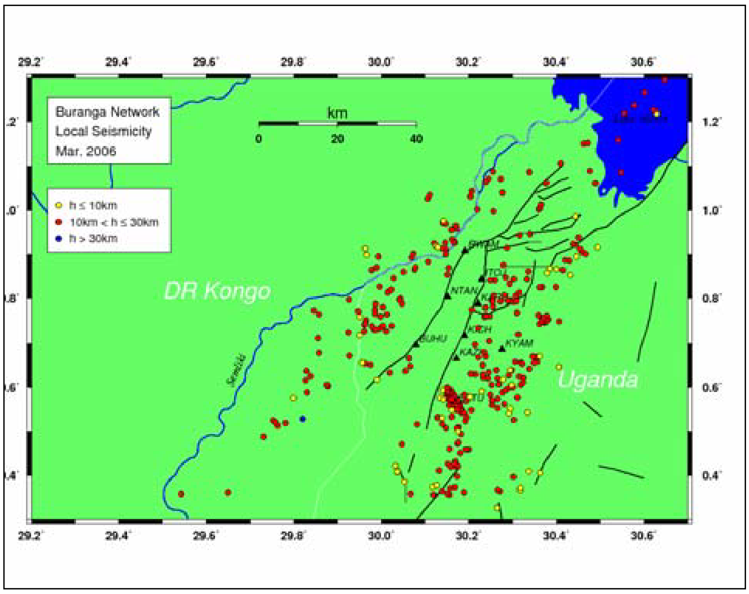


FIGURE 9: Buranga Network Local Seismicity map

2.1.6 ICEIDA-WB project.

Icelandic International development Agency (ICEIDA) together with Ministry of Energy and Mineral Development undertook exploration in Kibiro and Katwe-Kikorongo. This work included geophysical studies (TEM, gravity, magnetics, and temperature gradient measurements), geological and geochemical survey is intended to up-grade conceptual working models of these areas to pre-feasibility level. The local counterparts and their logistics were funded under Power IV. Under this programme a national geothermal reconnaissance was carried out to rank all other prospects for more future detailed investigations. Panyimur hot spring was ranked better and it was added on the list of best ranked. Swallow gradient wells were drilled in Kibiro and Katwe-Kikorongo but results were not encouraging.

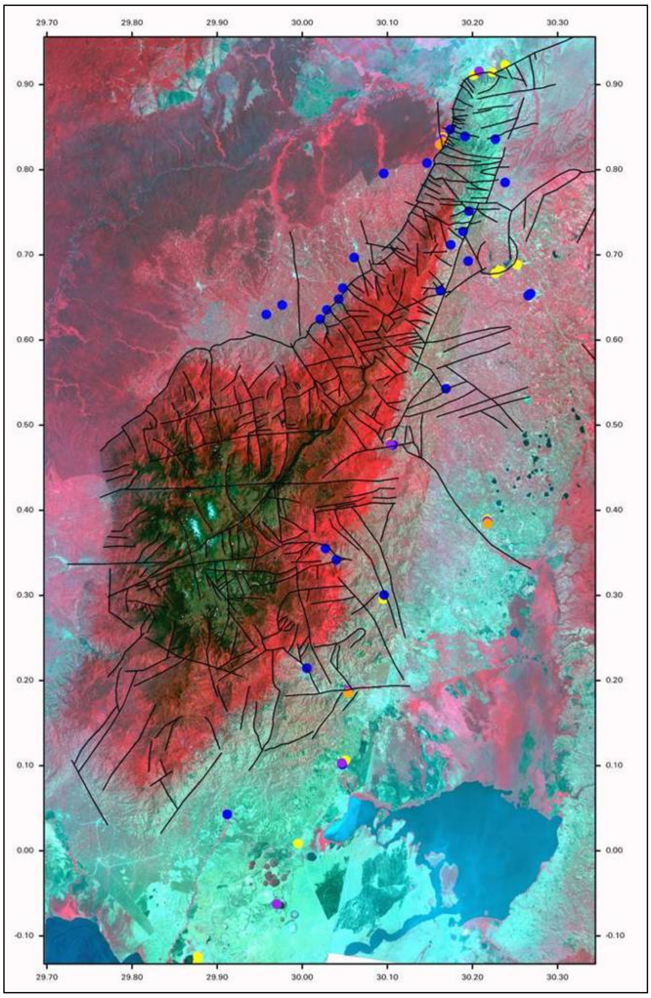


FIGURE 10: Sampling points of Rwenzori system

2.1.7 UGA/8/005 – Isotope Hydrology for Exploration Geothermal Resources- phase 2

The International Atomic Energy Agency (IAEA) funded a project "UGA/8/005 – Isotope Hydrology for Exploration Geothermal Resources- phase 2". This project was intended to refine conceptual working hydrological models for Kibiro, Buranga and

Katwe-Kikorongo prospects using isotopes. It will provide answer to questions still pending on these models.

2.1.8 Introducing Isotope Hydrology for exploration and management of geothermal resources, RAF/8/047

This project was funded by IAEA together with GoU to improve the conceptual models of the geothermal systems in Uganda.

2.2 Uganda Geothermal Resources Development Project (1199)

This project is solely funded by the Government of Uganda using public funds. The main objective was to carry out pre-feasibility study of Katwe-Kikorongo, Kibiro, Panyimur and Buranga and Feasibility study on one best ranked prospect. Under this project ground geophysical surveys (gravity and magnetics) have been undertaken in Kibiro, Panyimur and Buranga. Geological mapping has been undertaken all the four sites. Aero magnetic data was acquired, processed, analysed and interpreted. Geochemical surveys and Environmental baseline surveys have been undertaken as well.

2.2.1 Kibiro Geothermal Resource Site

Ground geophysical surveys were undertaken to define and refine the low magnetic anomalies indicated on the airborne magnetic map (Figure 11). These were believed to be related to thermal de-magnetisation of these rocks. A low magnetic signature was identified north-westwards and ground verification confirmed hydrothermally altered rocks

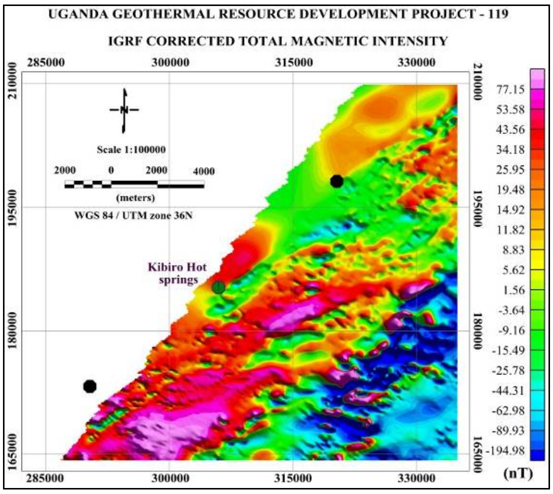


FIGURE 11: Processed and interpreted airborne magnetic map of Kibiro (left) and hydrothermally altered rocks (right)

Digital Elevation Models were prepared to aid in structural mapping. Other studies included XRD analysis of hydrothermally altered clays at Kibiro. Geological mapping was extended northwards and southwards (Figure 12). New Surface manifestations were discovered which included gypsum flakes, hydrothermally altered clays and volcanic remnants (Figure 13).

Environmental baseline survey was carried out in Kibiro. Description of natural, social and economic environment considered local community, land-use, proximity to infrastructure and housing, amenity, noise, dust, air quality, topography, landscape, climate, geo-hazards, hydrology, groundwater, flora, fauna, topsoil, subsoil, heritage (geological, cultural), proximity to conservation areas, pre-existing site contamination and previous disturbance.

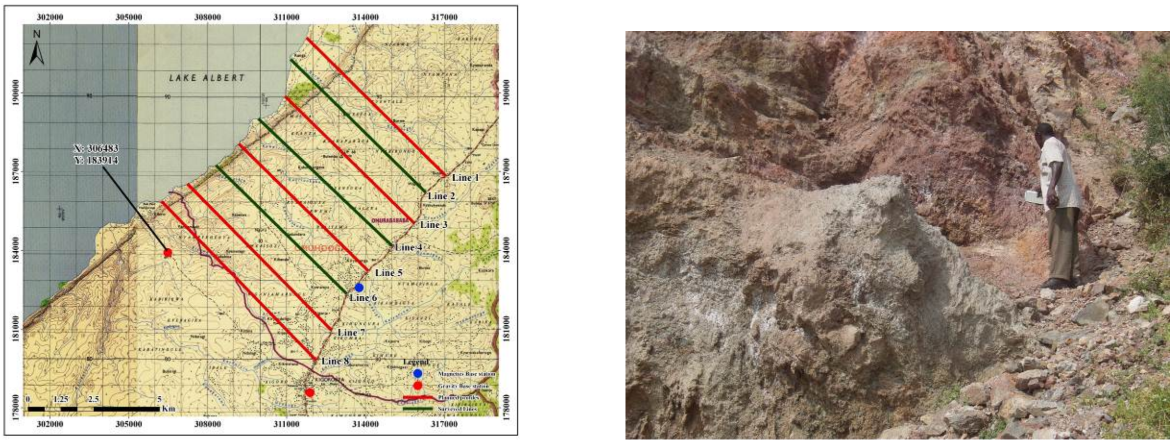
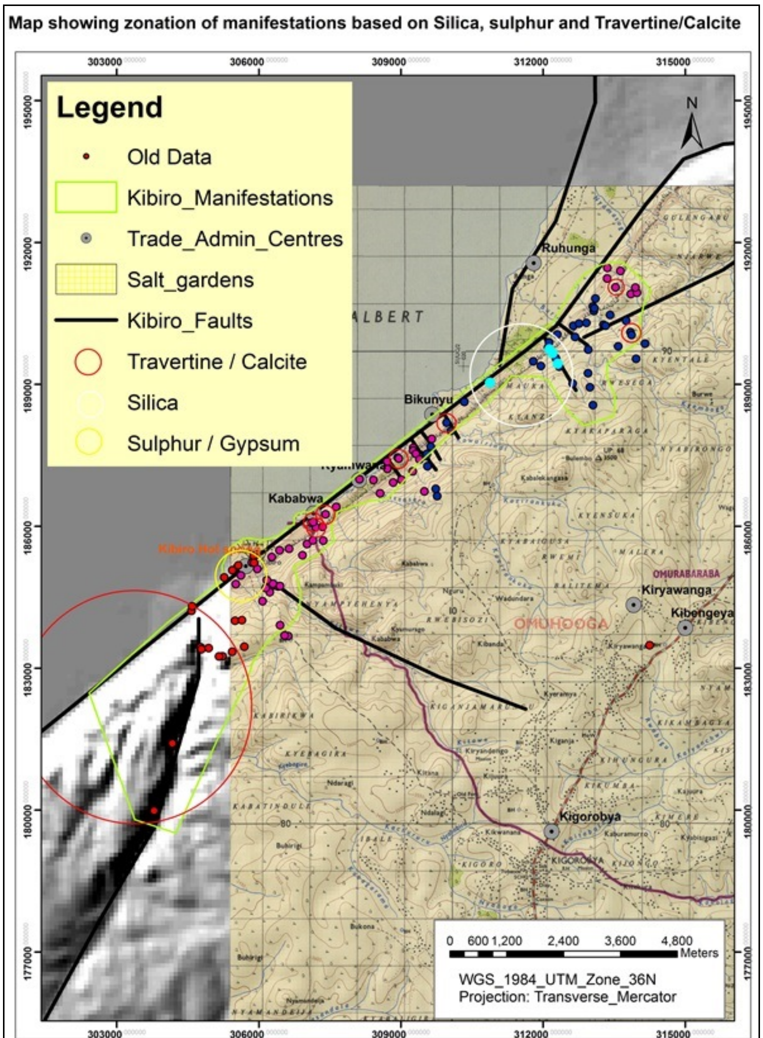


FIGURE 12: Area covered by ground geophysical surveys (magnetics & gravity) (left) and hydrothermally altered rocks (right)



Map 3 Zonation is based on three minerals; Calcite, sulphur and silica. It is assumed that silica and sulphur are indicative of high temperatures, while calcite or travertine is indicative of low temperatures. Note the smaller red circles around way points for calcite and travertine. Hot surface manifestations are only found inside the yellow circle. Note the 4 selected observation points inside white circle for silica depositions

FIGURE 13: Geology map of Kibiro

The occurrence of geothermal evidence at widely scattered localities from one end to the other is highly suggestive of the existence of large geothermal system than previously known. Planned work includes soil gas sampling, MT and TEM surveys. Additional structural mapping and micro-seismic are planned.

There is no evidence of volcanism in this area and it is not yet clear what the source of the heat is whether it is from buried high heat producing granites or it is a swallow buried magma body. This can be confirmed by studying helium isotopes from gases or carbon-13 isotopes of the travertine at Kibiro.

2.2.2 Panyimur Geothermal Resource Site

It was discovered that diatomite are structurally controlled along *fault traces* (Figure 14 and 15). The source of silica for the diatoms is presumed to be high silica laden fluids more probably geothermal fluids. The diatoms had to flourish in a stable environment which produced *high silica laden fluids*. In the same area swelling clays were mapped interlayered with diatomite. *Diatomite* is not extensive but it is fault controlled by NE trending faults. One has to note that diatomite is more predominant in NE than in south west where the hot springs are located. This might imply that *diatomite* deposits are more proximal to the up-flow zone than the hot springs.

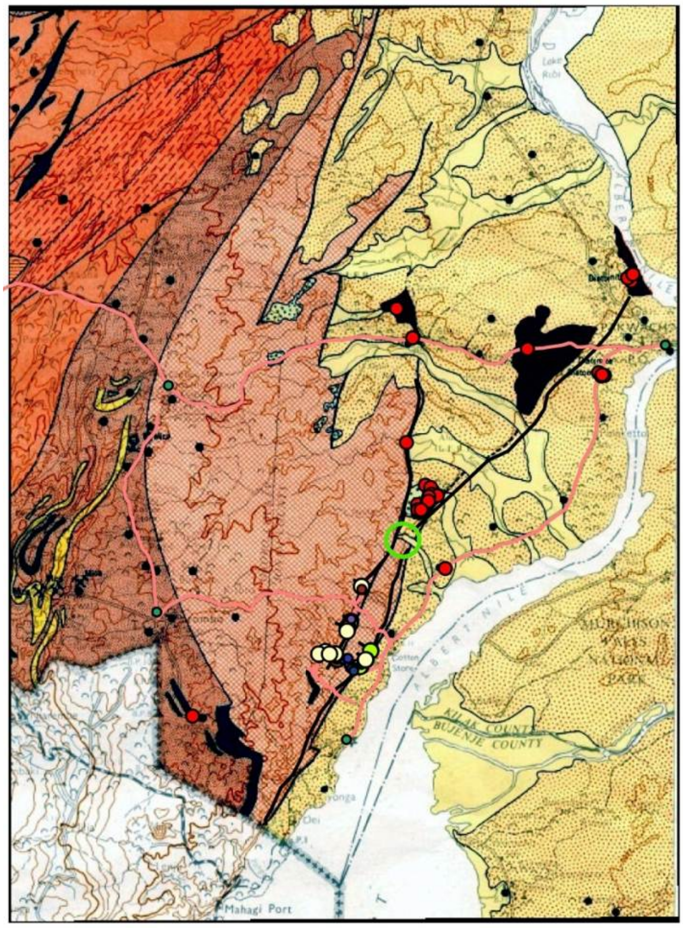


FIGURE 14: Geology map of Panyimur showing diatomite (brown colour) along fault traces

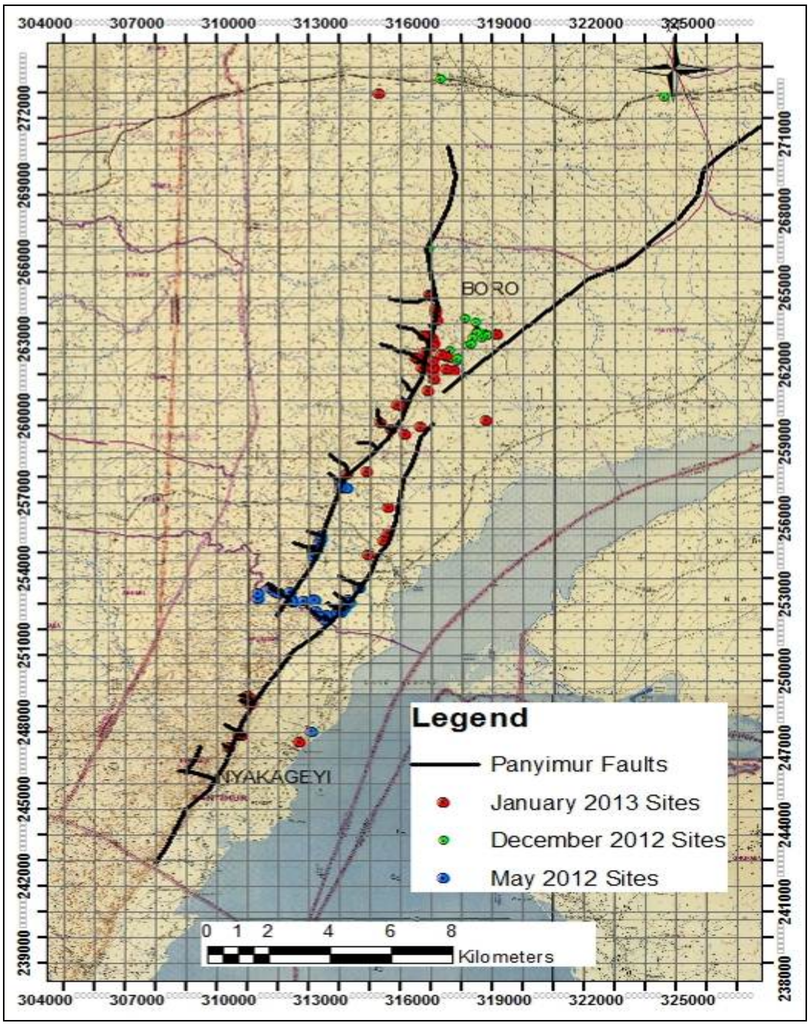


FIGURE 15: Faults acted as conduits / pathways for geothermal fluids which deposited silica rich fluids for the diatoms. These *diatomites* have elevated levels of *Zirconium* and indication of magmatic origin of these fluids

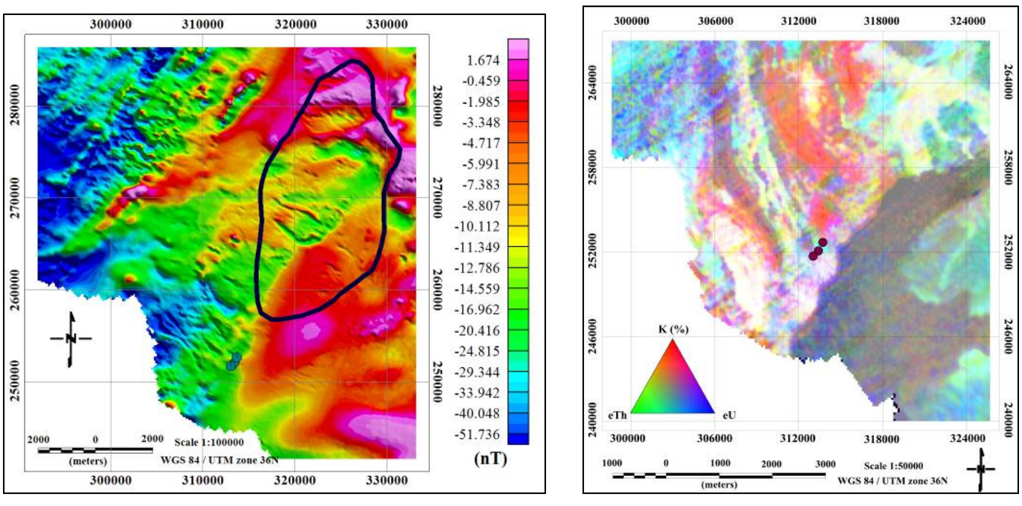


FIGURE 16: Airborne magnetic map (left) and radiometric map (right) of Panyimur

On the magnetic map, warm colours (red and purple) indicates areas with high magnetic signatures and cool colours (green and blue) indicate areas with low magnetic signatures probably related to demagnetisation by hydrothermal fluids. The linear magnetic lows are interpreted to represent fault zones. Temperatures from neighbouring oil wells indicate elevated values (Figure 16).

Digital elevation model of the area shows well marked NW-SE transverse faults cross cutting the SW-NE major fault in areas where diotomite is located (Figure 17). This increases or enhances permeability for fluids flow. Geologically, this is highly prospective area judged on the inter-play between faults and diatomite occurences which indicate existence of high silica fluids. Various maps were made for the area (Figures 18-21).

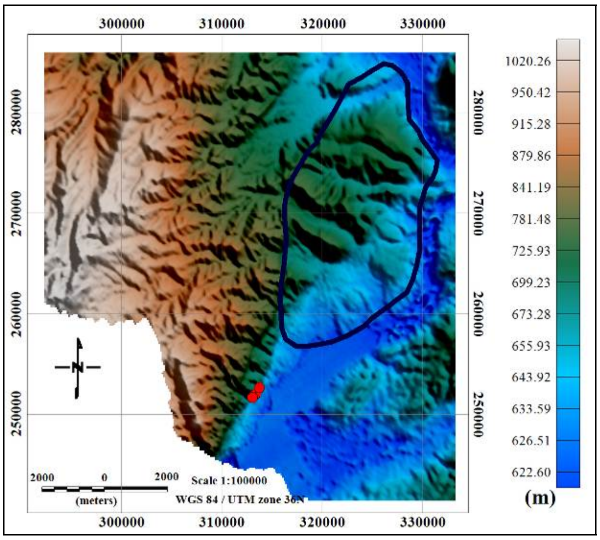


FIGURE 17: DEM map of the area showing cross cutting structures.
Red dot indicates hot springs location

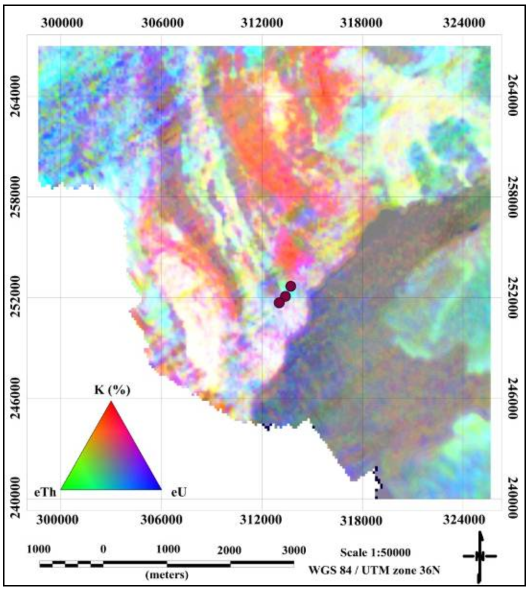


FIGURE 18: Radiometric map of the area

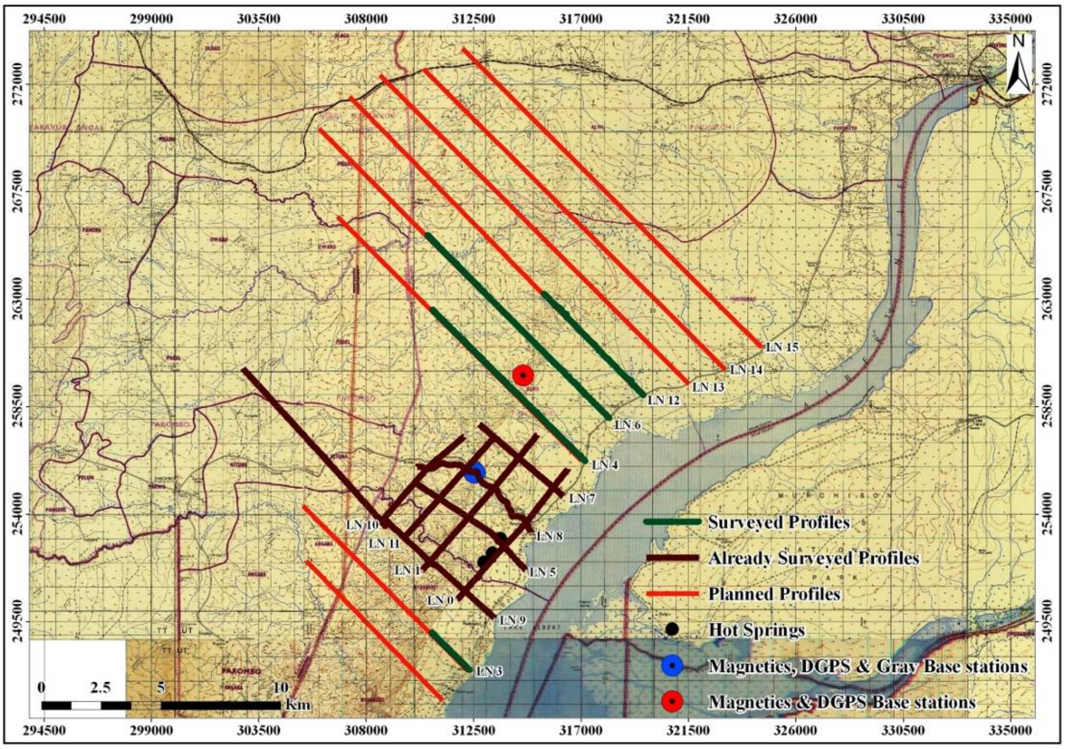


FIGURE 19: Traverse for geophysical surveying

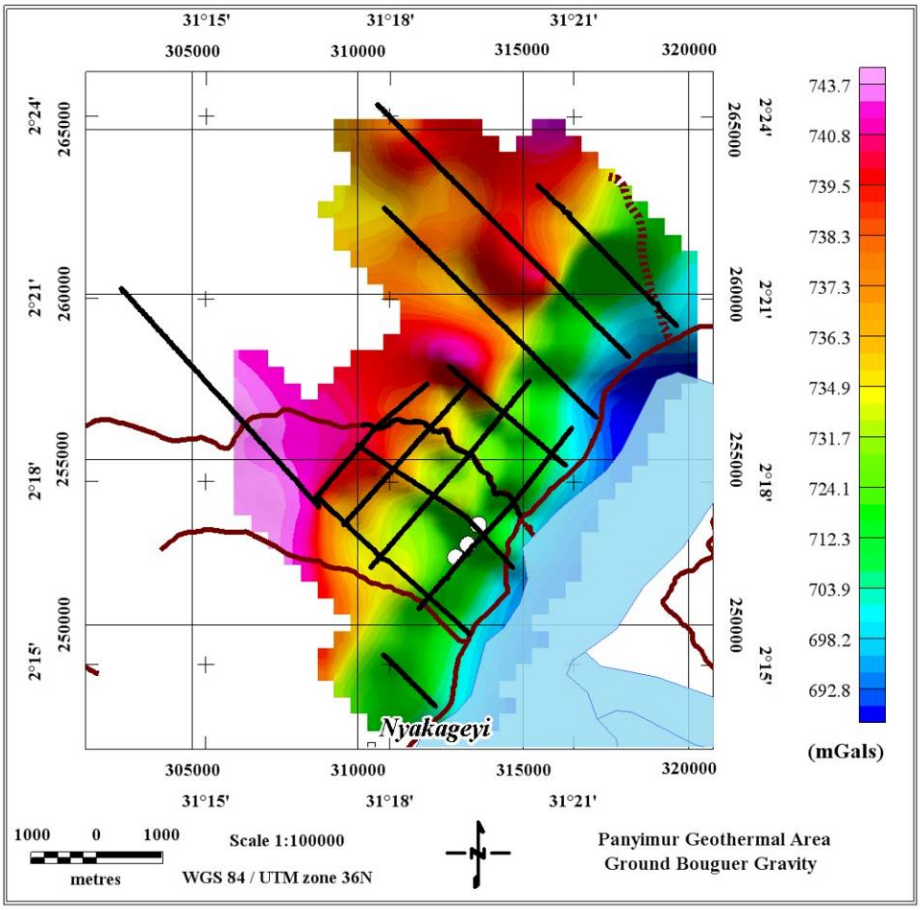


FIGURE 20: Bouguer gravity anomaly map of Panyimur geothermal prospect, brown lines denote roads and white dots are hot springs

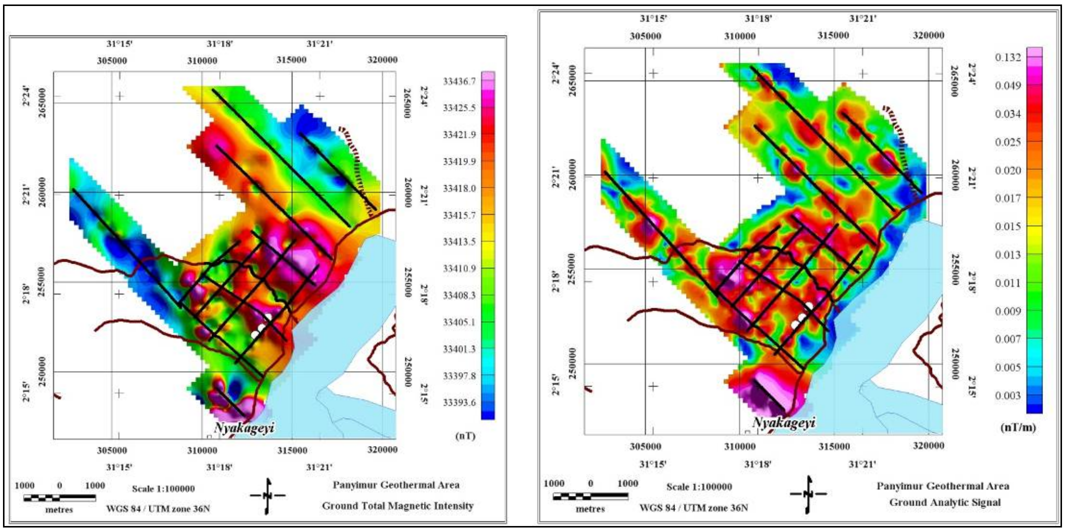


FIGURE 21: Total magnetic intensity map (b) Analytical signal map, brown ticked lines denote roads and white circles are hot springs

Ground gravity and magnetic surveys are still on-going. The occurrence of geothermal evidence at widely scattered localities from one end to the other is highly suggestive of the existence of large geothermal system than previously known. Planned work includes soil gas sampling, MT and TEM surveys. Additional structural mapping is recommended.

Structural control: Diatomites at Panyimur are aligned along faults hence are structurally controlled according to geology map of the area.

Alligned hot springs: Hot springs and hydrothermal deposits are similarly aligned along faults indicating a structural control of these features.
Hydrothermal activity: Diatomites are known to be associated with hydrothermal systems deriving silica saturated waters from hot springs. This association is postulated in this particular case and is plausible.

Source of silica: Diatoms are adapted to a wide range of aquatic environments including marine, brackish and fresh waters. The organism require suitable environmental conditions if they are to flourish including appropriate temperature and photic conditions, a narrow salinity and acidic range, and a stable supply of nutrients including silica, nitrogen, phosphorous, iron, oxygen and carbon dioxide. The only plausible source of silica saturated waters and carbon dioxide in this area could have been geothermal solutions upwelling from a deep geothermal reservoir.

Exploration targets: Since near neutral alkaline solutions with high silica content are targets of most geothermal exploration, areas with diatomite deposits are highly prospective as these might be proximal to the up-flow zone of this system.

Out-flow zones: Hot springs at Panyimur deposits travertine and there is gradual change in chemistry of hot springs from south west to north east. This might indicate that they are at outflow zones which are normally associated with travertine deposits. They might be discharging at the surface after flowing many kilometers down gradient from a hydrothermal reservoir.

Prospectivity: Most promising area in north east from the hot springs characterized by diatomite and cross cutting fault zones.

There is no evidence of volcanism in this area and it is not yet clear what the source of the heat is whether it is from buried high heat producing granites or it is a swallow buried magma body. This can be confirmed by studying helium isotopes from gases or carbon-13 isotopes of the travertine at Okumu.

- Magnetic measurements do not show indications of intrusive bodies close to the surface. Alteration to the north-east seems to be related to the bed-rock geology.

- Gravity results have differentiated the low density sediments of the blue-Nile from the denser basement rocks mainly consisting of granite-gneiss as evident on the modeled profiles.

Planned work include a combined MT/TEM survey, soil gas survey, integration of data from petroleum companies drill wells, micro-seismic surveys and additional geochemical and isotopic surveys.

2.2.3 Katwe Geothermal Resource Site

Work included studying DEM maps (Figure 22), aerial photo (Figure 23), and satellite images (Figure 24) to map structures. This was followed by ground trothing of the interpreted data.

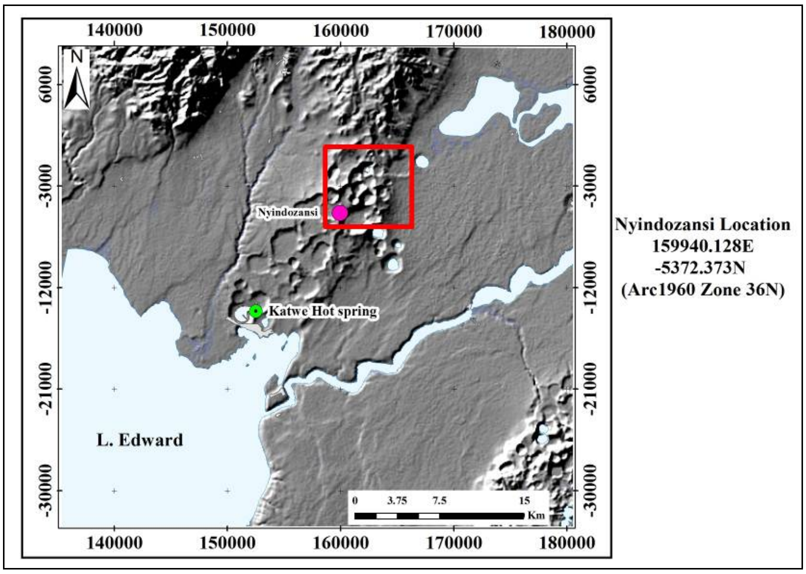


FIGURE 22: DEM map of the area showing structure and explosion crater lakes

During the Sustainable Management of Mineral Resources Project (SMMRP), airborne magnetic data was acquired over 80% of whole country. This data was retrieved and processed around the area of study. Unfortunately the area of study was not covered and hence this data was not useful (Figure 25).

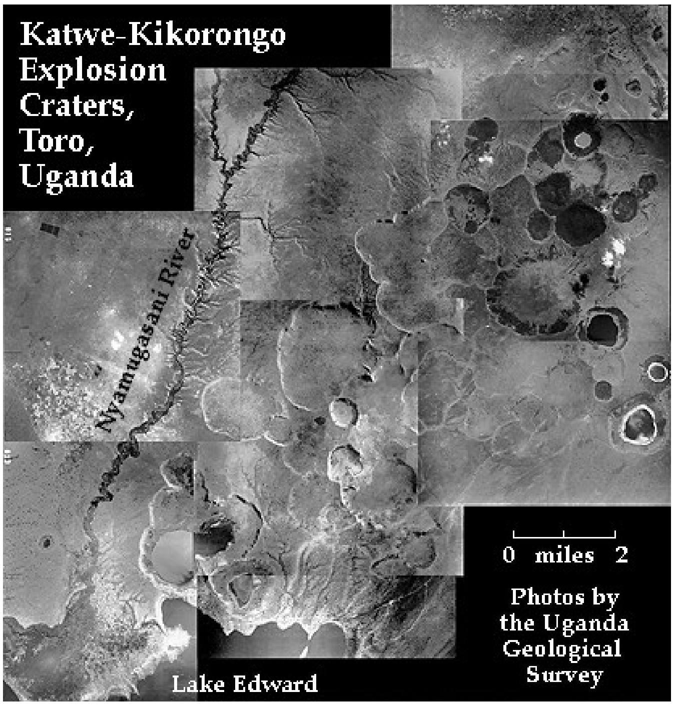


FIGURE 23: photo interpretation of the area


FIGURE 24: Satellite image of the area aided in mapping structures

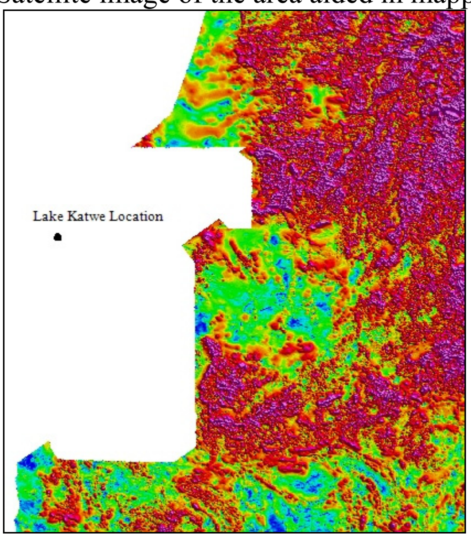


FIGURE 25: Total magnetic map of the study

During Petroleum Exploration campaign (1983-84), airborne magnetic data was acquired over the entire Albertine Graben. Aeromagnetic surveys identified three sub-basins and hence three exploration areas. Katwe-Kikorongo geothermal field lies in exploration area 3. These were very encouraging results. Total magnetic field map reduced to pole was produced for the whole Albertine Graben. This magnetic data was retrieved, processed, analyzed and interpreted. Results are shown in the airborne magnetic maps below.

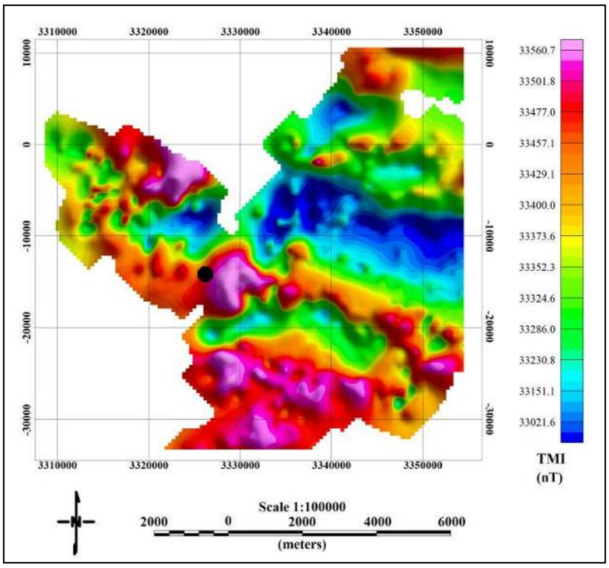


FIGURE 26: Total magnetic intensity map (PEPD data). Note the blue zone standing out with distinct magnetic characters that contrast with surrounding rocks

According to airborne magnetic map above (Figure 26), warm colors (red and purple) indicate areas with high magnetic signature and cool colors (green and blue) indicate areas of low magnetic signature. The linear magnetic lows are interpreted to represent fault zones, some of which appear to correlate with surface geothermal manifestations. These interesting low magnetic signature detected by airborne survey will be followed up with a ground magnetic survey to better define the nature and location of the anomaly. Geothermal activity may have destroyed magnetic fabric in these rocks and produced zones with lower magnetism than the surrounding rocks.

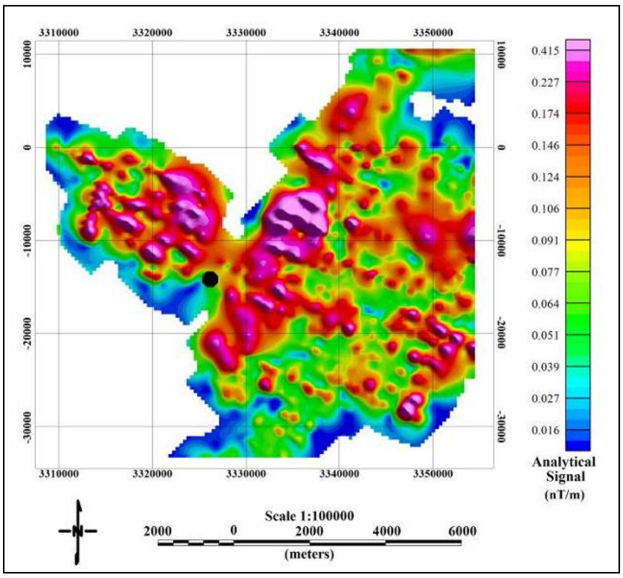


FIGURE 27: Analytical signal map (PEPD data)

The north west south east magnetic grain stand out on this magnetic map (Figure 27). It might correlate with structural trend in this area.

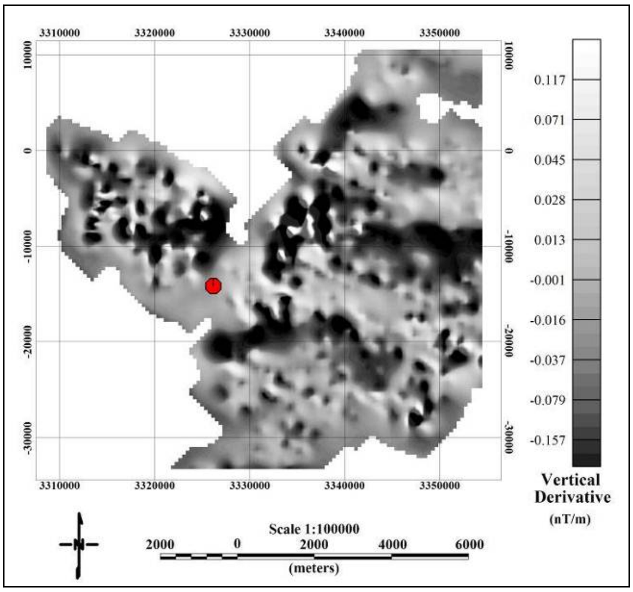


FIGURE 28: Vertical derivative map (PEPD data)

The low magnetic zone east of red dot stand out in contrast with surrounding rocks once again (Figure 28). TMI maps are used to provide a representative sample of the measured data while the AS maps are used to locate the magnetised rocks. The AS is a very good tool that can be used in differentiating the various rock types especially in complex geological situations and delineating structural trends that maybe obscured in the TMI map (Assran S. 2002; Colla 2005).

Old airborne magnetic data from DGSM archives was retrieved, processed, analyzed and interpreted. Magnetic maps are shown below.

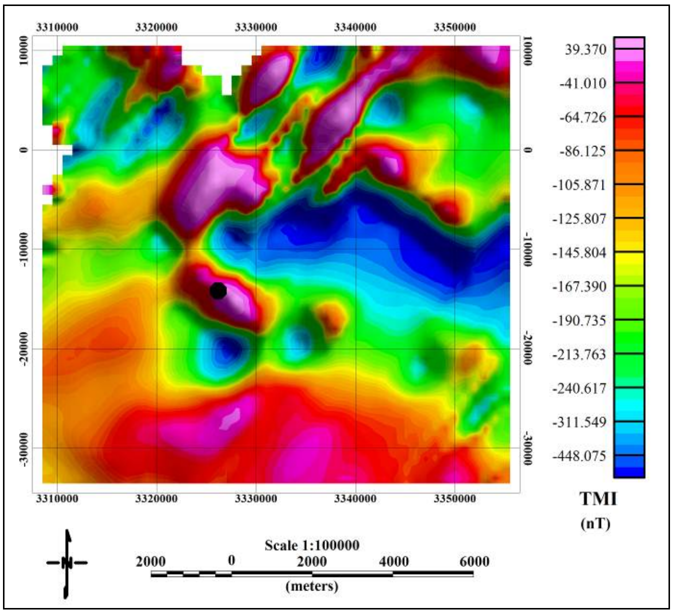


FIGURE 29: Total Magnetic intensity map (DGSM data)

According to airborne magnetic map above (Figure 29), warm colors (red and purple) indicate areas with high magnetic signature and cool colors (green and blue) indicate areas of low magnetic signature. The linear magnetic lows are interpreted to represent fault zones, some of which appear to correlate with surface geothermal manifestations. Figure 30 and 31 show an analytical signal map and a vertival derivative map, respectively.

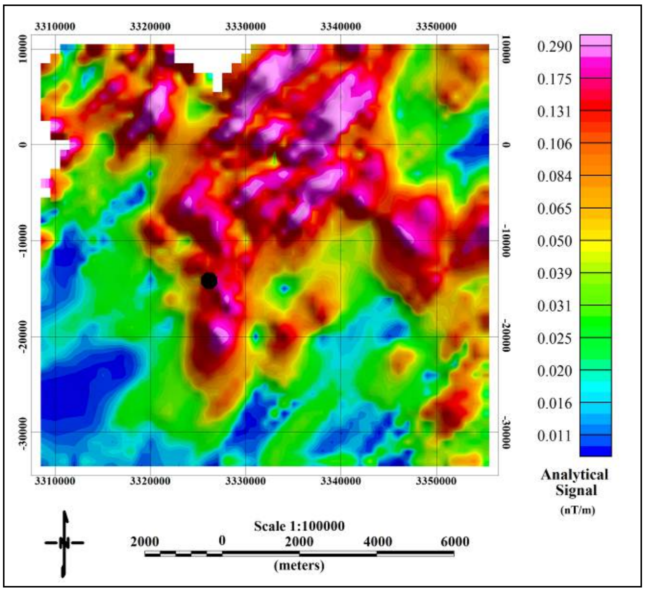


FIGURE 30: Analytical signal map (DGSM data)

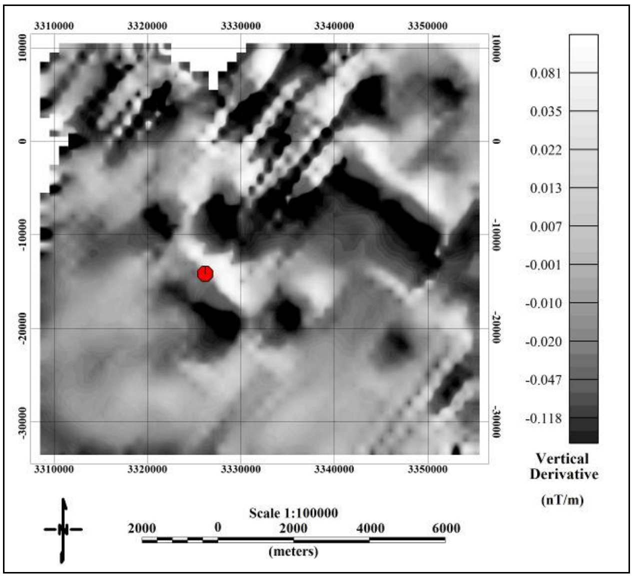


FIGURE 31: Vertical derivative map (DGSM data)

This map shows areas enriched with potassium (Figure 32). These rocks are ultra-potassic but at the same time the potassium rich zone might be due to hydrothermal alteration zone associated with geothermal activity. Katwe-Kikorongo volcano is located on the NE shore of Lake Edward. It is part of a kamafugite-carbonatite province of southwest Uganda in the western rift valley branch. Volcanic rocks at Katwe-Kikorongo volcano contain katungite, which is a potassium-rich glassy olivine melilitite tephra.

Of interest in the coincidence between two data sets indicating a low magnetic signature east and north east of Lake Katwe. It is too early to say it is related to geothermal activity but the area merit further work. Bourger gravity data of the whole Albertine Graben was acquired by PEPD from 1991 to date. This data need to be reviewed and information incorporated.

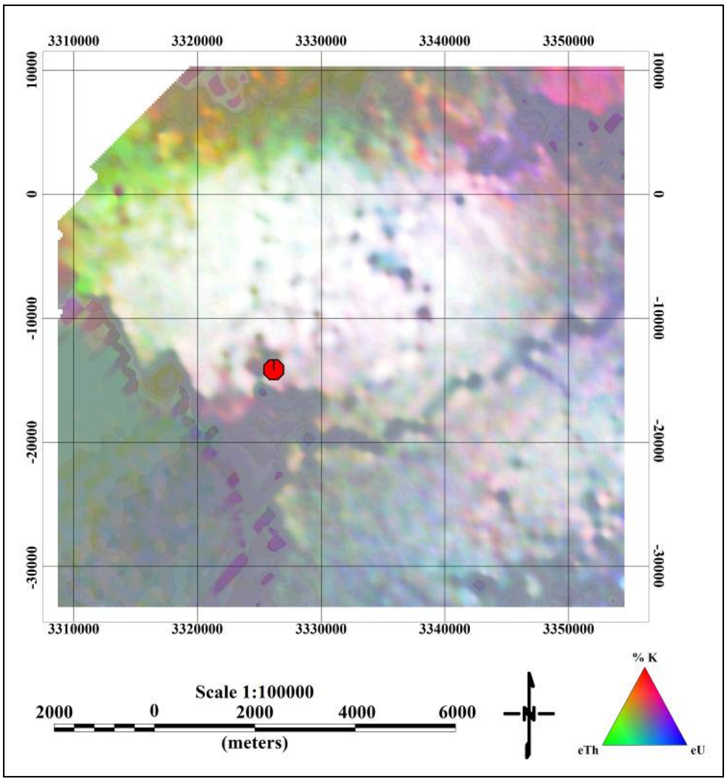


FIGURE 32: Ternary map of the area

Geological mapping has been undertaken in this area as well as environmental baseline surveys. New surface manifestations were discovered and the geothermal area is quite big as evidenced by widely scattered manifestations. Planned work includes combined MT/TEM survey, gravity, seismic, soil gas sampling, more structural mapping, geochemical and isotopic studies.

2.2.4 Buranga Geothermal Resource Site

DEM maps were prepared to aid in structural mapping of the area (Figure 33). Mapping surface manifestations was undertaken and these stretch far than previously known. The occurrence of geothermal evidence at widely scattered localities from one end to the other is highly suggestive of the existence of large geothermal system than previously known.

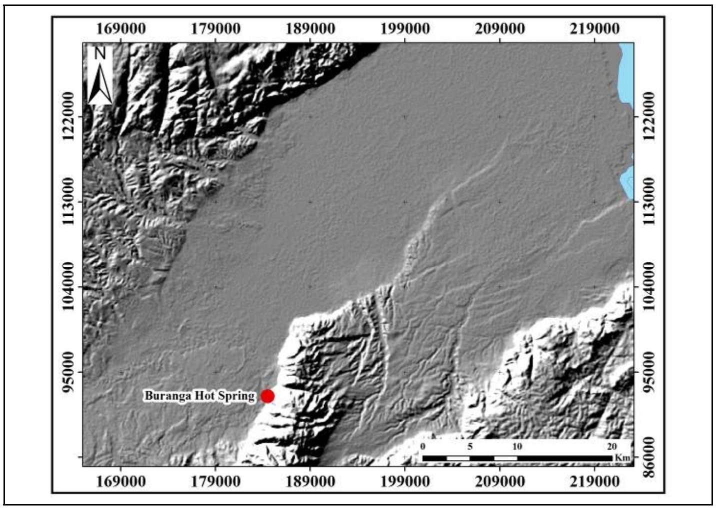


FIGURE 33: DEM map of the area

Of interest here is gas reservoir discovered during oil exploration. It is not clear whether it is of sedimentary origin of related to hydrothermal activity.

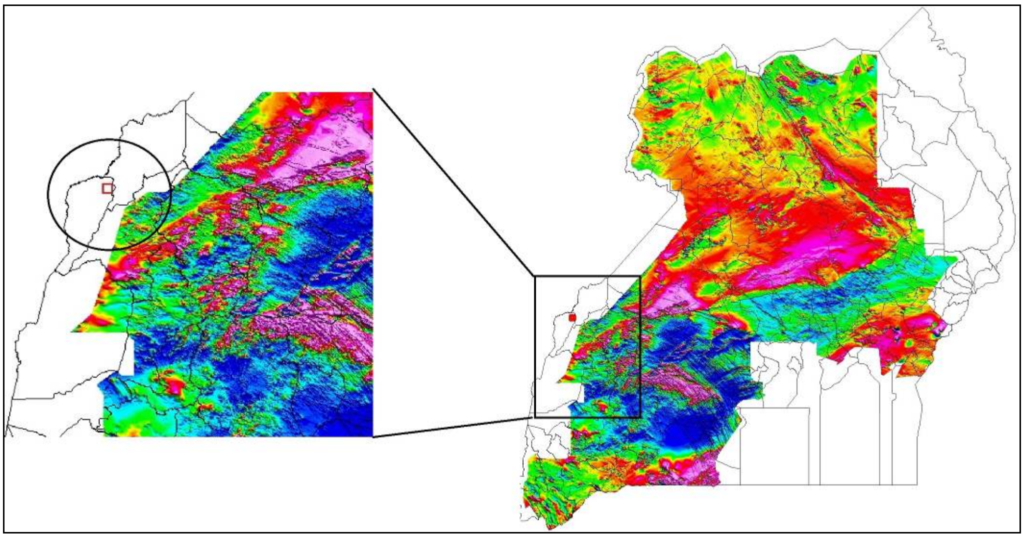


FIGURE 34: SMMRP airborne magnetic data showing Buranga in circle

SMMRP data was not available for Buranga area being near the border as well as being near high altitude Rwenzori (Figure 34). Other sources of geophysical data were considered.

According to airborne magnetic map below (Figure 35) warm colors (red and purple) indicate areas with high magnetic signature and cool colors (green and blue) indicate areas of low magnetic signature.

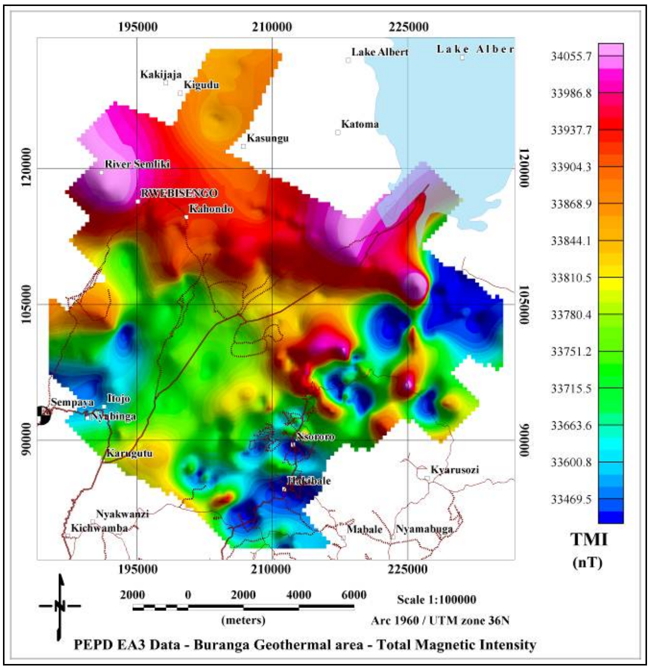


FIGURE 35: Airborne magnetic map

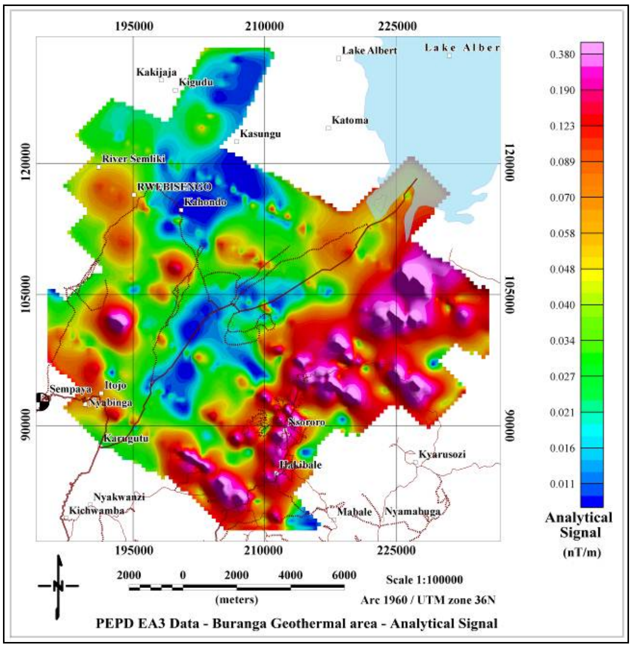


FIGURE 36: Airborne magnetic map

According to airborne magnetic map above (Figure 36), warm colors (red and purple) indicate areas with high magnetic signature and cool colors (green and blue) indicate areas of low magnetic signature.

Ground geophysical methods (magnetics & gravity) so far applied are structural and an electrical method (MT, TEM) should be applied to locate the conductive reservoir. MT surveys can be used to locate high conductivity associated with geothermal reservoirs at depth 2-5 km.

2.3 Jica technical programme

In 2010, JICA undertook a situation analysis study of geothermal development in Africa including Uganda. Following this situation analysis, JICA and Ministry of Energy and Mineral Development are undertaking a joint venture technical study of Uganda's geothermal resources. The preliminary survey is being implemented by West Japan Engineering Consultants Inc. and Mitsubishi Materials Techno Corporation. Seventeen geothermal resource sites were sampled for geochemical surveys. These included Kagamba, Karungu, Bubaale, Kiruruma, Ihimbo, Kanyinabalongo, Rubaare, Kitagata, Minera, Rubabo, Kizizi, Biarara, Rwimi, Kibenge, Muhokya, Rwagimba and Bugoye-Ndugutu. On ground verification of interpreted satellite data was undertaken as well as preliminary geological mapping. Satellite images used included LANDSAT/ETM+ and SRTM/DEM, ASTER, and ASTER/GDEM. The main objective of this study is to locate a prospective site for possible further technical assistance from JICA.

This study was conducted to obtain fundamental information to consider the future contribution by JICA to geothermal development in Uganda. For this purpose, the previous study by JICA (Situation Analysis Study on Geothermal Development in Africa, 2010) will be updated through this study, collecting the latest information about situation and condition of geothermal development in Uganda. In this study, hot spring water and rock samples were collected and are being analyzed for detailed consideration about geothermal potential in Uganda.

2.4 African Rift Geothermal Development Facility (UNEP-Argeo Project)

The Uganda Government submitted a proposal to UNEP in 2011 for technical and financial assistance in order for the Government to undertake surface exploration studies in the Kibiro geothermal resource site. This proposal was prepared in 2011 for which UNEP supported the activity through its consultant. However, the Government of Uganda has undertaken more studies in Kibiro. The data was reviewed by Department of Geological Survey and Mines and UNEP Consultant. Data gaps were identified for future exploration work. The Government of Uganda has re-submitted a proposal to for a prefeasibility study in Kibiro geothermal resource site.

2.5 Mou between the Governments of Uganda, Rwanda and Kenya For exploration and development of geothermal resources

During the last Regional Integration Projects Summit held in Kigali, Rwanda on October 26-28, 2013 the Heads of State directed that a Memorandum of Understanding be finalised and signed before the next summit. In this arrangement the Government of Kenya represented by Geothermal Development Company Limited will be a "Consultant" while Uganda and Rwanda will be "clients".

2.6 Human Capital Development

Several trainings have been undertaken to build a geothermal industry work force with the skills and capacity necessary to enable the rapid development of the industry. These trainings are being conducted at UNU-Iceland, GDC-UNU Naivasha Kenya, West Jec Japan and SEVERAL In-house training seminars. In addition staffs have attended several workshops.

2.7 Geothermal insitution

One of the counter measures to the barriers of geothermal development in Uganda is institution building. This involves intensive capacity building. There is urgent need to have a standalone state-run institution for administration and management, with professional and technical capacities to steer development of geothermal energy in Uganda. This institution must have a budget and logistics. Investigating geothermal sources requires a specialized team, approach, equipment, processing software, and oversight. The Ministry is working with the industry to identify the industry's knowledge gaps in areas of policy, legislation, engineering, science and environment and provide education opportunities to fill those gaps.

The Government of Uganda has restructured the Ministry of Energy and Mineral Development and is in process of establishing a Geothermal Resources Department. Procuring of several survey equipment and software has been initiated.

2.8 Legal and regulatory framework

Cuurently geothermal development is administered under the Mining Act (2003). Lack of legislative and regulatory regimes have constrained effective and efficient permitting and licensing of geothermal exploration companies. Private companies are not willing to come in without legal and business security. It is not easy also to regulate existing exploration programs. There is need to have an action plan for developing and drafting geothermal law. A white paper has been drafted for Geothermal Energy Act.

2.9 Data base management

Data acquired has to be managed if it is to be useful in driving geothermal development in Uganda. DGSM has embarked on developing databases to house all geoscience data relevant to geothermal exploration. DGSM will expedite building the necessary databases and packaging of data for dissemination across the industry. DGSM is also working with UNEP-ARGeo facility in establishing regional data bases.

2.10 Private vs public funding

Since the grant of the first Geothermal Exploration Licence on 12th February 2011, several Geothermal Exploration Licences have been granted and the total number is as of now ten (10). For Geothermal Energy, the associated high risks and costs of proving the resource is one of the key barriers facing the industry. In developing countries like Uganda which lack the required financial and skilled human resources, a combination of both private and public funding may be required along with significant support from both national and international funding agencies (bilateral and multilateral). This support funding may come through grants, loans, or risk mitigation strategies. An application has been submitted to Geothermal Risk Mitigation Facility at African Union.

Due to extremely high risk and costs associated with geothermal exploration, it is difficult to attract sufficient funds from private sector equity investors. Therefore government of Uganda has to play an important role in financing early phase of exploration. Government has demonstrated a strong will towards geothermal development.

3. CONCLUSION

a. **Exploration phase**: Uganda is at exploration phase of geothermal development at Katwe-Kikorongo, Buranga, Kibiro and Panyimur. At other geothermal resource sites studies are at Preliminary phase.

b. **Aeromagnetic data**: Processing and interpretation of aeromagnetic data is cost effective in the contest of survey objectives and budgetary constraints. This should be done prior to initiating expensive and lengthy exploration methods.

c. **Magneto telluric MT Method**: Geothermal exploration currently needs breakthrough geophysical techniques which include indispensable Magneto-telluric surveys (MT) in order to fast track exploration timeline. So far the geophysical methods (gravity and magnetics) used are structural in nature. Other surface geoscience studies like geological mapping will not provide sufficient confidence for a drill target. We urgently need an electrical resistivity / conductivity survey method to breakthrough and generate sufficient exploration data which can image the sub-surface and aid in locating drill targets.

d. **Geothermal Institution**: There is urgent need to have a stand-alone state-run institution for administration and management, with professional and technical capacities to steer development of geothermal energy in Uganda. This institution must have a budget and logistics.

e. **Human Capital Development**: One of the counter measures to the barriers of geothermal development in Uganda is institution building. There is need for intensive capacity building.

f. **Public Funding**: Due to extremely high risk and costs associated with geothermal exploration, it is difficult to attract sufficient funds from private sector equity investors. Therefore Government of Uganda has to play an important role in financing early phase of exploration.

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