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Tectonic-volcanic study of the southern flank of Nyiragongo volcano between 2004 and 2008

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Abstract
The Democratic Republic of Congo in its eastern part, particularly in the Virunga region, is threatened by two active volcanoes, namely Nyiragongo and Nyamulagira. The Nyiragongo volcano presents the greatest threat to the city of Goma, and is characterized by a permanent lava lake and fractures crossing the city into Lake Kivu. The monitoring of this volcano requires a regular follow-up of these fractures, which are weak zones where lava can easily come out. It is in this perspective that we studied the influence of tectonic activity on the active bills on the southern flank of this volcano. This study has allowed us to see, after analysis of the measurements made by the extensometer, how tectonics and magmatic intrusions play on the spreading of the southern fractures of the Nyiragongo volcano. We understand that the tectonism of this area causes movements of the earth's crust which in turn generate earthquakes in the area and are responsible for elastic deformations; the latter can also motivate the magmatic intrusions allowing the dilation of fractures and the opening of faults (plastic deformations). Based on the results of extensometric measurements carried out between 2004 and 2008 in the Summit, Bitunguru, Cabane and Munigi fractures, we have noticed that the latter have experienced elastic deformations during possible earthquakes that occurred in the Lake Kivu basin and plastic deformations due to magmatic intrusions especially in 2006 and 2007.

Keywords: Volcanic, southern, Nyiragongo volcano

1. Introduction

The Virunga region, located in the western branch of the East African Rift over geological time, has been the scene of geological phenomena that have created mineralization on the one hand, and geological hazards on the other. These geological risks strongly affect this region and are pronounced by volcanic eruptions, tectonism, repetitive earthquakes, landslides, not to mention the potential threat posed by the presence of gases in Lake Kivu, To these are added other risks or natural hazards whose magnitude and or high frequency, currently constitutes a community concern. This continental rift highlights the geodynamics of a basin in extension, continues over a distance totaling more than 300 km for an average width of 40 to 80 km and a variable depth distensive regime that has allowed the collapse of a narrow zone separating the continent along pre-existing weaknesses, the major structures coinciding spatially with the ancient belts of deformation (Stoffers, P. &Hecky, R.E. (1978) [7, 8]. It is separated from the Subscribe to DeepL Pro to edit this document. Visit www.DeepL.com/profor more information.

Lake Tanganyika Basin by the Nyangezi-Kamanyola sill to the south and the Lake Edward Basin to the north (J. Chorowicz & et al. (1979) [2]. Seismic and volcanic activity in this basin is always accompanied by surface deformation and changes in stress or physical, chemical or physicochemical changes in the environment.

This occurs in response to slow, transient or instantaneous motions occurring in the upper part of the lithosphere (especially motions along active faults) because the major tectonic and seismic activity is confined to the granitic layer between 0 and 20 km depth (Mishio Ishimoto, 1933, Danville, J.C. (1992) [3]. The Lake Kivu basin is currently one of the most active rift regions. Since 1997, an intense seismic activity has been observed there, whereas in the past there was a moderate seismicity. It is worth noting that two major earthquakes of magnitude equal to or greater than 6 occurred there from 2002 to 2008. Their occurrence had as consequences; the important deformations of surface caused by landslides and collapses, inflations before and deflations after the eruptions of the active volcanoes of Virunga namely Nyiragongo and Nyamulagira (Wafula, §all., 2008) [8]. The eruption of January 17, 2002 and the seismicity that accompanied it caused a reactivation of pre-existing fractures and created new ones, and caused a subsidence of the shoreline in the northern part of Lake Kivu. Like other lakes in the East African collapse trough, Lake Kivu is expanding at an estimated rate of 1cm per year (H., Hamaguchi, 2009) [6].

This region is threatened by two active volcanoes, Nyiragongo and Nyamulagira. The Nyiragongo volcano, which poses the greatest threat to the city of Goma, is characterized by a permanent lake of lava and fractures that run through the city into Lake Kivu. The monitoring of this volcano requires a regular follow-up of these fractures, which are zones of weakness where lava can easily come out. It is in this perspective that we want to study the influence of tectonic activity on the active bills on the southern flank of this volcano.

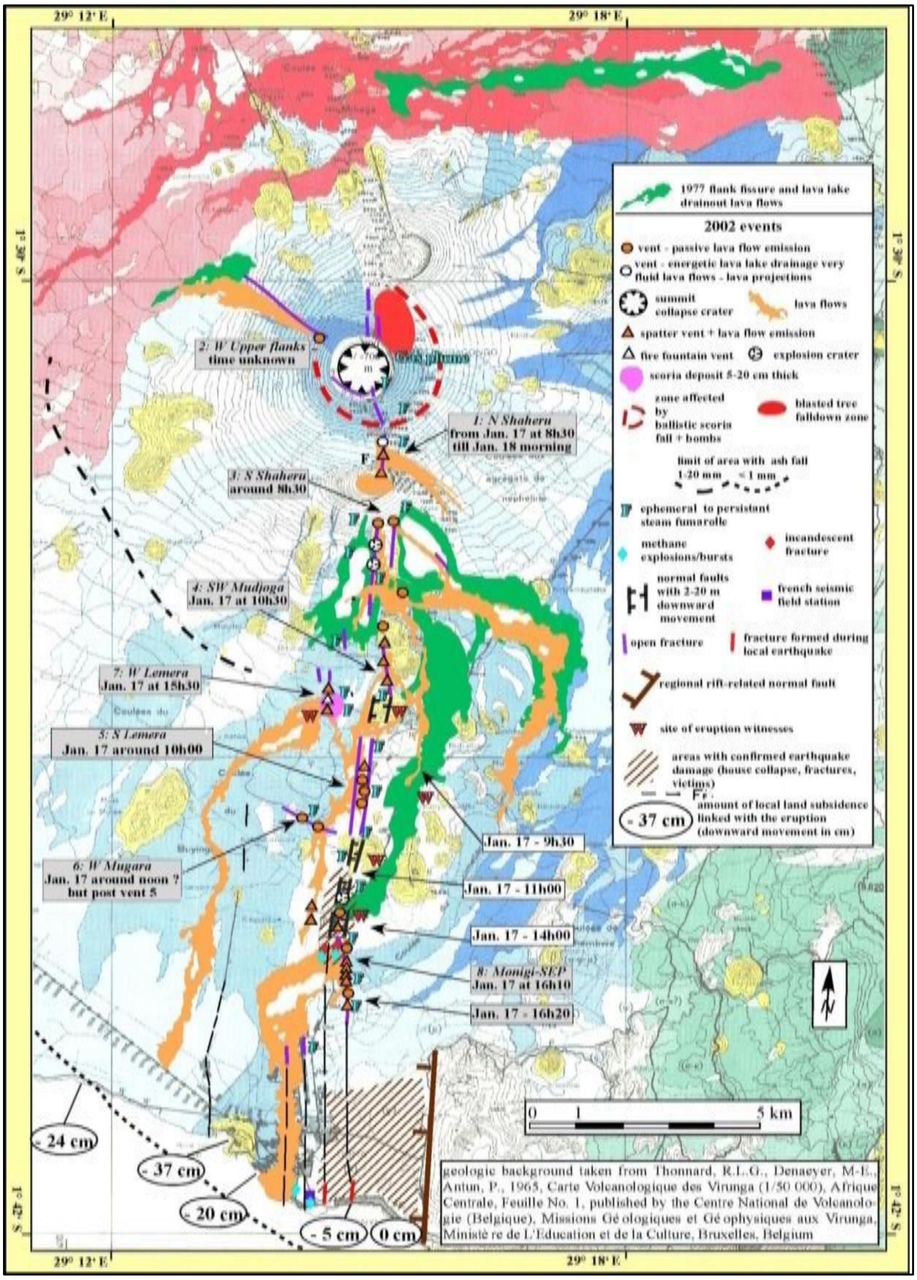


Fig 1: Map of the fractures of Nyiragongo volcano (OVG)

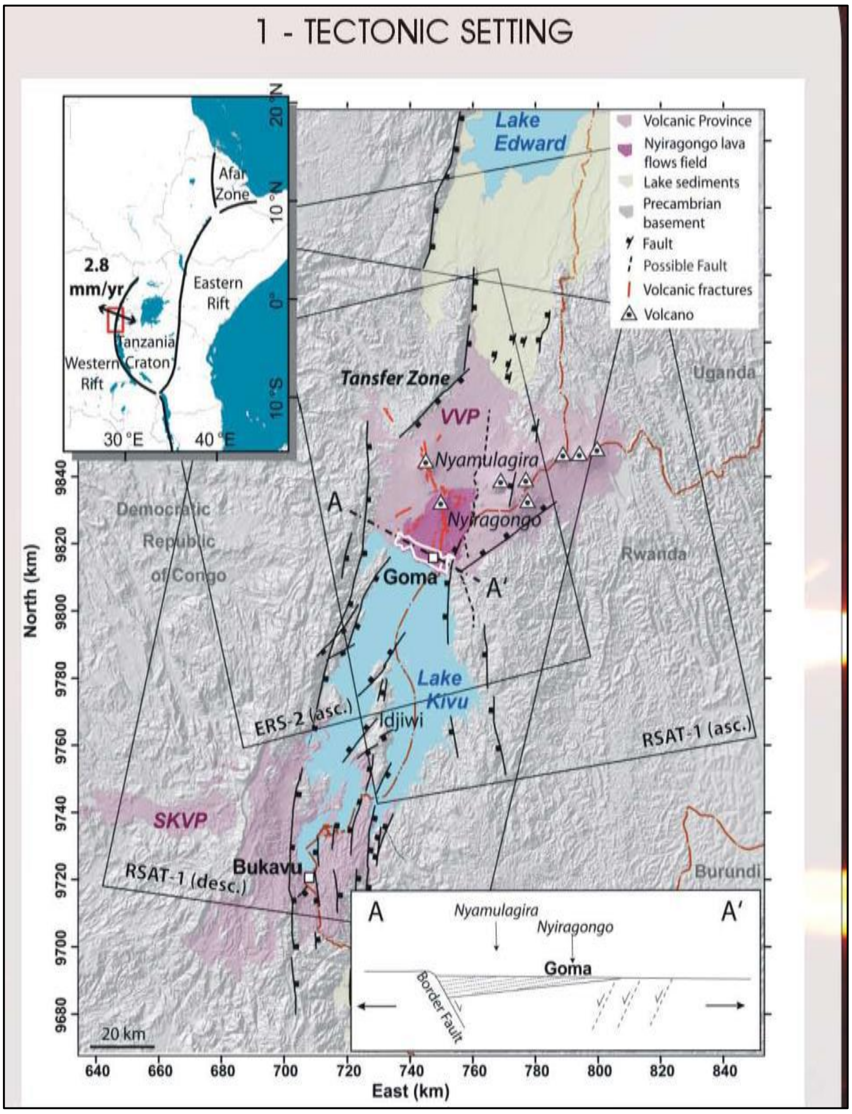


Fig 2: Tectonic map of the Virunga region (OVG)

2. Methodology

In the elaboration of the present work, we used the results of extensometric data in the fractures of Nyiragongo obtained thanks to the mechanical extensometer of the Volcanological Observatory of Goma which measures the distances until the hundredth of the millimeter with an accuracy of 0,02mm.

2.1. Extensometric data

The extensometric measurements are made with an extensometer that has an accuracy of 0.02mm.

2.2 Methodological approach

a) Implementation of the inks

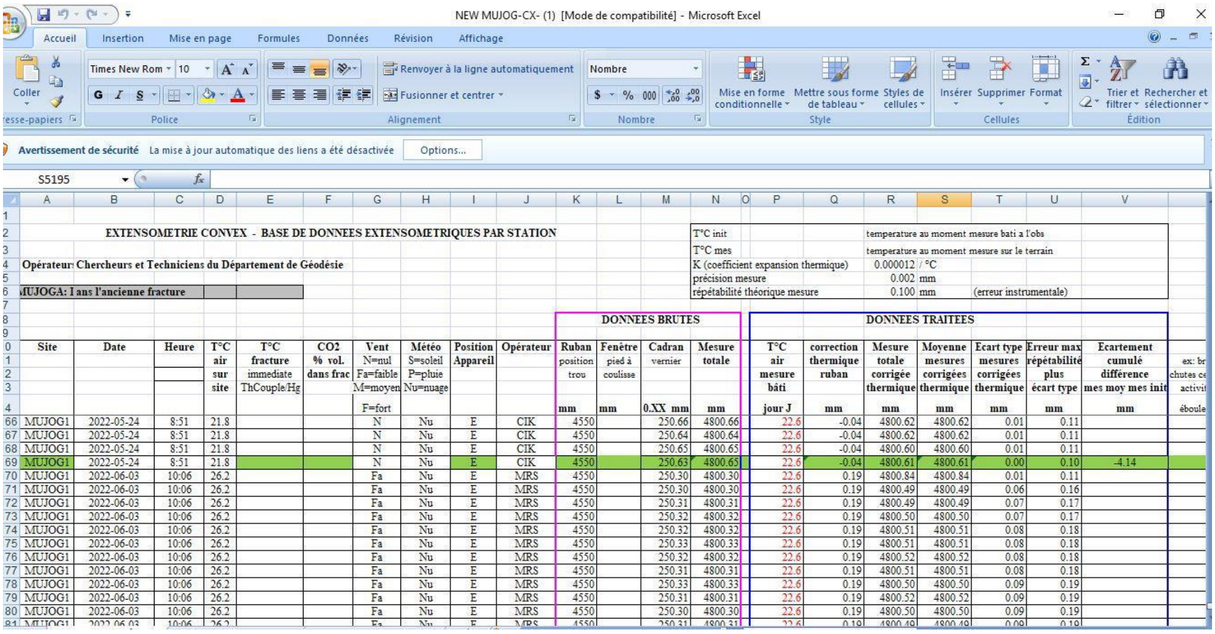
It is done in the extremities of the fractures. These fractures are, among others, those of the summit, Shaheru, Mudjoga, Mugara and Munigi.

b) Data collection

To minimize the error in the measurements, 20 measurements are taken and averaged, coupled with the air temperature. Thus, the average of the first measurements is considered as initial.

c) Data processing

An Excel sheet was designed to process the collected data. Thus, this sheet contains grids of air temperature, wind speed, weather and gaps. Thus, the average of the field measurements is always calculated and compared with the initial average to know if the fracture has expanded or compressed.



EXTENSOMETRIE CONVEX - BASE DE DONNEES EXTENSOMETRIQUES PAR STATION

Opérateur: Chercheurs et Techniciens du Département de Géodésie

MUJOGA: I ans l'ancienne fracture

T°C init		temperature au moment mesure bati a l'obs
T°C mes		temperature au moment mesure sur le terrain
K (coefficient expansion thermique)	0.000012	/ °C
précision mesure	0.002	mm
répétabilité théorique mesure	0.100	mm (erreur instrumentale)

Site	Date	Heure	T°C air sur site	T°C fracture immediate ThCouple/Hg	CO2 % vol. dans frac	Vent N=nul Fa=faible M=moyen F=fort	Météo S=soleil P=pluie Nu=nuage	Position Appareil	Opérateur	DONNEES BRUTES: Ruban position trou (mm)	Fenêtre pied à coulisse (mm)	Cadran vernier (0.XX mm)	Mesure totale (mm)	DONNEES TRAITEES: T°C air mesure bâti (jour J)	correction thermique ruban (mm)	Mesure totale corrigée thermique (mm)	Moyenne mesures corrigées thermique (mm)	Ecart type mesures corrigées thermique (mm)	Erreur max répétabilité plus écart type (mm)	Ecartement cumulé différence mes moy mes init (mm)
MUJOG1	2022-05-24	8:51	21.8			N	Nu	E	CIK	4550		250.66	4800.66	22.6	-0.04	4800.62	4800.62	0.01	0.11	
MUJOG1	2022-05-24	8:51	21.8			N	Nu	E	CIK	4550		250.64	4800.64	22.6	-0.04	4800.62	4800.62	0.01	0.11	
MUJOG1	2022-05-24	8:51	21.8			N	Nu	E	CIK	4550		250.65	4800.65	22.6	-0.04	4800.60	4800.60	0.01	0.11	
MUJOG1	2022-05-24	8:51	21.8			N	Nu	E	CIK	4550		250.63	4800.65	22.6	-0.04	4800.61	4800.61	0.00	0.10	-4.14
MUJOG1	2022-06-03	10:06	26.2			Fa	Nu	E	MRS	4550		250.30	4800.30	22.6	0.19	4800.84	4800.84	0.01	0.11	
MUJOG1	2022-06-03	10:06	26.2			Fa	Nu	E	MRS	4550		250.30	4800.30	22.6	0.19	4800.49	4800.49	0.06	0.16	
MUJOG1	2022-06-03	10:06	26.2			Fa	Nu	E	MRS	4550		250.31	4800.31	22.6	0.19	4800.49	4800.49	0.07	0.17	
MUJOG1	2022-06-03	10:06	26.2			Fa	Nu	E	MRS	4550		250.32	4800.32	22.6	0.19	4800.50	4800.50	0.07	0.17	
MUJOG1	2022-06-03	10:06	26.2			Fa	Nu	E	MRS	4550		250.32	4800.32	22.6	0.19	4800.51	4800.51	0.08	0.18	
MUJOG1	2022-06-03	10:06	26.2			Fa	Nu	E	MRS	4550		250.33	4800.33	22.6	0.19	4800.51	4800.51	0.08	0.18	
MUJOG1	2022-06-03	10:06	26.2			Fa	Nu	E	MRS	4550		250.32	4800.32	22.6	0.19	4800.52	4800.52	0.08	0.18	
MUJOG1	2022-06-03	10:06	26.2			Fa	Nu	E	MRS	4550		250.31	4800.31	22.6	0.19	4800.51	4800.51	0.08	0.18	
MUJOG1	2022-06-03	10:06	26.2			Fa	Nu	E	MRS	4550		250.33	4800.33	22.6	0.19	4800.50	4800.50	0.09	0.19	
MUJOG1	2022-06-03	10:06	26.2			Fa	Nu	E	MRS	4550		250.31	4800.31	22.6	0.19	4800.52	4800.52	0.09	0.19	
MUJOG1	2022-06-03	10:06	26.2			Fa	Nu	E	MRS	4550		250.30	4800.30	22.6	0.19	4800.50	4800.50	0.09	0.19	

Fig 3: Presentation of the extensometric measurement calculation sheet

3. Results and discussion

This part of the work will shed light on the different extensometric measurements taken in our different sites. It is at this level that we will understand the evolution of the gaps within the fractures that were the subject of our research in our various stations. Deformation in the northwestern part of the Lake Kivu Basin is the result of tectonic and volcanic movements. We distinguish two types of deformation; the elastic deformation due to tectonic activity and the plastic deformation due to volcanic activity (magmatic intrusion).

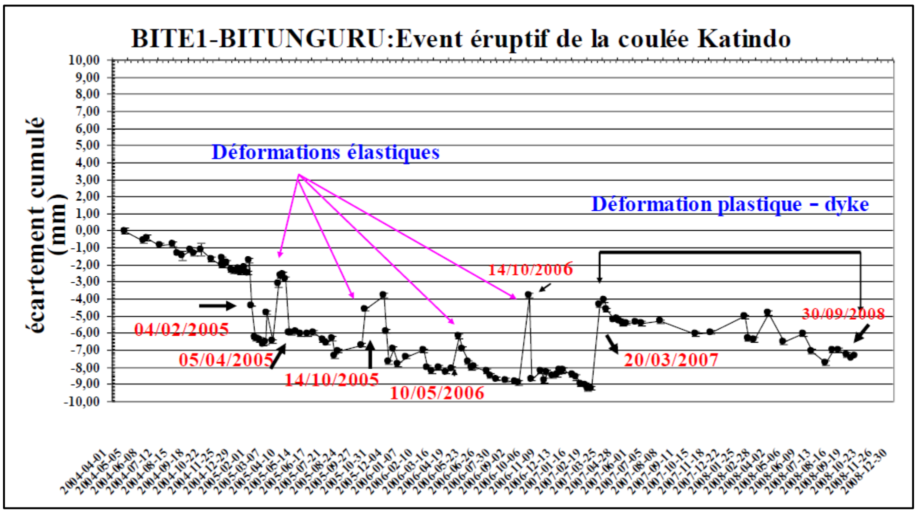


Fig 4: Cumulative spreads of the Bitunguru fracture between 2004 and 2008

The graph above represents the evolution of the Bitunguru fracture gauge in mm from April 01, 2004 to September 30, 2008. On this graph, we notice two intervals: the first one goes from February 04, 2005 to May 14, 2006 and corresponds to a period of repetition of the earthquakes causing elastic deformations in particular those of April 05, 2005, October 14, 2005, May 10, 2006 and October 10, 2006; and the interval which goes from March 20, 2007 to September 30, 2008 showing a plastic deformation due to a magmatic shrinkage or cooling in the fracture.

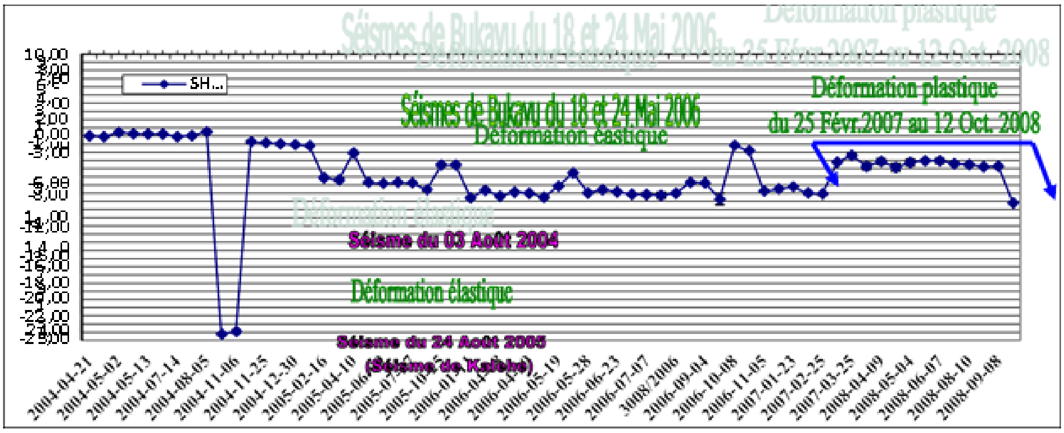


Fig 5: Cumulative spreads of the Shaheru fracture between 2004 and 2008

The analysis of this diagram shows three main parts marking the different dates of the earthquakes; the first is the date of August 03, 2004 which represents the earthquake causing an elastic deformation that occurred in Kalehe; from 18 to 24 May 2006, a plastic type deformation due to magmatic intrusions in this fracture during this period; and from February 25, 2007 to October 12, 2008, an interval characterized by a plastic deformation explaining the permanence of a continuous magmatic rise.

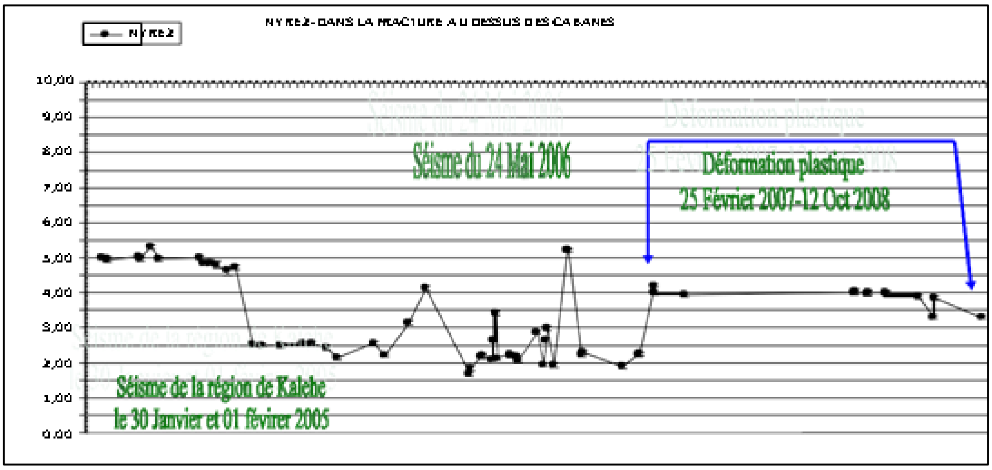


Fig 6: Cumulative spreads of the Cabane fracture between 2004 and 2008

We evaluated data from this site from April 1, 2004 to December 18, 2008.
The result shows us that between 2004 and 2006, elastic deformations due to the different earthquakes were manifested; between February 25, 2007 and October 12, 2008, an interval characterized by a plastic deformation explaining the permanence of a magmatic rise.

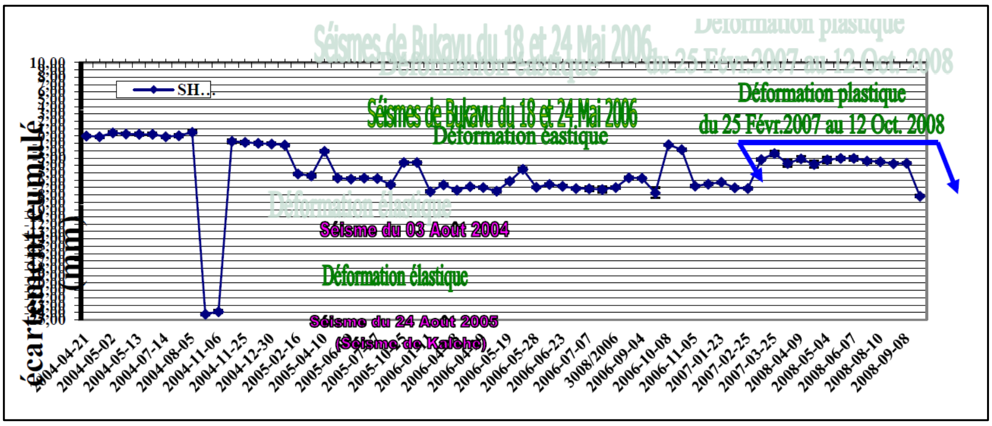


Fig 7: Cumulative spreads of the Nyiragongo volcano summit fracture between 2004 and 2008

The present graph demonstrates the impact of the great magmatic activity at the summit of Nyiragongo. It was in November 2004 that the site at the top of the Nyiragongo recorded a large earthquake responsible for an important elastic deformation in this part of the Lake Kivu basin. This projection of the fracture gps, clearly shows us that the observation of this activity of the magmatic rise takes its flow on April 01, 2004 and just at the beginning, it provoked only elastic deformations. It is since the year 2007 that the fracture had recorded other plastic deformations that signify us the presence of a continuous magmatic rise.

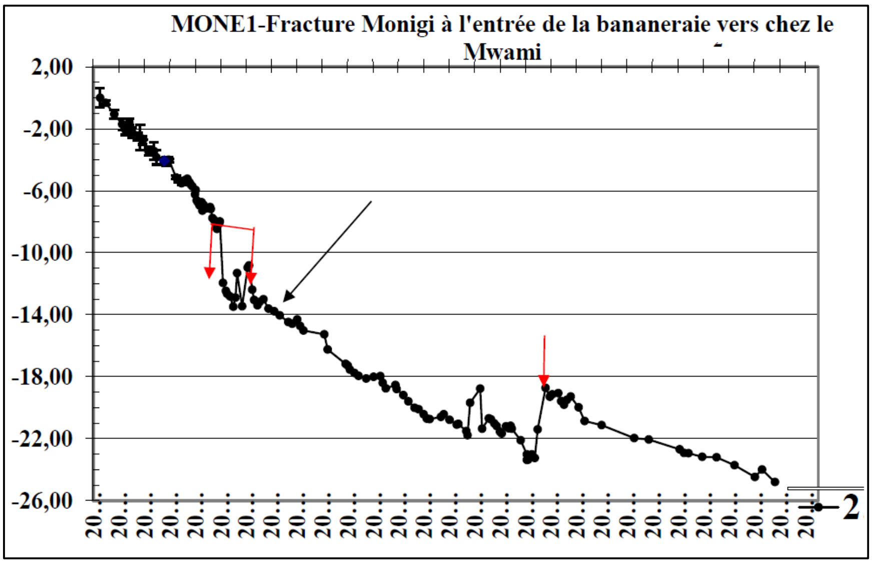


Fig 8: Cumulative deviations of the Munigi fracture between 2004 and 2008

On this graph, we notice that it had mainly undergone plastic deformations due to volcanic activity compared to the other fractures.

4. Conclusion

The constraint responsible for the appearance of all the structures and deformations in the region is that of rifting, which is responsible for the regional expansion of East Africa and is marked by the volcanic activity of the Virunga region. This study has allowed us to see, after analysis of the measurements made by the extensometer, how tectonics and magmatic intrusions play on the spreading of the southern fractures of the Nyiragongo volcano. We understand that the tectonism of this area causes movements of the earth's crust which in turn generate earthquakes in the area and are responsible for elastic deformations; the latter can also motivate the magmatic intrusions allowing the dilation of fractures and the opening of faults (plastic deformations). Based on the results of extensometric measurements carried out between 20004 and 2008 in the Summit, Bitunguru, Cabane and Munigi fractures, we have noticed that the latter have experienced elastic deformations during the possible earthquakes that occurred in the Lake Kivu basin and plastic deformations due to magmatic intrusions especially in 2006 and 2007.

The interpretation and analysis of these 5 different diagrams clarifying the data of the sites of this research, shows that all the distances of the fractures evolve at the scale of millimeters per year without exception of site. To the question of why? In answer, we can say that the gap of a fracture is exercised at the rate of the magmatic rise that causes it and the movement of the rift.

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