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Evidence of Geothermal Manifestations in the Gisenyi Geothermal Prospect, Western Virunga Massif, Rwanda.

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ABSTRACT

The Gisenyi prospect in the North-West of Rwanda was surveyed during the year 2013 by Rwanda Energy Group LTD (REG LTD). The survey showed the presence of two types of rocks which consist of the old basement and the recent lava flows. The latter were originated from the recent volcanic activity of Karisimbi volcano in Rwanda and Nyiragongo volcano in the Democratic Republic of Congo (DRC). These lavas contain plagioclase phenocrysts and/or quartz-dominated xenoliths. The basement has been dissected by N-S to NE-SW normal faults. It is difficult to locate the major accidents in the area covered by K-rich basic volcanic rocks. The way used to track them was done through identifying radial or NE-SW oriented depressions within the lava field. Most of the volcanic rocks are fresh and do not show any sign of hydrothermal alteration. However, the surroundings of the Gisenyi hot springs are theatre of Ca-rich depositions. Furthermore, the deposition of calcite in the Mufumba volcanic cone, the deposition of calcite and halite along the cracks and in the empty pockets of the hard rocks originated from gas-rich magmas of Bonde crater, confirm that the hydrothermal alteration in the Gisenyi prospect is evident.

I. Background

The surface investigations of the geothermal resources of Rwanda have been carried out along approximately the last 30 years by several geo-scientific institutions (Rancon and Demange, 1983; Newell et al., 2006; Jolie et al., 2009; EWSA, 2013; EWSA, 2014). These investigations were carried out on the one hand in the Quaternary to recent Virunga massif which is hosting active volcanoes in its western zone in the Democratic Republic of Congo (DRC). The active volcanoes are namely Nyiragongo and Nyamuragira. On the other hand, the studies concerned the Upper-Tertiary volcanic field of the Bugarama graben in the South-west of Rwanda on the border between Rwanda, Burundi and DRC.

In both fields, geothermal manifestations are mainly hot and warm springs, gas-rich mineralized springs and travertine (Jolie et al., 2009). The Virunga domain (Rwanda side) was investigated in details using sub-surface methods which are remote sensing-based geological investigations, ground geophysical surveys and waters geochemistry tracking (Jolie et al., 2009). The key outcome of the previous surface studies was that a high temperature geothermal resource may exist within the Virunga Massif. As follow up works, two exploration wells were so far drilled near Karisimbi volcano and the outcomes from it did not confirm the existence of a high temperature geothermal source (EWSA, 2013, 2014).

To cross-check different lithological units compiled in the geological map of Rwanda, tectonic features and different cones/craters (Jolie et al., 2009; De Mulder, 1985), from April 16th to April, 19th, 2013, a team from REG LTD has conducted a detailed mapping in the Gisenyi area (Ngaruye and Haganje, this paper). The geological, geothermal and geochemical mapping report is presented as follows:

II. Objectives

The key objectives of this paper is the description of the findings from the completed field work (Ngaruye and Haganje, this paper): cross checking of the previously identified geological structures in the Gisenyi prospect (Jolie et al., 2009) and mapping of new ones (if any). In addition, the geothermal manifestations and hydrothermal alteration zones were mapped.

III. Findings:

III.1 Geology

Three types of young eruptive rock units and two rock units within the basement were recognized in the area and mapped. Previously identified tectonic structures of the study area with the main focus on faults, fissure swarms within the basement and the recent basic lava flows and cones/crater were mapped. Recent (from Nyiragongo) to historic volcanic rocks were identified from the Mbugangari (Gisenyi sector) – Nengo – Nyabagobe - Byima (Nyamyumba Sector) -

Kamuhoza (Kanama Sector) – Mizingo - Shaba (Bigogwe Sector) axis in the south of Gisenyi prospect and cover, in the North, the rest of the prospect.. Thick layers of volcanic ashes exist (Figure 2) and host the main pozzolan quarries exploited for the raw materials (road construction and cement industry). These light volcanic ashes produced by explosive activity cover 0 to 3m thick paleo-soils and on the top of the ashes, fertile soils were developed. Hard volcanic rocks in the form of pahoehoe (Figure 1) were identified.

Figure 1: Picture showing pahoehoe.

Figure 2: Photo showing volcanic ash (left of the black line) and consolidated scoria in the Western side of Muhungwe mountain.

III.1.1 Rock classification (Figure 4).

Basement

The oldest meta-sediments are rare, scarce and sparsely distributed within in the North-Western part of Gisenyi prospect and mainly in the surroundings of Gisenyi town. They comprise metamorphosed muscovite-schist, hard, medium to coarse grained quartzite and thin layers of mica-schist, gneissic granites and pegmatite intrusions. The mylonitization is frequent within the muscovite-schist. The Gishwati complex dominates the lithology in the southernmost part of the Gisenyi prospect and is extended from Lake Kivu to Bigogwe. They probably represent the oldest geological formation of Rwanda which corresponds to the Butare complex. The dominant formations of the basement are granite intrusions and on their top, Sn- and Nb-Ta-rich small pegmatite bodies are occurring.

Young lava flows

The field observations have shown 4 types of volcanic materials:

Pyroclastics comprising pumice and fresh tuffaceous materials which were localized in the vicinity of Mount Muhungwe and East of Gisenyi town. Volcanic ashes are the main component of all the volcanic cones/craters found within the investigated prospect. The tuffs are partly lithic

and partly crystal tuffs. Its main component is with aphyric fine-grained clasts, occasionally coarse-grained and occasionally with medium-sized volcanic bombs.

Aphyric volcanic rocks which are hard, massive and dark to black colored. They are fine-grained and porous. They have been identified in the south-western to southern part of Muntango pit crater.

Volcanic rocks with plagioclase phenocrysts: these are fresh lava flows which show small to big plagioclase phenocrysts.

Lava flow embedding xenoliths: numerous lava flows and pyroclastics of Gisenyi area enclose bedrock inclusions. Majority of these inclusions are quartz xenocrysts-rich.

III.1.2 Structural geology

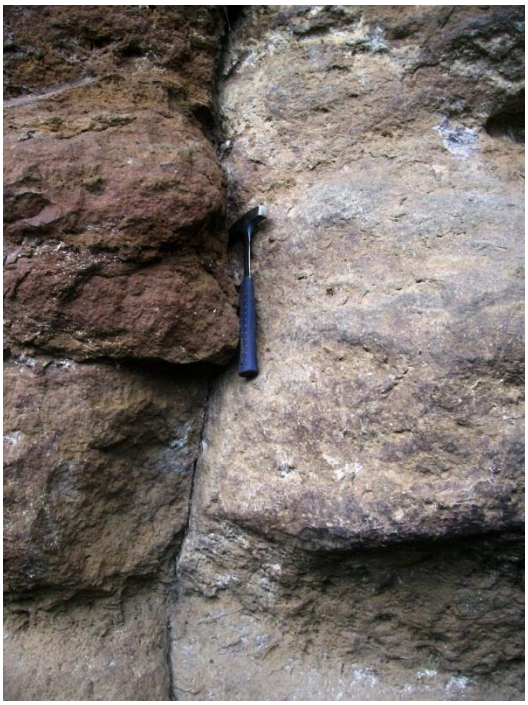

Figure 3: Picture showing cleavage plans in the volcanic rocks.

The topography of the Gisenyi field is dominated by NE-trending narrow graben expressed as depressions extending from Kabatwa zone (2700m high) to Lake Kivu (1460m high). Several steps at different elevation levels are identified within those grabens. The basement was dissected by NW and NE trending normal faults. The most important tectonic features which are possibly controlling the fluid flow in the Gisenyi area are open N-S to NE-SW faults. This is evidenced by the absence of springs, rivers or any other water point in the Gisenyi town-Kabatwa axis where the annual rainfalls range between 1600mm and 1800mm.

The collected water seems to flow through those open accidents to Lake Kivu. The throw of the faults is often difficult to measure, but ranges within hundreds of metres (side of Ibere rya Bigogwe-Mizingo). The faults that dissect the study area are more common in the basement than in the younger lavas where they followed the former micro-grabens dissected in the basement.

It should also be mentioned that additional to the normal faults, explosive craters have been mapped within the Gisenyi area. Among them we visited Kirerema, Ndoranyi, Mudende, Rungu adventive volcanic cones/craters and finally Rebero and Bonde craters in the Kabumba Cell, Bugeshi Sector, Rubavu District (Table 1).

They are generally formed by both pumices and tuffaceous materials which are the first products to come out during each classic volcanic eruption and hard volcanic rocks. As evidenced by Bonde crater, the recent volcanic rocks were cracked possibly by the current East African Rift Orogeny (Figure 3).

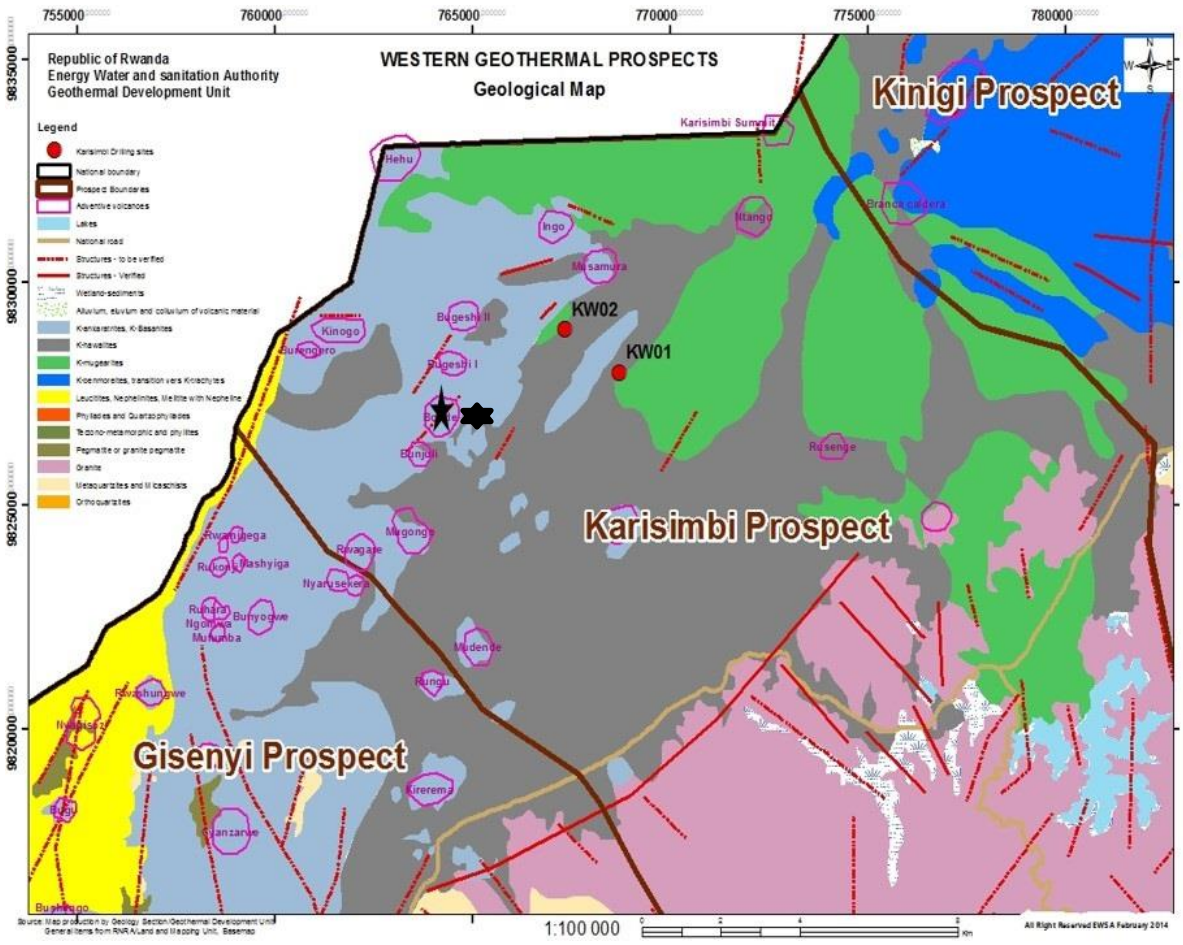

Figure 4: Geological setting of Birunga Geothermal prospects (EWSA, 2013). The black star indicates the surveyed volcanic cone of Bonde.

IV. Geothermal manifestations mapping

The active geothermal manifestations identified in the Gisenyi prospect are: the Gisenyi hot springs (surface temperature around 74˚C), the Iriba warm spring, the Nyamigogo warm spring (24.7˚C) and the hyrothermal alteration mineral deposition (calcite) in the pores of volcanic rocks of Mufumba crater (Cyanzarwe Sector). The same manifestation was observed at the adventive cone of Bonde (Bonde Village, Kabumba Cell, Bugeshi Sector, Rubavu District). Bonde is one of adventive cones/craters found in the Gisenyi geothermal prospect. It is mainly characterized by a lot of volcanic ashes in its western limb and hard and massive volcanic rocks in its Eastern limb. The crater of this cone exhibits hydrothermal alteration evidenced by several mineral depositions (calcite and halite) along the cracks and in the lenticular empty pockets hosted by the hard volcanic rocks. Another type of alteration observed was oxidation which is evidenced by the reddish coloured rocks.

To identify the calcite deposition, the use of the common method of testing calcite in the field was applied. The test is based on the fact that calcite ($CaCO_3$) reacts with diluted hydrochloric acid (HCl, 1M standard solution) and the reaction is manifested by vigorous effervescence.

$CaCO_3 + 2\ HCl \rightarrow CaCl_2 + H_2O + CO_2$; while $CaCO_3$ reacts with HCl the bubbles observed is CO_2 gas. No fumaroles, mud pools or hot grounds were found.

Figure 5: View of the crater on the top of Bonde cone.

Figure 6: Volcanic rocks found in the Bonde crater

Figure 7: Calcite precipitation

Figure 8: Halite precipitation

Figure 9: Red brown rock in Bonde.

Table 1: Springs Measured Chemistry in situ Parameters.

Spring name	**pH**	**T(^{O}C)**	**Cond(µS/cm)**
Nyamigogo Spring	**7,1**	**24,7**	**629**
Gisenyi hot spring	**6,7**	**72,9**	**2353**
Gisunyu River	**?**	**?**	**?**

The in situ monitored physico-chemical parameters of the Gisenyi cold/warm/hot springs show no significant variation from Jolie et al. (2009). However a new spring called Nyamigogo has been identified and measured for the in situ parameters. The measured temperature shows that Nyamigogo is a warm spring (24,7^{O}C). Its electrical conductivity confirms that the waters of

Nyamigogo spring host some minerals dissolved in it. The information provided by local people showed that Nyamigogo spring is not used for life water due to its strange taste.
It is not easy to understand the hydrology of the region, since you should come today and find a river flowing and the following time when you come back you find out that the river is no longer existent. A case in point is the Gisunyu River which was flowing on the field visit conducted on 17th March 2013 (Figure 10), and the river was not there in this field visit conducted on 16-19th April 2013, just one month later (Figure 11). The spring of Gisunyu is currently disappearing in a hole in the Nduruma area and possibly flowing along an open fault zone through which it is driven to Lake Kivu? This testifies that the water flows are likely controlled by the presence of caves, the tectonic features and the tectonic movements of the region.

Figure 10: Picture of Gisunyu river on 17/03/2013.

Figure 11: Photo of the dry Gisunyu on 18/04/2013

V. CONCLUSIONS

The Gisenyi prospect exhibits two types of rocks: the basement comprising foliated and mylonitized mica-schists, hard and massive quartzite, pegmatitic granites, gneissic granites and granite intrusions and the recent lava flows which are originated from the volcanic activity of Karisimbi and Nyiragongo volcanoes. These lavas contain plagioclase phenocrysts and/or quartz-dominated xenoliths. The basement has been dissected by N-S to NE-SW normal faults. It is difficult to locate the major accidents in the area covered by the basic volcanic rocks. The way used to track them was done through identifying radial or NE-SW oriented depressions within the lava field.

Most of the volcanic rocks are fresh and do not show any sign of hydrothermal alteration. However the surroundings of the Gisenyi hot springs are theatre of Ca-rich depositions (as evidenced by HCl, 1M). Furthermore, the deposition of calcite in the Mufumba cone, the deposition of calcite and halite along the cracks and in the empty pockets of the hard rocks of Bonde crater confirm the presence of active hydrothermal alteration in the Gisenyi prospect. Elsewhere, due to the high annual rainfall and tectonic features which drain the waters towards Lake Kivu and thus control the water flows, the geothermal manifestations are few or do not occur.

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