



GEOHERMAL EXPLORATION IN RWANDA

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ABSTRACT

Rwanda is looking at future strategy for solving the country's needs for electricity by developing over 500 MWe in 2020 through diversified least cost and cost reflective sources of electricity. Rwanda has no indigenous fossil fuels and the small hydro resources are almost fully developed. To resolve the increasing demand of electricity and diversify its energy resources, Rwanda has put its focus in developing the existing potential energy sources from peat, shared hydro sites and methane gas from Lake Kivu. When looking at other available options for energy, the concept of geothermal appears one option, given that the resource is proven and the development cost is acceptable. This paper outlines the background and current initiatives in geothermal exploration and development in Rwanda.

1. INTRODUCTION

In Rwanda, biomass dominates as the principal source of primary energy for 85% of the population followed by imported petroleum fuels dominating the local industries energy supply. In the third level is electricity and it is used by 24.5% of the population.

The vision for Rwanda's energy sector is established in the Energy Sector Strategic Plan (ESSP) and the National Energy Policy (NEP). These documents recognize the crucial role of electricity access in accelerating economic development, as well as improving health outcomes and standards of living for people in Rwanda. The target for electricity access is for 70% of households to have access by 2018, to be met through a combination of on-grid and off-grid supply. 100% access to electricity is targeted by 2020. Detailed plans including a rural electrification strategy have been developed to spread the electricity network across the country.

The Government of Rwanda plans to achieve by 2020 additional 400 MWe compared to the current installed capacity to be generated from a sustainable generation mix of hydro, methane, peat to power and solar to gradually phase out thermal power within two years. The current total installed generation capacity available in Rwanda is 191.6 MWe from hydro, thermal, solar and methane gas. The cost of electricity is still high with an average end-user cost at US\$ 22 cents/kWh for domestic consumers despite heavy government subsidies. For industrial consumers, the tariff is US\$ 16 cents/kWh. Therefore in order to minimize the dependency on energy imports and create conditions for the provision of safe, reliable, efficient, cost-effective and environmentally appropriate source of energy, renewable energy resources including geothermal seems to be the long term solution that could end the current energy crisis.

The development of geothermal energy resources in Rwanda is at early stages compared to some East African countries such as Kenya and Ethiopia. The exploration of this resource really boomed in 2006 with a view of diversifying energy sources for electricity generation and meets the electricity demand in the country. The volcanoes area, the geological context and the hydrothermal manifestations of Rwanda are an indication of the possible existence of potential geothermal systems. Early geothermal investigations (Egbert et al., 2009; Mariita et al., 2010) pointed out the north-west area as a potential for large, high temperature geothermal systems, while the rift in the south-west part of the country along the Lake Kivu is believed to present an environment for low to moderate temperature resources (Demange et al., 1983; Newell et al., 2006) but these predictions are being reviewed in consideration with the recent exploration drilling results of the Northern part of the country.

The current strategy of the Government of Rwanda (GoR) is to know how much geothermal potential is available for the country to meet its energy demand. This step will be implemented by analysing in detail the previous exploration work, identifying the gaps, carrying out detailed surface exploration in all potential prospects using appropriate methodology in order to rank them and finally exploration drilling to prove the existence of the resource.

2. BACKGROUND ON GEOTHERMAL EXPLORATION

Rwanda is located along the Western branch of the Great Rift Valley. The geothermal potential was estimated at 170-340 MW by the Geothermal Energy Association in 1999 (GEA, 1999). Geothermal investigations in Rwanda started in the 1980's but the existence of geothermal resources in the identified geothermal prospects is still to be confirmed. Several reports exist, indicating two areas as prospective zones for geothermal energy; the first zone (Gisenyi, Karisimbi, and Kinigi) in the north-western region associated with volcanoes and the second zone (Bugarama) in the southern region associated with faults in the East African Rift (Figure 1).

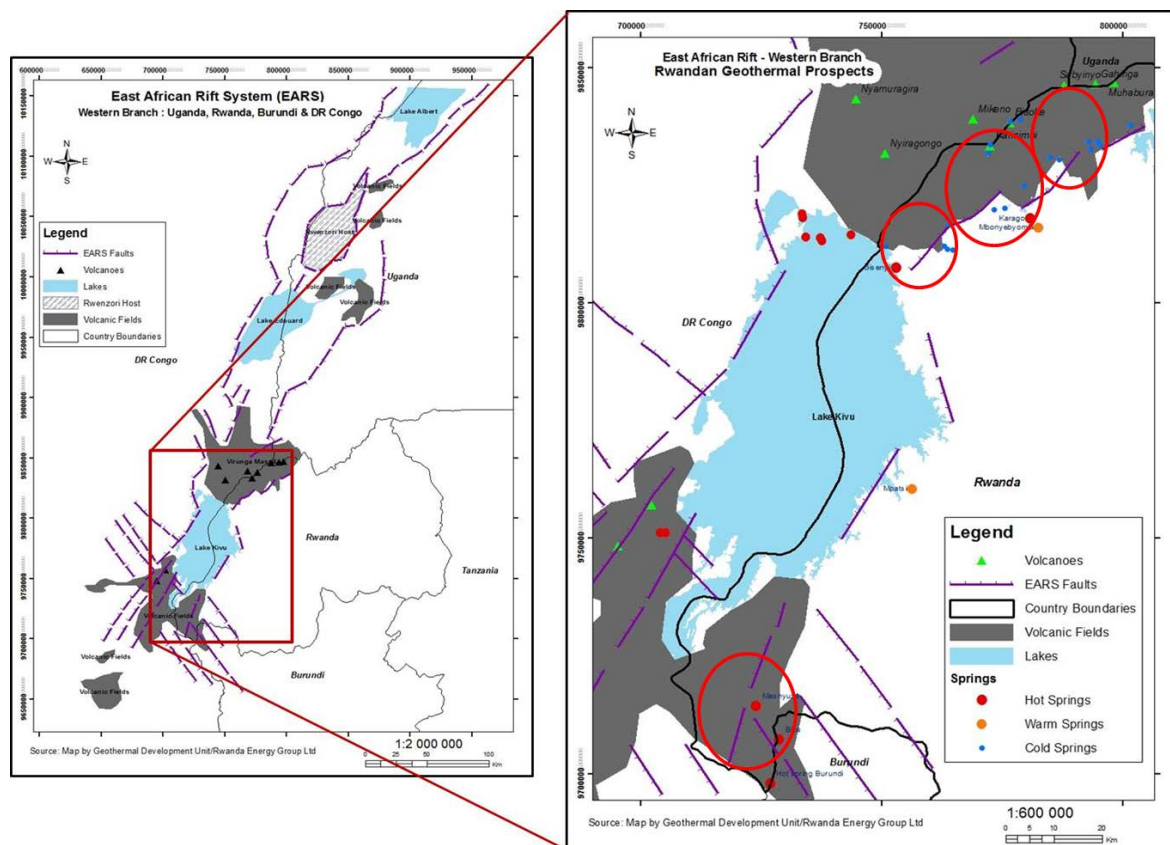


FIGURE 1: Location of Rwanda geothermal prospects (GDU, 2014)

Serious investigations on Rwanda geothermal resources started in 2006 with a view of diversifying energy sources for electricity generation and meet the electricity demand in the country. Surface exploration studies to prove the resource have been carried out in several phases:

In 1983, the French Bureau of Geology and Mines (BRGM) identified Gisenyi and Bugarama as potential sites for geothermal energy with estimated reservoir temperatures of over 100°C (Demange et al., 1983).

In 2006, Chevron carried out geochemistry studies in the Bugarama and Gisenyi geothermal prospects and estimated the geothermal reservoir temperatures to be more than 150°C (Newell et al., 2006).

In 2008, the Germany Institute for Geosciences and Natural Resources (BGR), in collaboration with the Kenya Electricity Generating Company (KenGen), the Icelandic Geo Survey (ISOR) and the Spanish Institute for Technology and Renewable Energies (ITER) carried out surface studies in the Gisenyi, Karisimbi and Kinigi areas. The results from this study concluded that a high temperature geothermal system (>200°C) may exist on the southern slopes of Karisimbi volcano and that a medium temperature geothermal system may exist around Lake Karago (150-200°C) (Egbert et al., 2009).

In 2009, KenGen acquired additional surface studies (geochemistry and geophysics) and carried out baseline environmental impact assessment (EIA) on the southern slopes of the Karisimbi Volcano. Findings recommended drilling three exploration wells in the Karisimbi prospect (Mariita et al., 2010).

In 2011, an additional geothermal survey was done by the Institute of Earth Science and Engineering (IESE) through Auckland UniServices, New Zealand aiming at developing a conceptual model for the entire western region and locating sites for exploration drilling in the three prospects, Karisimbi, Kinigi and Gisenyi (Shalev et al., 2012).

Workshops were organised in 2012 and 2013 with panel of experts aiming at merging all findings, to come up with one unified model for the Karisimbi area allowing for the definition of the location of sites for exploration drilling in Karisimbi (EWSA, 2012; EWSA, 2013).

In 2013-2014, two exploration wells were drilled in the southern slopes of the Karisimbi volcano to 3,015 and 1,367 m depth, respectively. Alteration mineralogy and measured temperatures are consistent with normal continental geothermal gradient (i.e. ~30°C/km) conclusively demonstrating that there is not a geothermal reservoir under the southern slopes of Karisimbi.

Presently, the four geothermal prospects can be ranked as shown in Table 1.

TABLE 1: Exploration status for Rwanda prospect (Rutagarama, 2015)

Geothermal prospects	Reconnaissance study	Detailed survey	Gradient wells	Wells sited	Wells drilled
Karisimbi	yes	yes	no	yes	yes
Kinigi	yes	yes	no	yes (1)*	no
Gisenyi	yes	yes	no	yes (1)*	no
Bugarama	yes	yes	yes	no	no

*: From Shalev et al., 2012

3. CURRENT DEVELOPMENT

3.1 Karisimbi geothermal prospect

The Karisimbi area is located near the Karisimbi volcano within the National Volcano Park and Virunga volcanic chain complex. No geothermal manifestations such as fumaroles or alteration have been reported in this area. Couple of hot springs are located south and out of the volcanic field with the highest temperature of 64°C at Karago (Figure 2). Detailed surface geo-scientific studies have been completed and two exploration wells drilled.



FIGURE 2: Location of Karisimbi geothermal prospect (Fridriksson et al., 2014)

Drilling of three deep exploratory wells was planned and funded by GoR but only two wells (KW01 and KW03 in Figure 3) were drilled. The drilling contractor was Great Wall Drilling Company (GWDC). Drilling materials were supplied by the China Petroleum Development and Technology Corporation (CPTDC). The rehabilitation of the road to the drilling site was carried out by a local company ERGECO and the contract for water supply system to the site and civil works was awarded to a Kenyan Company, YASHINOYA Trading and Construction Company Limited.

Well testing services were provided by the Geothermal Development Company (GDC) from Kenya. Technical assistance prior to drilling was provided to the Geothermal Development Unit by the Japan International Corporation Agency (JICA). On job training was provided by the Icelandic Geological Survey (ISOR) through funding from the Icelandic International Development Agency (ICEIDA). The drilling supervision for the first well was carried out by Reykjavik Geothermal Company (RG) and funded by the Nordic Fund through the Nordic Environment Finance Corporation (NEFCO) while the drilling management and geology supervision of the second well was provided by Geothermal Resources Group (GRG) in collaboration with GDC as drilling supervisor.

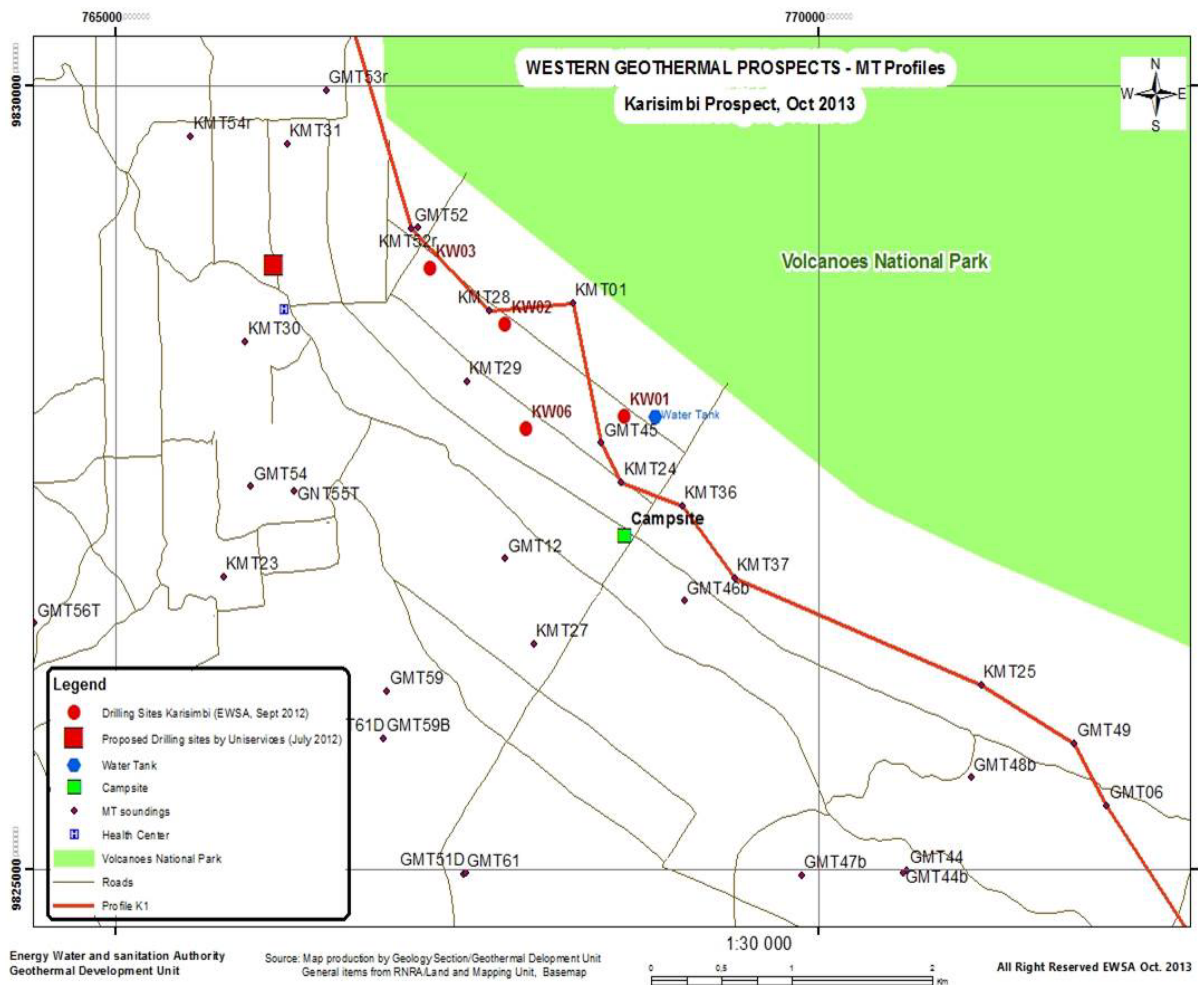


FIGURE 3: Location of drilled wells in Karisimbi prospect (GDU, 2013)

Exploration drilling began with the Karisimbi prospect in July 2013 with the first well KW01 to a depth of 3,015 m followed by the second well KW02 on December 2013 to a depth of 1,367 m. From these two wells, there was no evidence of the existence of a geothermal system in the area and this led to the decision of halting the drilling activities.

The existing geo-scientific data and drilling data were reviewed by ISOR, the United Nations Environment Programme-African Rift Geothermal Development Facility (UNEP-ARGeo) and JICA. The outcome of the analysis was the basis for the elaboration of a new strategy for Rwanda geothermal exploration and development.

3.2 Kinigi geothermal prospect

The Kinigi geothermal area is located to the east of Karisimbi (Figure 1). Detailed surface studies as well as Environmental and Social Impact Assessment (ESIA) have been completed. Supplementary studies were required to decide on the way forward for the exploration of this prospect.

Therefore, additional geoscientific surveys in Kinigi carried out by the West Japan Engineering Consultants (WestJec) and funded by JICA started in June 2015. Remote sensing data analyses, volcanic rock sampling and gravity surveys were completed followed by the construction of a conceptual model (Figure 4).

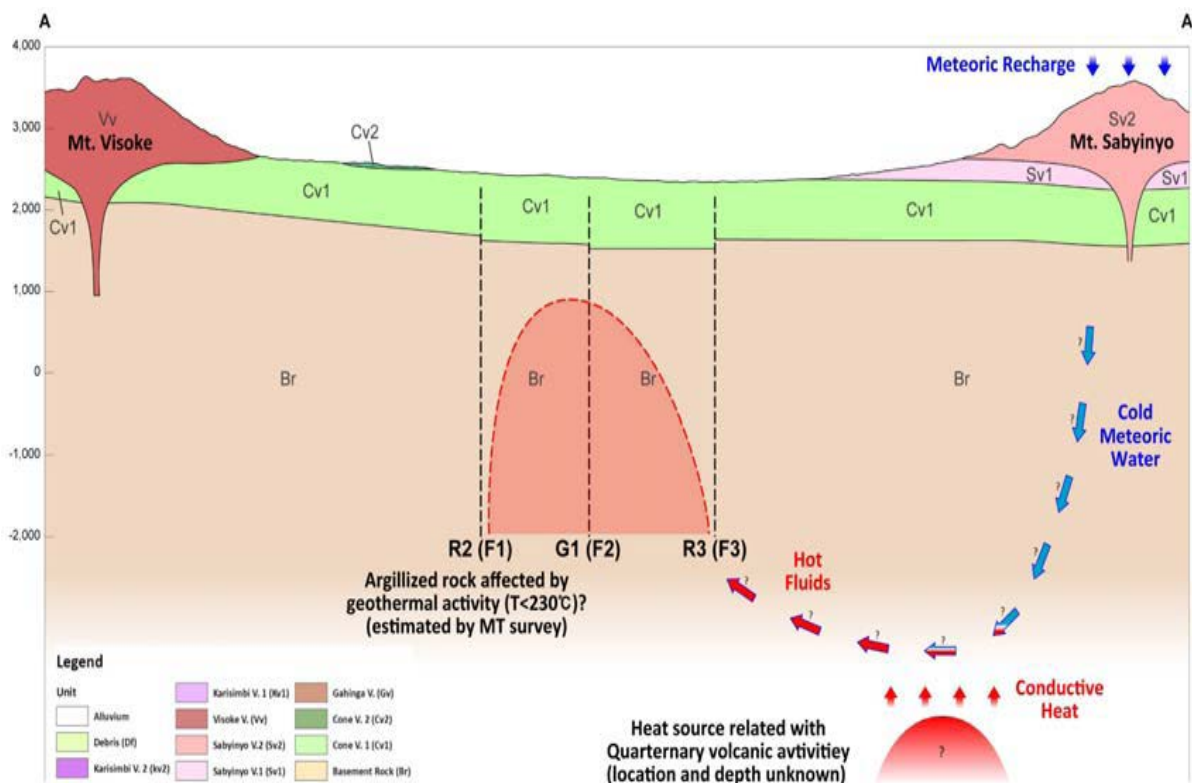


FIGURE 4: Conceptual model of the Kinigi geothermal area (JICA, 2016)

Results of the study were shared during a Technical Review Meeting (TRM) organized by UNEP-ARGeo in May 2016. Additional studies to focus on summit of Sabyinyo and associated volcanic centres were recommended.

In addition to the above initiative, the Government of Rwanda submitted an Expression of Interest to the Geothermal Risk Mitigation Facility (GRMF) for support in infrastructure and exploration drilling of slim holes in Kinigi. The Kinigi project was qualified for grant award for slim holes drilling.

3.3 Gisenyi geothermal prospect

The Gisenyi geothermal prospect is located south-west of Karisimbi (Figure 1). Hot springs of about 75°C are located in the prospect at the shores of Lake Kivu. Geoscientific investigations have been carried out in the area. Additional studies to complement existing data in the Gisenyi area was awarded to the Consortium SARL Geo2D and Geothermal Development Company Ltd (GDC/Kenya) and funded by the European Union (EU).

Structural geology is completed and has identified four areas of interest for geothermal detailed surveys (Figure 5). Geophysical and geochemical data collection in area A1 is completed and the final report is expected by December 2016.

3.4 Bugarama geothermal prospect

The Bugarama geothermal prospect is located in the southern province of Rwanda (Figure 1). The geothermal manifestations in this area are hot and warm springs and travertine deposits, which is being mined as feedstock for a nearby cement factory. The highest temperature for the springs is about 55°C.

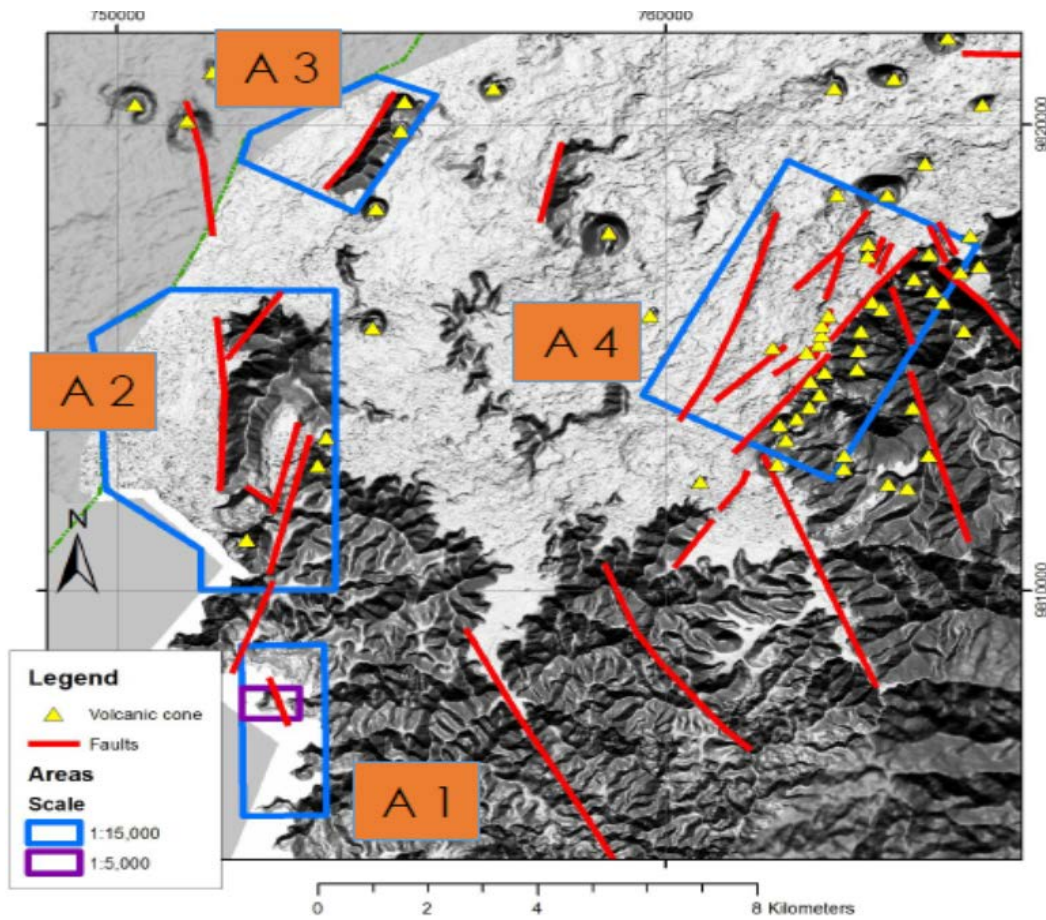


FIGURE 5: Geothermal target areas in Gisenyi prospect (GDC and SARL, 2016)

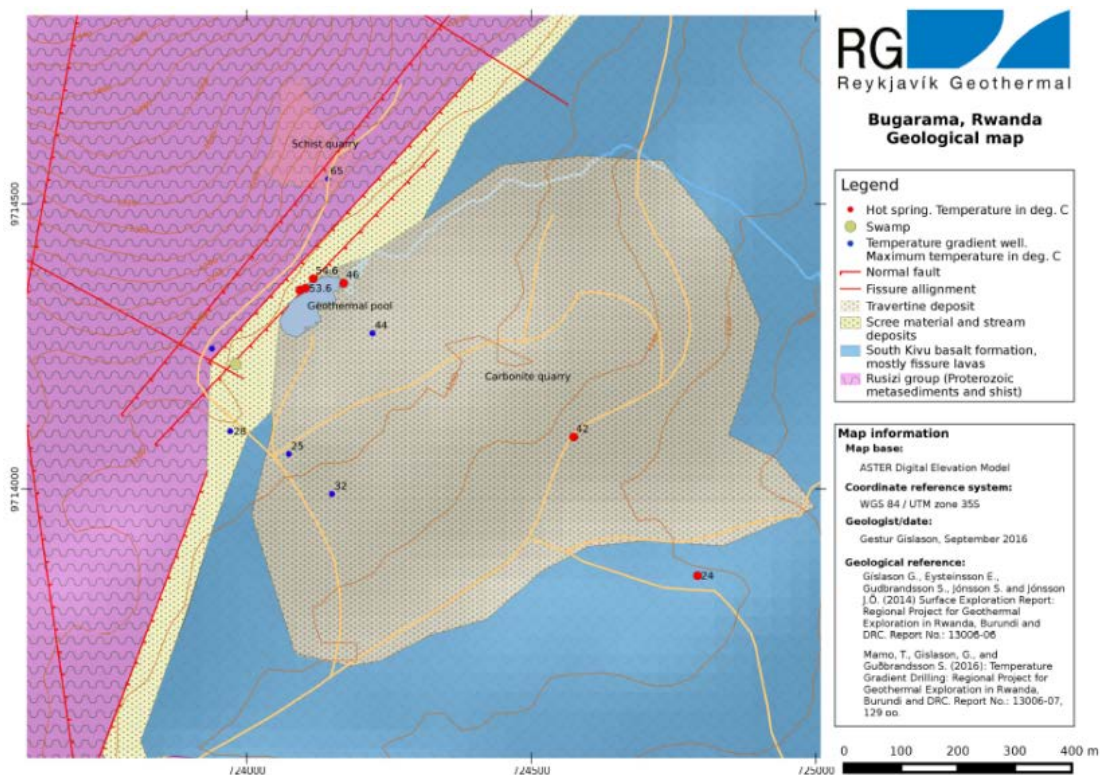


FIGURE 6: Geological map of the Bugarama geothermal area (Gíslason et al., 2014)

A regional geothermal exploration study funded by EU started in November 2013 for the three countries, Democratic Republic of Congo, Burundi and Rwanda. The consultancy firm hired for this project is Reykjavik Geothermal (RG). Great Lakes Energy Agency (EGL) is mandated for the implementation of this regional project.

Detailed geo-scientific surveys for the three countries are completed. Surface exploration (Figure 6) and drilling of thermal gradient wells in the Rwandan part is completed and a conceptual model was constructed. The final report was submitted in June 2016. Additional surveys are recommended to fill the information gaps from this survey.

4. OTHER INITIATIVES

A detailed Geothermal Strategy and Geothermal Act have been developed but are yet to be formally approved. The existing geothermal strategy has been reviewed through the support of EU Energy Initiative Partnership Dialogue Facility (EUEI-PDF). This study has considered the existing geothermal data and has developed a new strategy for geothermal exploration that will define the approach to private sector involvement in geothermal exploration and development in the country.

Furthermore, JICA supported the preparation of electricity development plan for sustainable geothermal energy development and its integration into the Electricity Master Plan. This master plan (JICA, 2015) gives estimates of the identified potential geothermal prospects based mainly on existing data with an action plan for exploration and development of each prospect. Conclusions indicate a maximum estimation of 90 MWe geothermal resources potential for the country

Technical assistance and capacity building in the sector have been provided and financed by several institutions; the United Nations University Geothermal Training Programme (UNU-GTP), ICEIDA, UNEP-ARGeo, JICA, GDC, KenGen, EUEI-PDF and others.

5. ISSUES AFFECTING THE DEVELOPMENT OF GEOTHERMAL ENERGY IN RWANDA

Theoretically, the estimates of geothermal energy potential can highly contribute to the supply of the national power needs for Rwanda. However, the pace and level of development of geothermal resources has not been effective. This is mainly due to lack of funds and the perceived risk in developing geothermal resources. Financing from multilateral institutions or international lenders is difficult without adequate data. The GRMF is one of the alternatives to be utilized.

Geothermal energy development generally has very high project development costs. Unlike diesel plants, where you can purchase the fuel when required, in geothermal you have to prove the availability of fuel (steam) in advance before power construction.

Other issues affecting the development of geothermal energy are marketing, institutional, and policy impediments. The role of geothermal development in the energy mix needs to be clearly defined with set and funded targets to prove the viability of a geothermal resource. There is need to share and disseminate information among all stakeholders and potential investors. The fear of developing geothermal energy has to be overcome among policy makers and opinion leaders. There is need to build adequate human resource capacity while at the same time encouraging local education institutions to provide training relevant to geothermal development. Clear guidelines on the level of participation of local community and other stakeholders in geothermal development and utilization are required.

Furthermore, the western branch of the East African Rift System (EARS) is yet to be well understood in order to apply adequate methodology for geothermal exploration in Rwanda. The western branch workshop held in Kigali early 2016 was the first step to understand the reason for unsuccessful projects in countries lying in the western rift despite exhaustive exploration activities. Appropriate methodologies and techniques for the exploration and development of geothermal resources in the western rift are therefore highly recommended.

6. CONCLUSIONS AND RECOMMENDATIONS

Rwanda has positive indicators of geothermal potential but the resource still need to be confirmed. Four potential geothermal prospects, Karisimbi, Gisenyi, Kinigi and Bugarama, have been identified and two exploration wells were drilled in one prospect, Karisimbi. There is however need in the future to carry out a thorough assessment of the data to minimise the risks of sinking unproductive wells and apply appropriate methodology for resource exploration. A criterion for sitting wells therefore needs to be established.

Existing data need to be reviewed and additional data collected through appropriate methodology in order to define a clear way forward and strategy for geothermal development in Rwanda. A careful approach is to be utilised in the exploration program to increase the success rates in future.

Efforts to understand the geothermal system of the western branch of the Rift needs to continue. This will help increase the rate of success of geothermal exploration in countries lying along the western rift including Rwanda.

Considering the high risk for exploration drilling, the GoR should continue to involve development partners to assist in the exploration and development of Rwanda geothermal resources. Capacity building is required from the first stage of reconnaissance to the implementation of the project. There is a lack of appropriately trained local graduates from Rwandan Universities in some fields related to earth sciences (geology mainly). On job training and equipment are needed for young graduate scientists and engineers to understand the steps for geothermal exploration and development.

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