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Tectonophysic Approach of the Masambo Thermal Spring in the Ruwenzori Sector/ D.R.Congo

Mukandala Syakengwa P., Kambale Maliva T and Sekeravithi Kivava A.

P.O. Box 560 Butembo

amipacmknl@gmail.com , thmaliva@gmail.com and alainsekeraviti@gmail.com

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ABSTRACT

The Masambo geothermal site is located in Masambo. The water flows through quartzite formations at various locations on the mountain. Tectonics have acted strongly on the sector to extent that quartzites fractured during the Tertiary on Kibalian formations. Realization of a structural map of the site's environments will guide and develop geothermal resources at the Masambo site. This structural study made on quartzites must also go through geochemistry. The interest to increase the structural independently on the Masambo thermal site is that this site takes some development works which are in growth.

1. INTRODUCTION

We study the structural geothermal field of the Masambo hot spring. The Masambo hot spring is one of hot springs in the Ruwenzori area of the Democratic Republic of the Congo: Kikura, Mutsora, Masambo, Kambo, etc. The tectonics mastery in the Masambo geothermal field is of great importance in the development of geothermal resources. In the Masambo thermal spring water flows through several open bills within the quartzites. The region contains several other types of fractures and rocks. It comes out at several sites on the same mountain from quartzites. The thermal water of Masambo has a surface temperature of 52°C (Mukandala et al., 2018).

The present research aims to control the tectonics of the Masambo geothermal field. One aspect will be reserved for the petrography of the site. Structural research on the Masambo restricted site is not yet completed. They are still general throughout the sector. The research site is Ruwenzori sector in Beni territory, North Kivu Province, Democratic Republic of the Congo. It is in the context of the western branch of the East African rift system. The study area in Masambo is located on the 4th national road on the Beni-Kasindi axis with Northing, Easting and Elevation coordinates. Its hydrography is dominated by the Semuliki flow.

2. LITERATURE REVIEW

There are several structural research projects in and around the Ruwenzori area (Debelmas, 2008;Lavreau and Ledent, 1975; Noel, 1981; Michot, 1937, 1938; Tanner, 1970, 1973 cited by Mukandala et al., 2018). Most explorations were in the colonial setting in the mining objective. Recent updates are even less important. The region is located in the context of rifting formed rifts, active rifts and rifts, which are still active (Paul, 2009). They proved the intense tectonic activity characterized by a system of several bills. The formations are also diverse in the rift. Thus, it is formed of several aborted rifts. The major constraints are thus variously oriented on the field of study.

The area of Ruwenzori would be marked by a dormant volcanism. Michot (1937) characterized the petrography and geology of the Ruwenzori sector. At the beginning of the century, Alfred Wegener was the first one to observe in detail that the Atlantic coast of Africa and that of South America have complementary traces (Davies, 2009). Since the time, the earth's crust has undergone several major phases of tectonics. This led to the formation of spectacular structures such as formation of mountain ranges, continental collision, rifting like the East African Rift, etc. (Debelmas et al., 2008) Our study sector is found in the western branch. The Rift region is still characterized by seismic phenomena and tectonic structures of any form. The East African Rift undergoes various extension stress directions in some places. Some works by Delvaux have evaluated them (Delvaux. and Barth, 2009, Delvaux et al., 2012). According to Noel (1981), the ante-Kibarian series that give the West the ortho-gneissic complex supporting its metamorphic series of cover disappears to the East. The arrangement of these ante-Kibarian series gives the general structure of the Kibalian formations. From west to east, we pass successively from an anticlinorium to a synclinal structure and then to an anticlinal bulge. The East African Rift has several orientations of extensive movements in places. In the Albertine rift, they are generally oriented NW-SE. It is the same in Kivu. In North Tanganyika, they are oriented ENE-WSW. South of Tanganyika, they are generally NE-SW (Delvaux and Barth, 2009). Ilunga (1991) characterized the fault system in the South Kivu Rift. The western branch of the East African Rift or Albertine rift is characterized by intense tectonic activity as well as significant geothermal potential (Hardason, 2017). The valorization of geothermal resources goes through several approaches including tectonics.

Geologically, it includes formations of several ages: the Burundian or Karagwe-Ankole, the Kibalian or Buganda-Toro system (Uganda) and the Crystallophyllian complex or West-Nile complex or Basement complex. The Kibalianfacies are hard to differentiate. As a result, the following connections are important in the Ruwenzori sector: Stanley volcanic formations or Luhule Mobisio Basic Complex: lower to middle Burundian; high peaks schist group: upper Kibalian and, probably, the sedimentary base of Luhule-Mobisio (Lower Burundian); Kilembe schist group: Lower Kibalian (Noel, 1981).

3. METHODOLOGY

3.1. Field works

The results presented in this research work came from field observations, bibliographic synthesis based on available data, and data processing and interpretation.

Geology is a field science. It proceeds by observations, sampling, and interpretations. The surface geological survey was of paramount importance. During the field works, it was discussed to get to know different outcrops in order to proceed to their petrographic and structural interpretation. In front of the outcrop, the geographic coordinates must be taken in the Universe Transverse Mercator units form using a Global Positioning System, Etrex Garmin brand and precision 3m. Some benchmarks also marked our attention. Petrographically, outcrops must be macroscopically described with respect to color, structure, grain size, etc. The magnetic pen made it possible to test and detect the presence of ferromagnetic formations. Then, were samples taken by site by using the hammer. These samples were brought to the camp and then described before proceeding with the nomenclature of the rock. In the case where the outcrop has cracks or fractures, the latter have also been studied. Structural measurements were taken using a Sylva geologist compass using the right-hand method. The direction of the streams was also taken using the same compass. At the end of the outcrop work, photographs were made using a digital camera. The depth investigations, drilling and soundings may be considered later.

3.2 Analytical work, processing and data interpretation

To find the various orientations of the study area, the structural data were processed using the Dips software. The nature and direction of the major stresses acting on the field of study were found using Win tensor software. The data was processed and interpreted using Win tensor software according to the model of Delvaux and Sperner (2003). Prior to any processing, the azimuth was found from the value of the direction. At the end of the treatments, the structural data were interpreted, and structural conclusions were found.

Some representative rock samples were taken from the field for a lithological and geochemical approach to the study area.

3.3 Bibliographic synthesis

The study area is the East African rift system. It is part of the vast geothermal field of Ruwenzori in which several thermal springs remain to be discovered because the region has not known enough for geothermal or geological exploration. The Ruwenzori sector is located in the western branch of the East African rift system. Understanding of Masambo's structures is equivalent to understanding of the structural rift.

4. RESULTS

4.1. Understanding the rift structure

The East African Rift system is a system structurally subdivided into two branches: the western branch and the eastern branch (BJÖRN S, 2017). Figure 1 shows some rifts of the western branch of the East African Rift.

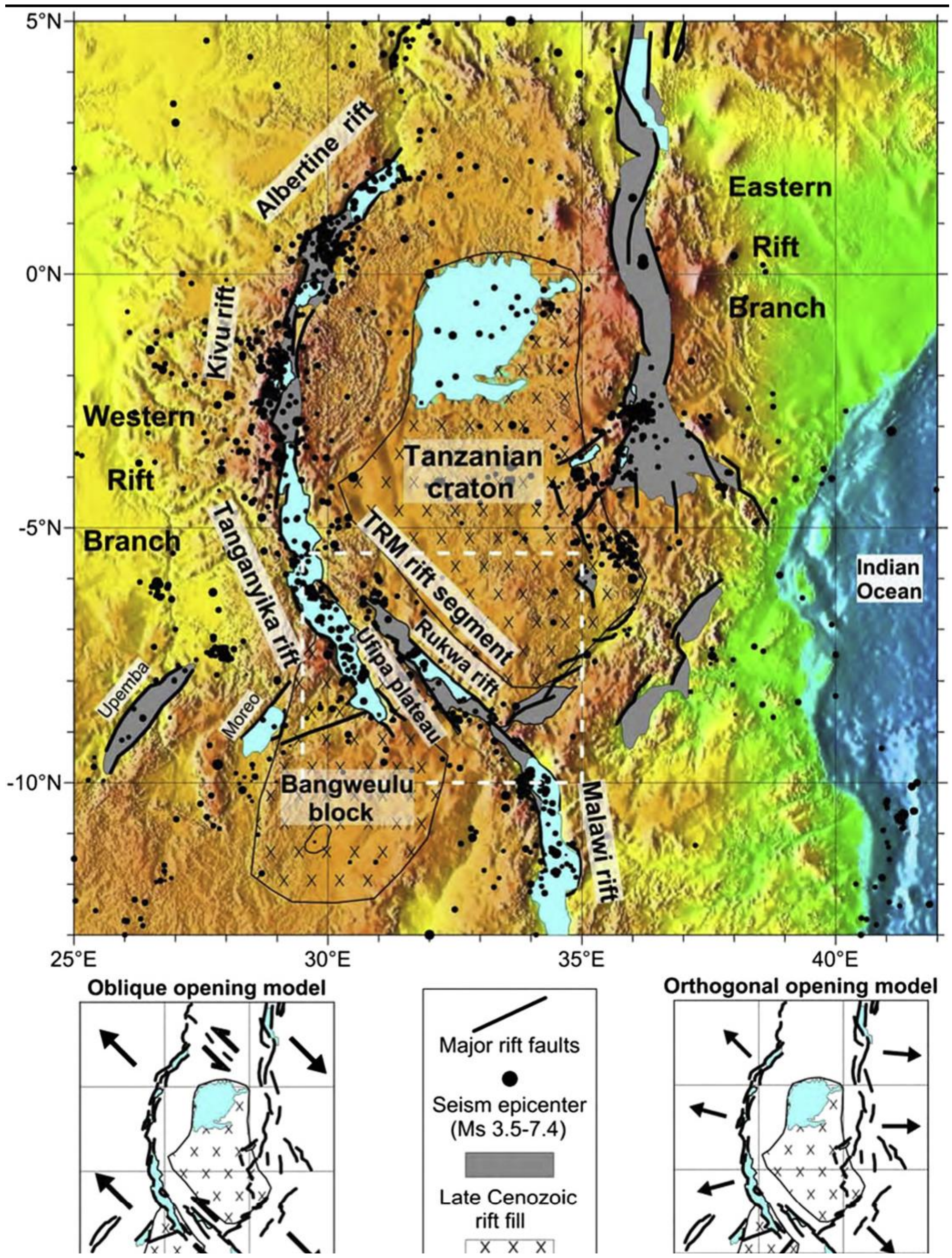


Figure 1: General setting of the East African Rift System (EARS) with sketch of the opening models (Delvaux al., 2012).

The East Africa is structurally a system of faults and fractures, which are still active. The rifting is also characterized by a volcanism with intense seismicity. It is considered the biggest tear in East Africa. To this system of tears and volcanism is associated geothermalism. Delvaux and Barth (2009) characterized the structural evolution of East Africa according to tectonic stress (Figures 2 and 3). It's a real structural laboratory.

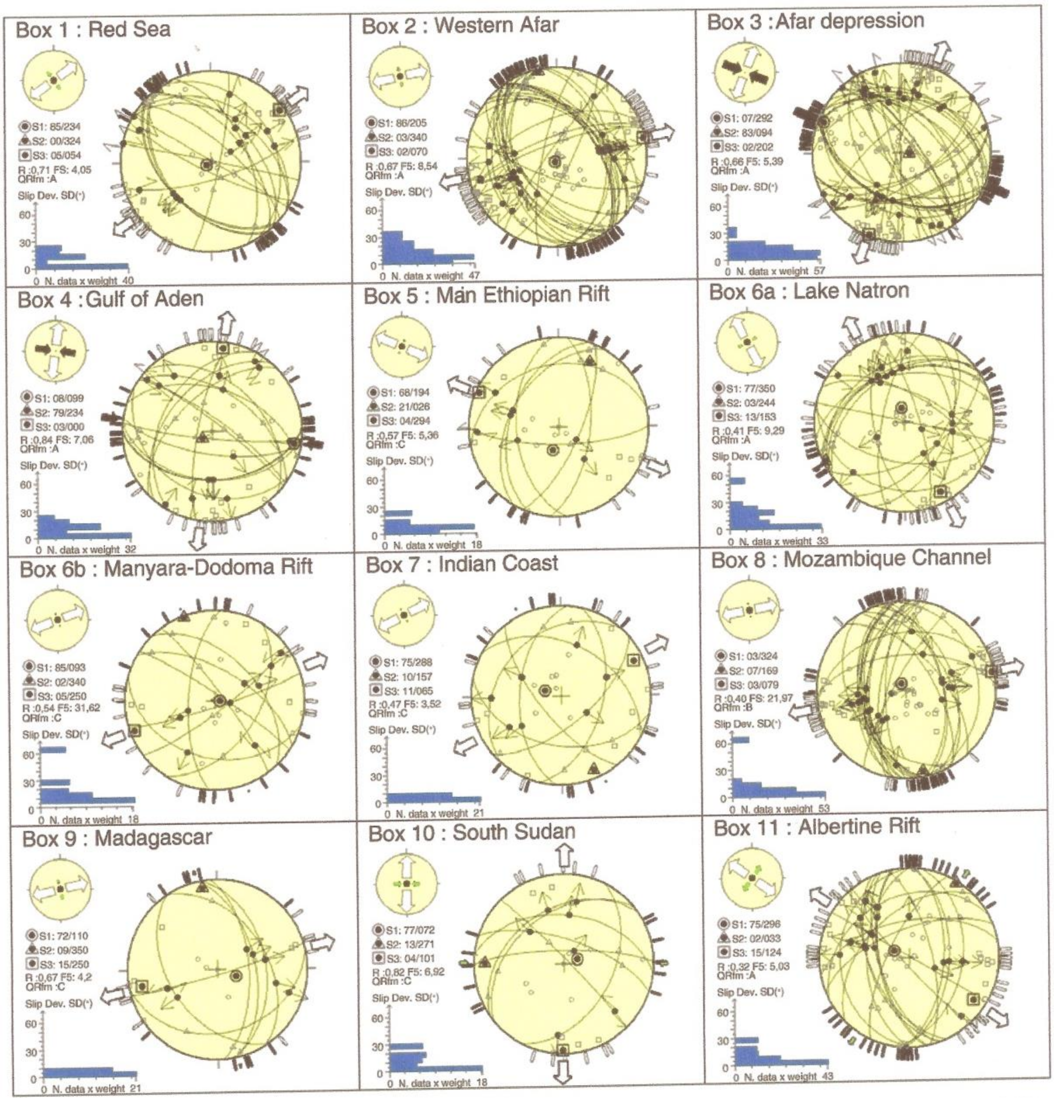


Figure 2: Lower-hemisphere equal-area stereoplots of the selected focal planes (shown as cyclographic trace) and associated slip lines (black dot with outward arrow for normal faulting, inward arrow for reverse faulting and double semi-arrows for strike-slip faulting). Stress inversion results are represented by the orientation of the 3 principal stress axes (a black dot surrounded by a circle for σ_1, a triangle for σ_2 and a square for σ_3). The related SHmax and Shmin orientations are represented by large arrows outside the stereogram. Their type, length and colour symbolise the horizontal deviatoric stressmagnitude relative to the isotropic stress (σi) and are in function of the stress regime and the stress ratio$R=\sigma_2-\sigma_3/\sigma_1-\sigma_3$.White arrows when σ_3 is subhorizontal (always Shmin), green arrows when σ_2 is subhorizontal (either Shmin or SHmax), black arrows when σ_1 is subhorizontal (always SHmax). Outward arrow indicates extensional deviatoric stress ($b\sigma i$) and inwards arrows, compressional deviatoric stress ($N\sigma i$). The vertical stress (σv) is symbolised in the small circlewith stress arrows on the upper left corner of the figures by a solid circle for extensional regimes ($\sigma_1 \approx \sigma v$), a dot for strike-slip regimes ($\sigma_2 \approx \sigma v$) or an open circle for compressional regimes ($\sigma_3 \approx \sigma v$). The histogram on the lower left corner of the figures represents the distribution of the misfit angle α (Slip.Dev. SD), weighted arithmetically according to the magnitude. The contribution of data with misfit angles N65° are all summed up and represented together along the vertical axis betweenα at the 60–65° interval (sites 6b, 8, 16, 17, 23). The bars outside the stereogramrepresent the SHmax (black) and Shmin (white) directions for individual focalmechanisms and the small grey symbols inside, the orientations of the related kinematic axes (circle: p axis, triangle: b axis, square: t axis).

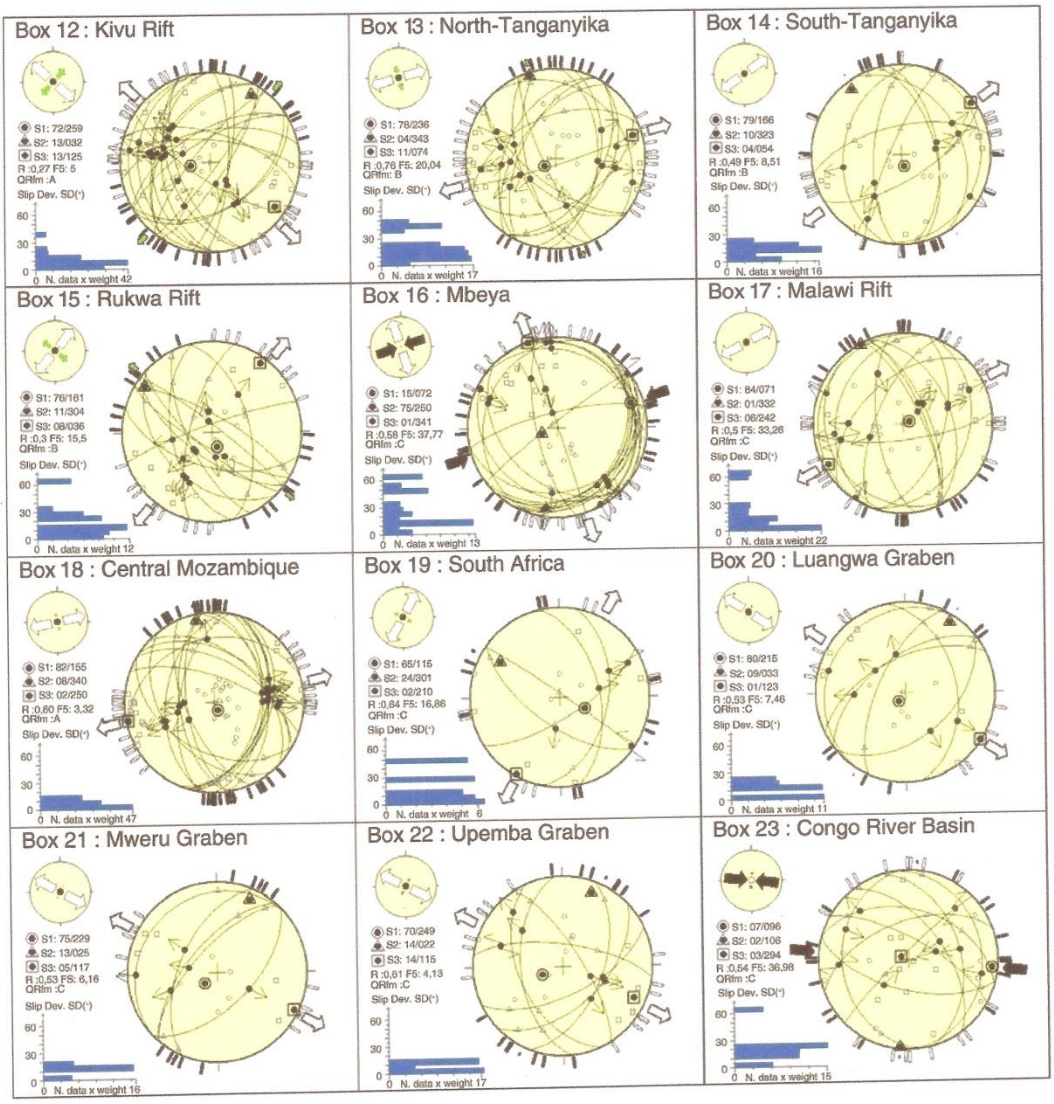


Figure 3: Lower-hemisphere equal-area stereoplots of the selected focal planes (shown as cyclographic trace) and associated slip lines (black dot with outward arrow for normal faulting, inward arrow for reverse faulting and double semi-arrows for strike-slip faulting). Stress inversion results are represented by the orientation of the 3 principal stress axes (a black dot surrounded by a circle for σ1, a triangle for σ2 and a square for σ3). The related SHmax and Shmin orientations are represented by large arrows outside the stereogram. Their type, length and colour symbolise the horizontal deviatoric stressmagnitude relative to the isotropic stress (σi) and are in function of the stress regime and the stress ratioR=σ2−σ3/σ1−σ3.White arrows when σ3 is subhorizontal (always Shmin), green arrows when σ2 is subhorizontal (either Shmin or SHmax), black arrows when σ1 is subhorizontal (always SHmax). Outward arrow indicates extensional deviatoric stress (bσi) and inwards arrows, compressional deviatoric stress (Nσi). The vertical stress (σv) is symbolised in the small circlewith stress arrows on the upper left corner of the figures by a solid circle for extensional regimes (σ1≈σv), a dot for strike-slip regimes (σ2≈σv) or an open circle for compressional regimes (σ3≈σv). The histogram on the lower left corner of the figures represents the distribution of the misfit angle α (Slip.Dev. SD), weighted arithmetically according to the magnitude. The contribution of data with misfit angles N65° are all summed up and represented together along the vertical axis betweenα at the 60–65° interval (sites 6b, 8, 16, 17, 23). The bars outside the stereogramrepresent the SHmax (black) and Shmin (white) directions for individual focalmechanisms and the small grey symbols inside, the orientations of the related kinematic axes (circle: p axis, triangle: b axis, square: t axis) (Delvaux and Barth, 2009).

4.2. Understanding the structural of the Ruwenzori sector and the locality of Masambo

The Ruwenzori lands date from the Archean to the Middle Proterozoic. The tertiary sector was structurally marked by East African system rift tectonics. These lands include fluvio-lacustrine and continental series. The formations are more or less metamorphic to epizonal to mesozonal deep facies of sedimentary or volcano-sedimentary origin, having undergone one or more more or less intense plating tectonics: it is the Kibalian of Ruwenzori sector. They are based on granitic and gneissic crystalline substratum with metaquartzites, mica schists, amphibolites, sandstones, etc.

- The Orthogneissic Complex and its Kibalian coverage

In general, the arrangement of the ante-Kibarian (Ante-Burundian) series defined previously, with in the West the orthogneissic complex supporting its metamorphic series of cover which disappear to the east under a thick schisto-gréseuse series of the upper Kibalien, for reappearing in the extreme East, gives the general structure of Kibalian formations; from west to east, we pass successively from an anticlinorium to a synclinal structure and then to an anticlinal bulge. The game of brittle tectonics, with principal north-south faults, which can be unhooked by East-West or NNE-WSW faults, affects all of these formations and can complicate the normal arrangement of the different terms of the Kibalian series. These structural units have a regional NW-SE to N-S orientation; stratification directions, when observable, range from N-S to NNW-SSE. They correspond on the one hand to the direction of foliation of the base and, on the other hand, to one of the two directions of foliation of the metamorphic cover. Which leads to saying that the North-South and NNW-SSE directions represent, it seems here, the main direction of the Kibalian orogeny.

- Relationships between the Upper Kibalian and the Lower Kibalian

These relationships remain poorly known despite the reconnaissance work carried out in 1973. The difference in structural style between the two sets and the complementarity of their degree of metamorphism. In fact, the lower Kibalian generally shows a rather ample flexible tectonics, and a mesozonal metamorphism, while the Upper Kibalian shows an intense plicative tectonics and an essentially epizonal metamorphism. However, their structural directions are often comparable but both formations show unequivocal cartographic discordance. J P Mroz (1974), quoted by Geological map of recognition to 1/200000 of the territory of Beni N0 / 29, proposes the hypothesis of a detachment of the upper Kibalian at the level of micaschists with a relative thrusting. The possibility of such displacements had been evoked, while conferring on him a greater, by P. Michot (1933), cited by Geological map of recognition to 1/200000 of the territory of Beni N0 / 29, by referring only to the Structural look of the Upper Kibalian.

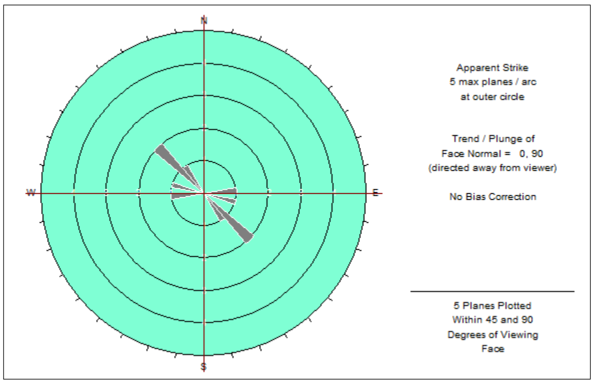
- Structural data of Masambo hot spring

The structural measurements are presented in the appendices in Table 1.

Table 1:Structural measurements of open fractures

SOURCE	NORTHING (UTM)	EASTING (UTM)	ELEVATION (UTM)	Direction	Dip	Dip Direction
Masambo	800140	20017	1069	144°	60°	234°
				130°	48°	220°
				134°	60°	224°
				84°	60°	174°
				108°	72°	198°

By simulating these breakout plans with the Dips software, we obtained the preferential direction of these open breaks varying between N130 ° and N140 ° and have almost all their dips in the third frame referring to the "Rose of the Winds" (Figure 4).



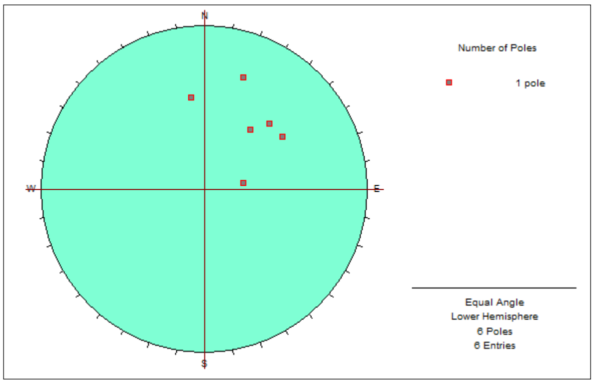


Figure 4: Preferred Direction Stereograms

We also studied the constraints (Figure 5) responsible for these cleavages in the Ruwenzori sector, by doing the simulation with the Win-tensor software (stress tensor), we found that the principal stress ($\sigma 1$) would have acted by compression and following a direction N134/19 almost parallel to that of breakage and the minimum stress ($\sigma 3$) would be oriented perpendicular to $\sigma 1$ where its modulus is N35/25 and the tangential stress ($\sigma 3$) which is the resultant of these first two was oriented N257/58.

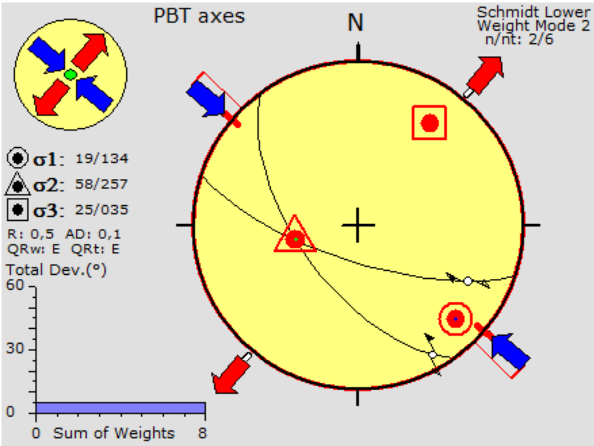


Figure 5: Stress tensor of open fractures

5. DISCUSSION AND CONCLUSION: STRUCTURAL

The rift formations, and even more so of the East African Rift, remain a favorable ground for the various major lithospheric movements and events of the Earth's crust. They can be permanent seismicity, volcanism, oceanization, etc. This situation has been studied with force-details by several researchers including Debelmas et al., 2008; Davies, 2009; Delvaux and Barth, 2009; Delvaux et al (2012); Geoffrey (2009); Hardason (2017), Ilunga (1991). Moreover, in terms of chronology, Noel (1981) characterized the Kibalian structure which results from the disposition of the ante-Kibarian series.

5.1. Orientation of geological formations

The results obtained after treatment of the structural data made possible to draw the conclusion that the fractures affecting the formations of the study area present several directions as shown in Figure 1. These various directions testify to the presence of the conjugated breaks in the medium of study. Nevertheless, the statistical distribution of the poles of the planes for which the measurements of directions and dips were taken on the outcrops proves that the poles are distributed in all the quadrants. The open breaks are predominantly oriented NW-SE.

5.2. Nature of stress generating open breaks and filled breaks (Veins)

The research results proved the following:

The stresses are variously oriented in the Rift. In its western branch, they preferentially orient NW-SE. Nevertheless, this orientation varies by location. This is the case in Kivu. An ENE-WSW orientation is observed north of Lake Tanganyika when in the South; there is a NE-SW orientation. These are the fruits of the research work of researchers Delvaux and Barth (2009).

The researcher Ilunga (1991) characterized a fault system in the rift of South Kivu. In view of all the circles of Morh made in this work, the same situation can apply to our study area which presents formations all of a brittle nature. This character is likely to cause faults and movements called earthquakes. This was characterized in 2012 by Hardason, B.S., by Delvaux D., et al., 2012, by Davies, et al. (2009), Geoffrey (2009), and Castaing et al., (1984).

The interpretation of open fracture measurements shows a compressive domain, which suggests that their emplacement took place during the Kibarian orogeny. Nevertheless, the filling of these closed breaks (veins) would have occurred during the tectonics that gave rise to the East African Rift. The evidence is that the veins and tectonics that gave rise to the Rift both resulted from an extensive domain.

This research shows how much of our study area belongs to the unstable tectonic domain. We took place on a smaller and smaller space considering the previous works of other researchers. The results mainly focused on tectonics aspects. They consisted of several phases of observations, treatments and interpretations of the data. On the structural level, the ground undergoes tectonic forces due to the forces of natural tectonic stresses.

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