MANAGEMENT AND DEVELOPMENT ISSUES OF GEOTHERMAL ENERGY IN THE WESTERN BRANCH OF THE AFRICAN RIFT SYSTEM: CASE OF THE DEMOCRATIC REPUBLIC OF CONGO

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ABSTRACT

In additional to the Virunga active volcanoes Nyiragongo and Nyamulagira, Eastern side of the DRC has more than 136 hot springs including the MAYI YA MOTO (Latitude S00°53'54.4'', Longitude E029°21'06.9'', Altitude 953 m) in Virunga National park at Rwindi with the highest vapor temperature around 92° Centigrade. The Rift System encompassing geothermal resources is very active; the seismic activity is very abundant. Violent earthquakes that occur in the region have a significant impact on the faults that litter the rift. The focal mechanism of the earthquakes would have an impact on the behavior of hot springs in the region. This geodynamics of the rift is a major obstacle/issue on the development of the research on geothermal in certain areas of study. Thus, a seismology, geodesy, climatology, hydrogeology, geomagnetism, geochemistry monitoring network has to be implemented and/or improved in the region along the western branch of the African Rift System to clearly identify the areas likely to exploitation of geothermal energy. These studies, when conducted, allow to develop a realistic mapping of the geothermal potential of the western branch of the Rift.

1. INTRODUCTION

From South Sudan to the Tanganyika region, the Western African Rift branch system extends over 1500 km. This area is littered with several active faults, geothermal sources at temperatures ranging from 40° to 95° Celsius, with active volcanoes including the Nyiragongo lava lake Standing observed since its discovery in 1894 and today Nyamulagira whose appearance the lava lake remained from 2014 to today.

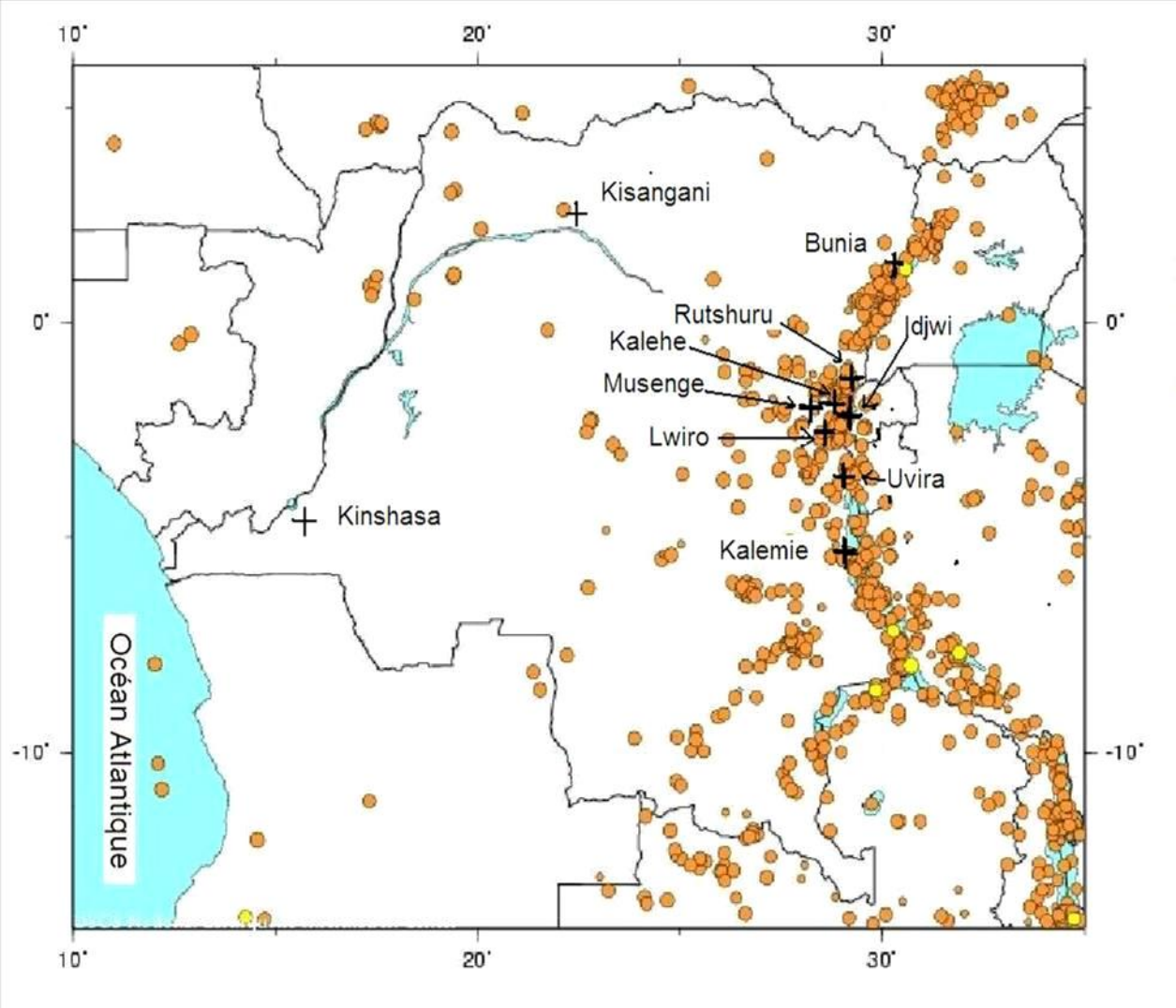

Figure 1: Seismological network digital and analogic
•: Seismicity in R.D. Congo 1973 - 2009.((USGS PDE, Lwiro/GVO)
+: Seismic stations

Since 2008 to 2013, at least, 6 earthquakes per year are felt by the population of Ruwenzori region. The most recent felt earthquakes dated from 17 and 24 July 2016.

In the Lake Kivu basin during and after the eruption of Nyiragongo volcano on 2002, the region experiencing the upsurge in earthquakes. The most violent earthquakes with magnitude greater than 6 on the Richter scale occurred respectively on October 24, 2002, February 3, 2008 and August 7, 2015.

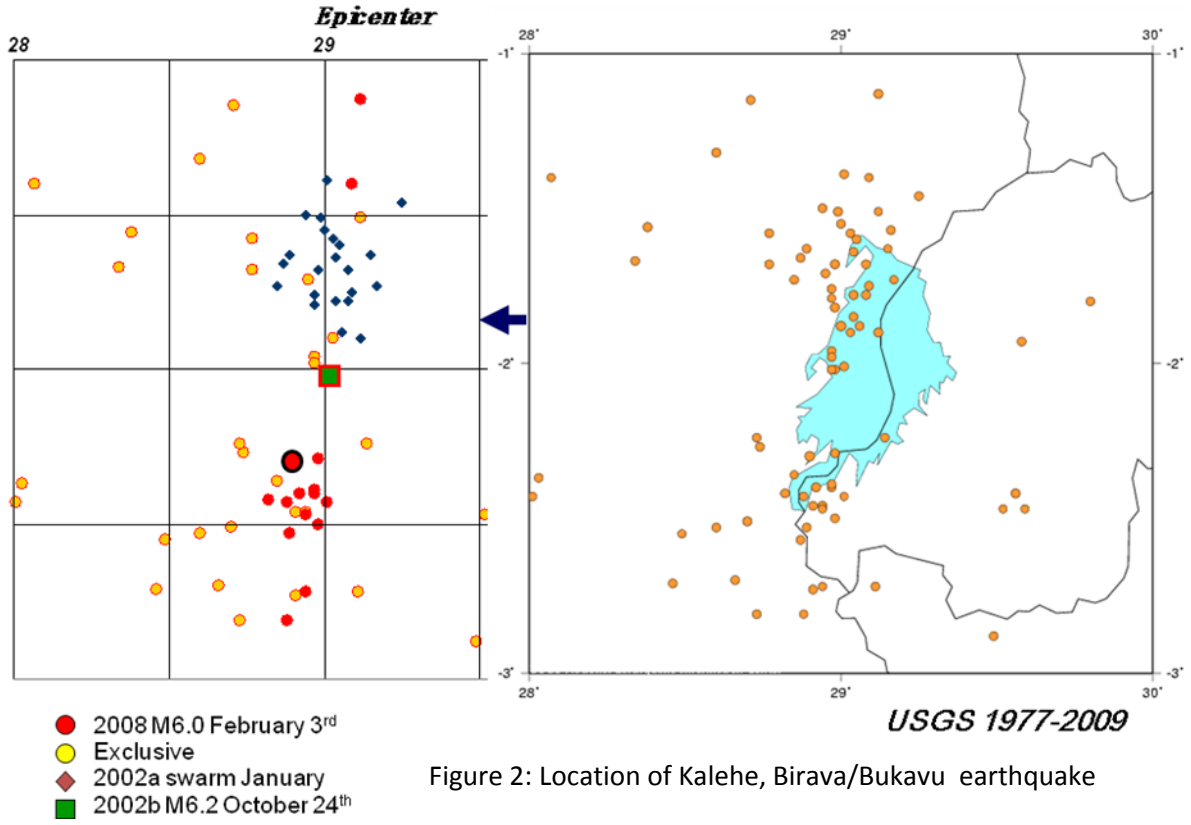

Figure 2: Location of Kalehe, Birava/Bukavu earthquake

Many Human and material damage caused by these events affected some hot springs, rivers have either disappeared or increased volume and collapse land.

From Lake Tanganyika to Mweru, strong earthquakes occurred and massive displacement of the population observed. During the Uvira earthquake on 1960; the great port of Kalundu was destroyed , about 2,000 people dead across Burundi and Congo.
In 1972, the village of Mumosho, south Kivu, slid into Lake Kivu.

Paradoxically, this rift is inhabited by over 107 million people and suffers a flourishing development. However, the need for electric power is necessary because this population primarily uses that wood fuel (wood, charcoal and plant waste, etc). In many places, the population has invested in the use of solar energy that can hardly last for 5-9 hrs per day.

Our communication is more focus on the functioning of the West African rift, Congolese side, our field. In the specific case, our main interest is the monitoring of this rift in order to develop the population who suffer from an energy deficit during the demonstrations of geothermal resources are predictable.

2. HISTORICAL SEISMIC STUDIES

- Seismic hazard in Democratic Republic of Congo and surrounding areas crossed by the Western Rift Valley of Africa has been previously assessed by Midzi et al. (1999), Twesigomwe (1997) and that of Zana et al. (1992).
- Due to large area of approximatively 50° x 25° to be investigated, Midzi et al. (1999) considered only regional structures in their seismic zonation but did not take the local details of observed seismicity and tectonic features in the Western Rift.
- Twesigomwe [1997] study was focused mostly to the assessment of seismic hazard in Uganda

- The estimation of earthquake hazard in Zaire (now DR Congo) by Zana et al. [1992] was based only on the spatial distribution of epicentres, equivalent earthquake magnitude distribution, and trends of a and b in the Gutenberg Richter formula but they did not include the attenuation of ground acceleration into account.
- G. Mavonga Tuluka and R.J. Durrheim (2009) Study was the Seismic hazard assessment in the Democratic Republic of Congo and surrounding areas, Western Rift Valley of Africa,
- Etc.

3. CURRENT OBSERVATIONS AND RESULTS

This paper focuses more on the Lake Kivu basin where a network of seismic observations as well, monitoring of ground deformations and studies of magnetism exists respectively since the years 1953, 2003, 2006.

3.1 From GPS (Hamaguchi, 2003- 2009)

The North-South (NS) and East-West (EW) direction of the Western rift branch change of about 1 cm per year in the lake Kivu basin.

3.2 From the October 2002, February 2008, August 2015 earthquakes

a) The earthquake occurred amid the morning service at a church, where the steeple was collapsed or damaged by shakings.
b) Large buildings such as school, church and hospital were mainly made with bricks and their earthquake-resistances seemed to be very weak.
c) Children taking lake water at the lake shore were attacked by sudden jerk of water disturbance called “Tsunami”
d) Mahyuza hot springs water disappeared for some points and for others the volume of water increased.

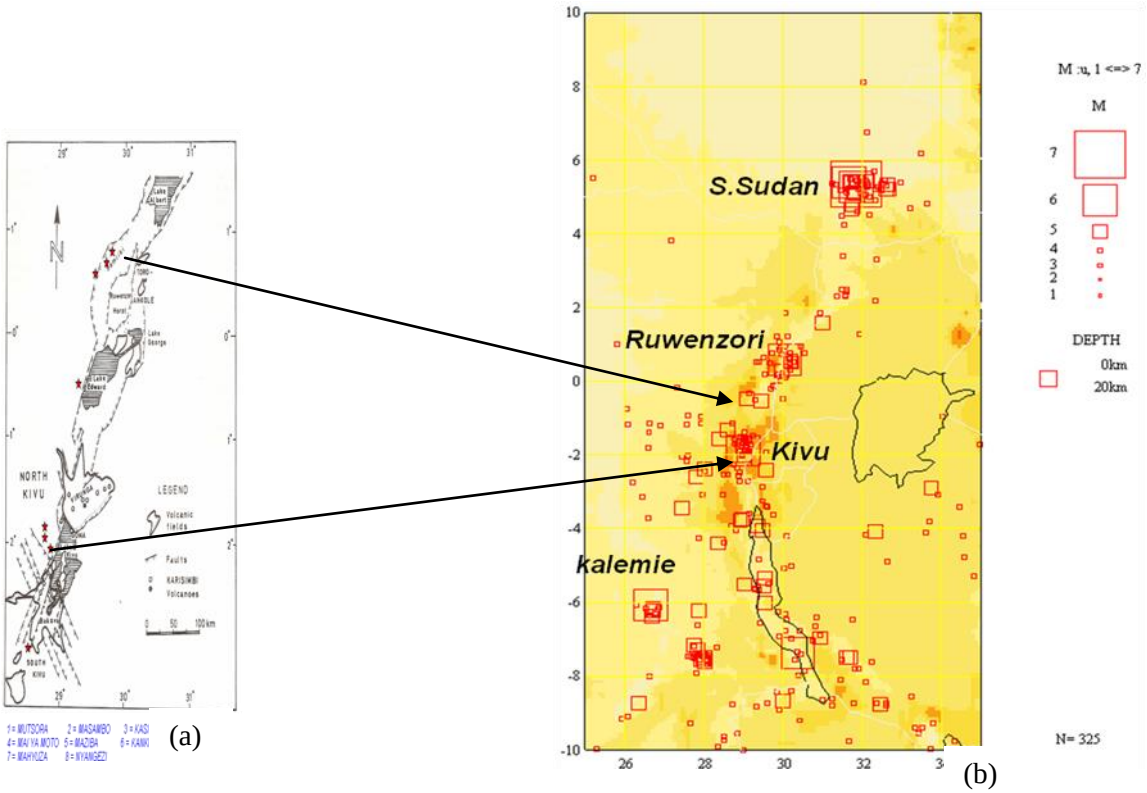

Figure 3: a,b : Rift with hot springs and seismic activities 1973-2009 (Mambo, 2012), (NEIC USGS)

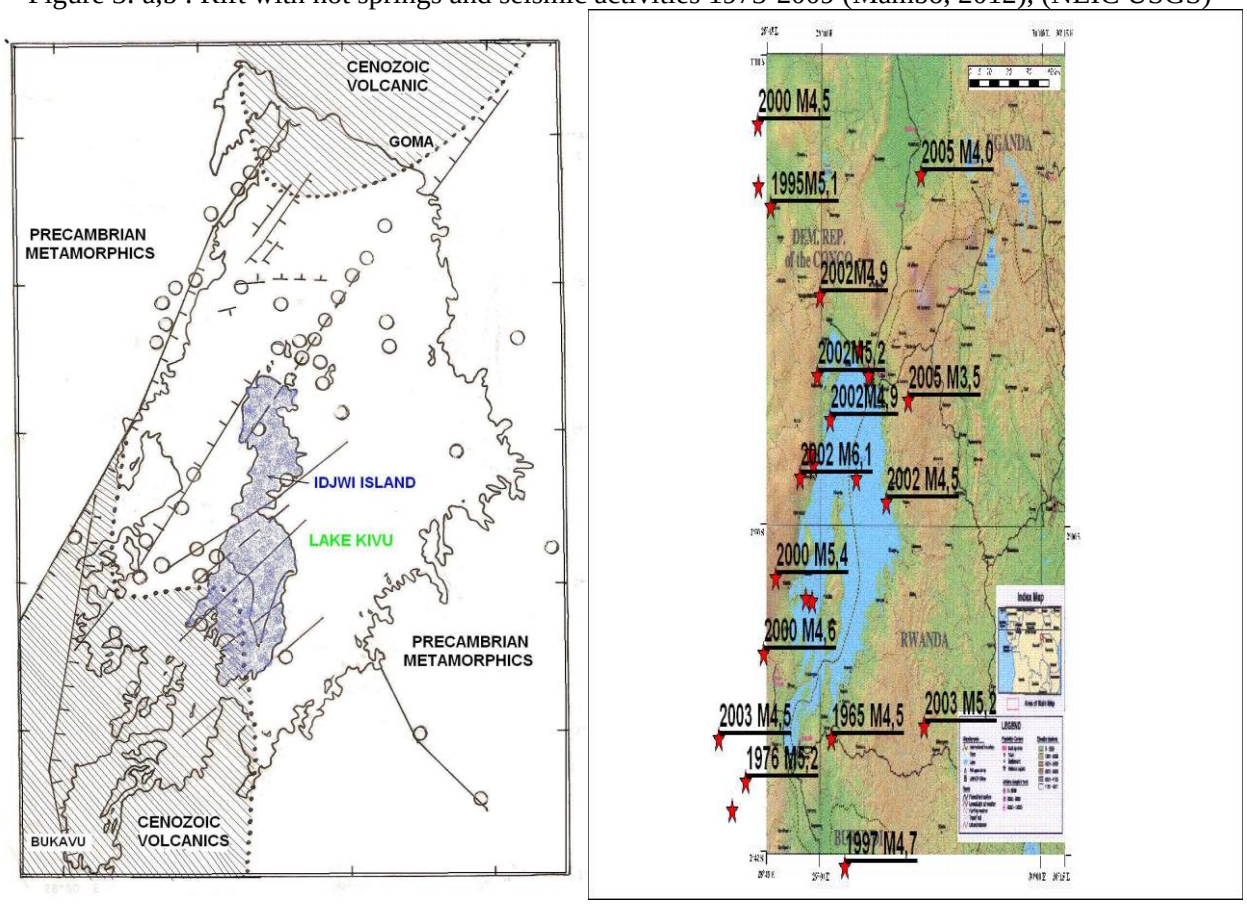

Figure 4: Lake Kivu basin, an active faults zone (Komorowsky, 2003; GVO and Kasahara, 2009)

Hot spring dried after the February 3rd, 2008 earthquake.

Hot spring flow increased after Feb. 3, 2008 earthquake.

Figure 5c,d: Hot springs at Mahyuza, south Kivu, DRC

Figure 6: Subduction zone during the February 3d, 2008 earthquake

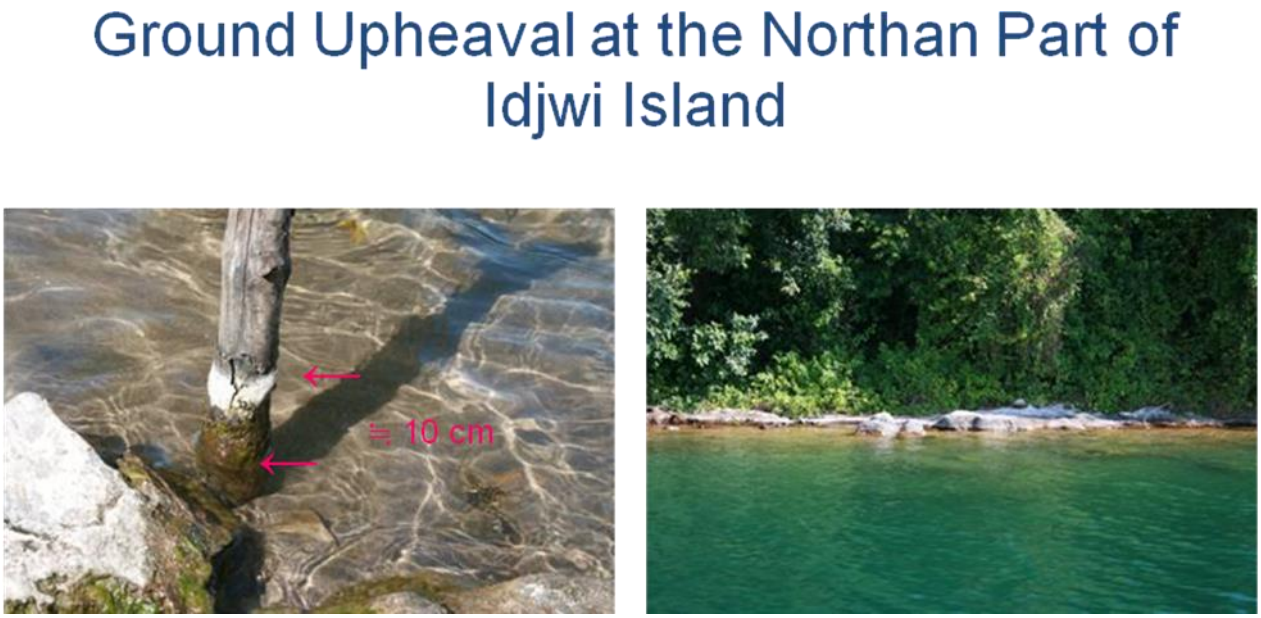

Figure7: About 10 cm ground upheavals were clearly recognized at the northern part of Idjwi

Figure 8e: Church constructed on a soft alluvial soil Figure 8f: Hospital constructed at the edge of small cliff(NE of Cyangugu, Rwanda) In an eroded valley (Ncombo Island Rwanda)

Comparative activities of the 1977 and 2002 eruptions of Nyiragongo Volcanoes

	1977	2002
Duration	1-2 hours	24 hours
VER	2900 m^3/s	290 m^3/s
Volume crater	234 x 10^6 m^3	60 x 10^6 m^3
Lava flow volume	22 (10 %)	25 (40 %)
Magma intruded	211 (90 %)	35 (60 %)
Surface area flows	16 km^2	13 km^2
Number of vents	3	6 + ...
Vent elevation	3050-2260 m	3070-1589 m
Max runout distance	13 km	19 km
Length of fractures	9 km	14 km
Trend of fractures	NW, N, SW, SE	S + (NW)
Cummulative extension	30-35 m	5.6 / 20 /39 m
Date return magma crater	1982 (5 years)	05-03/02 (3-5 months)
Magma flux into crater	high	low

Figure 9: Characteristics of Nyiragongo eruption of 1977 and 2002 (Mahinda, 2016)

3.4 About tectonic movements of Idjwi Island in Lake Kivu as revealed by magnetic anomalies from 1900 to 2010

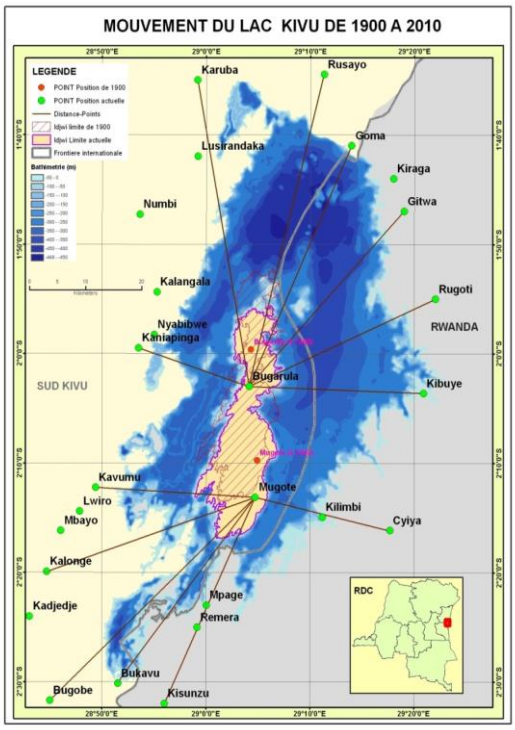

Figure 10: Geomagnetic anomalies due to the dynamics of Idjwi Island (Kavuke, 2012)

The high seismic activity in the Lake Kivu basin has a significant impact on the dynamics of Idjwi Island. Geomagnetic anomalies observed from variations of parameters of the magnetic field over time showed that the Idjwi Island is due to three movements: the N-S displacement, lateral movement E-W and subsidence, The North South movement would be the most dominant compare to the others.

- Need for implementation of GPS stations and tide gauges in Goma, Kibuye, Rusizi / Cyagungu Kalehe and around the lake to follow the movement and the lake level

Calculate and estimate the correlation coefficient between distance and change in Lake level that could allow the proposal of a model

4. **CONCLUSIONS**

The temporal and spatial distribution of the aftershock sequences of the Ruwenzori (February 5th, 1994, Mb (5.8)), Masisi (April 29th , 1995, Mb (5.1)), Kalehe (October 24th , 2002, Mb (5.9)) and Bukavu (February 3rd, 2008, Mb (6.0)) earthquakes have been studied. Some of these earthquakes that occurred in the Lake Kivu basin had an impact on the hot springs in the region.

The rate of decrease in aftershock activity with the time (N=kt**(-p)) has shown that the p-value for Ruwenzori and Masisi earthquake equals 0.6, somehow smaller than that found in other geotectonic zones where p is close to 1. The p-value of the Kalehe earthquake is a normal value equal to 1.

The spatial distribution of aftershocks may be used to estimate the linear dimensions of the fault-rupture. From an area delimited by spatial distribution of aftershocks, the linear dimension of the fault was estimated. Using previous studies which occurred in the Western Rift Valley of Africa including the Tanganyika and Upemba Rift, a statistical relationship between fault area and moment magnitude was established as : log S = 3.221Mw + 6.058 where S is the fault area (km 2) and M w is the moment magnitude.

5. PROJECT/FUTURE

-Imaging the details of the crustal and the upper mantle structure along the Kivu Rift zone located in the Western branch of the East African Rift System using P-wave receiver function method beneath many

seismic stations around Lake Kivu. From converted phases, receiver functions will be applied to estimate the crustal thickness, Poisson's ratio and local velocity structure using teleseismic data.

-The integration of this method will provide the best constraint in the crustal and the upper mantle structure beneath the Kivu Rift zone in order to improve the localization of earthquakes and building realistic catalogue of seismic events to be shared with other partners.

-Understanding the relationship between the active volcanoes with the movement of the rift system

-Focal mechanism solutions of earthquakes in the region using local, regional and teleseismic events will be determined in order to highlight the characteristics of the source faults and produce an improved probabilistic seismic hazard map for the lake Kivu basin using local geology and tectonic.

- Need for implementation of GPS stations along the western African Rift Branch System particularly in Lakes Kivu, Tanganyika basins and Ruwenzori region to follow the ground deformations.

- Identify, proceed to the geodynamics studies areas of geothermal resources then we can develop a realistic mapping of the geothermal potential in the Western Branch of the African Rift System.

REFERENCES

Mavonga T. and Durrheim R.J., Seismic hazard assessment in the Democratic Republic of Congo and Western Rift Valley of Africa, 11th SAGA Biennial, Technical Meeting and Exhibition, Swaziland, 16-18 September 2009, pages 64-68

Hamaguchi H., comments on GPS data in 2002-2009, Sendai, Japan, April 2009

Kasahara et al, Earthquake of February 3, 2008 and its Disaster, Bukavu, DRC, November 2009

Komorowski et al, The January 2002 Eruption of Nyiragongo Volcano (Democratic Republic of Congo): Chronology, evidence for a tectonic rift trigger and impact of lava flows on the city of Goma, Acta Vulcanologia, 2003, pages 27-62.

Mahinda C. et al, Comparative study between the current activity of Nyamulagira volcano and its activity before the 1938 eruption, Gisenyi, Rwanda, May 2016.

Kavuke K, Mahinda K, Musumba T, Mukambilwa K et Ciraba M, A propos des Mouvements Tectoniques de l'Ile d'Idjwi dans le Lac Kivu tel que les Anomalies Magnétiques de 1900 à 2010, cahiers du CERUKI, Nouvelle Série 42, 2012, pages 137-153

Mambo V, Mahinda K, Yalire M, Nsabimana R, Luse B, Mumbere K., Status of Geothermal Development in D.R.Congo: a country updateARGeo_C4, 2012

Zana N et al, 1992, Estimate of Earthquake risk in Zaire, Tectonophysics, 209, 321-323

Midzi V et al, 1999, Seismic hazard assessment in Eastern and Sothern Africa, ann. di Geofisica 42, 1067-1083

Twesigomwe E, 1997, Probabilistic Seismic hazard assessment of Uganda, PhD. Thesis, Dept of Physics, Makerere University, Uganda