



## Risks related to the eruption of the Nyiragongo Volcano on 22 May 2021: Case of Fracturation in the Mabanga and Bujovu quarters. Goma /North Kivu Province/DR Congo

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### Abstract

Nyiragongo is one of the most active volcano in the virunga volcanic chain. The three eruptions of Nyiragongo namely January 10, 1977, May 17, 2002 and May 22, 2021 were all fissural.

These three eruptions developed a series of fractures starting from the summit to the level of the city of Goma. It turns out that the last eruption created new fractures and reactivated old ones; these characterized by the presence of heat flows but also gases and were used for the passage of lava in some places. As part of the Monitoring of this volcano, a GPS survey was carried out along the old fractures and cracks and those reactivated at the point of exit of the lava until in the city of Goma, the objective was the follow-up of the fractures for s'inquire about cracks, fractures and other damage that occurred during the strong seismicity that followed the eruption of the Nyiragongo volcano on May 22, 2021. However, there are cracks and fractures from the summit of the Nyiragongo volcano down to town level.

**Keywords:** Cracks, fractures, heat flow, GPS

### 1. Introduction

The African tectonic trench system extends into East Africa from where it constitutes the rift system (Wafula, 2011). East Africa has a considerable level of seismic hazard due to the presence of the East African Rift System. This seismicity in the rift valley is characterised by activities confined to or extended to a shallow depth. South of Lake Kivu, the fault direction changes from NNE-SSW to NNW-SSE; the major structures in this region are the edges of the Lake Tanganyika and Lake Rukwa fault systems that join in the faulted edges of Lake Malawi. The Kivu Rift is part of the high-altitude lands of the eastern Democratic Republic of Congo which belongs to the western slope of the Central African Rift. Its step-like morphology corresponds to a succession of faulted blocks or horsts and grabens progressively sloping from the outer (west) to the inner (east) rift to local base levels. Komorowski *et al* (2004) and Schmid *et al* (2005) add that a remarkable high scarp of more than 1800 m bound the Kivu Basin on the western edge of the basin. This rift is affected by transverse fractures or faults and the volcanism associated with these fractures has petrological features such as alkaline potassic to hyper potassic, basic to ultrabasic lavas and carbonate tuffs. With the exception of a short-lived lava expulsion on the northern flank of Visoke, recent eruptive episodes in the Virunga region have been restricted to Nyiragongo and Nyamulagira volcanoes (Poucllet, 1975; Brousse *et al.*, 1979, Kasahara *et al.* 1992) <sup>[5]</sup>. These two volcanoes are well known for their lava lake eruptions and Hawaiian-type flows. Some authors believe that they are representative of hotspot volcanism in the African tectonic plate (Hamaguchi *et al.* 1983) <sup>[7]</sup>.

The Virunga volcanic region is located just north of Lake Kivu in the western rift valley and is composed of 8 main volcanoes (Figure 2) divided into 3 groups: *East [Muhavura (4127m), Gahinga (3474m) and Sabinyo (3674m)], Central [Visoke (3911m), Karisimbi (4506m), Mikeno (4437m)] and West [Nyiragongo (3474m), Nyamulagira (3056m)]*. The eastern and central volcanoes are all in a dormant stage, however those in the western group (Nyiragongo and Nyamulagira) are among the most active volcanoes in the world (Hamaguchi and Zana, 1983; and Wafula, 2011) [7] and are of interest to this work. These two volcanoes, Nyiragongo and Nyamulagira, located only 13 km apart, are located in the same rift axis fracture zone. However, Nyiragongo volcano is in the category of the most dangerous volcanoes in the world because of its proximity to the city of Goma and the fluidity of its lava, which flows at a speed of more than 40 km/h (Wafula, 2011). A lateral eruption of Nyiragongo volcano took place on 10 January 1977, after which the volcano completely lost its long-lasting lava lake that has persisted in the summit crater for more than 50 years. Although surface eruptive activity ceased in less than 30 minutes (Tazieff, 1977) [2], the extremely rapid liquid lava covered several villages, killing at least 400 people and spreading 15-20 million cubic metres of lava. Another lateral eruption occurred on Nyiragongo volcano on 17 January 2002 after about 25 years of relative dormancy. Liquid lava flowed in several places along a fracture system that had opened on the southern flank of the volcano (Komorowsky *et al.* 2003). Two lava flows entered the city of Goma, causing major devastation and leaving about 100,000 people homeless. A new fissural eruption of Nyiragongo occurred on 22 May 2021 after a lull of almost 19 years. However, the volcano had sent out strong signals long before, notably with

its intra-characteristic eruption on its third platform on 29 February 2016. This eruption had an effusive phase, with flows oriented in three directions following the fractures that had opened up, notably: the north-east flank (Kaneza axis), the north-west flank (Rusayo axis) and the north-south flank (Munigi axis). It caused material and human damage in the outlying areas of the town, which was much more affected in terms of buildings and various infrastructures. However, the damage was less extensive than that of the 2002 eruption, and there is a specificity of the Nyiragongo eruption of 2002 and 2021 compared to that of 1977. Indeed, based on the reports of Tazieff (1977) [2] and Ueki (1983) [7], the length of the cracks associated with the 1977 Nyiragongo eruption did not exceed 1 to 13 km. In contrast, after the 2002 Nyiragongo eruption, Komorowsky (2002), carried out a kinematic survey of the southern flank of Nyiragongo with GPS and found that the fracture system had extended beyond 15 km. Similarly, the very remarkable extension of fissures in the town after the 2021 eruption points in the same direction. The Nyiragongo volcano, located about ten kilometres from the city of Goma, poses a permanent risk to the population of the city of Goma and its surroundings (Munigi, Kibati, Mugara, Mutaho, Mudjoga, Bitunguru, Lemera), all of which are located to the north of the city of Goma and at the foot of the Nyiragongo volcano. These eruptions often occur on its southern flank; some fissures extend into the city, which can make future eruptions more catastrophic. Volcanism is one of the manifestations of plate tectonics, along with earthquakes. Two long fissures have appeared in the city of Goma. These cracks, a few dozen centimetres wide in places, have fractured the ground in the middle of the city in certain districts such as Mabanga and Bujovu, which are the subject of our work.

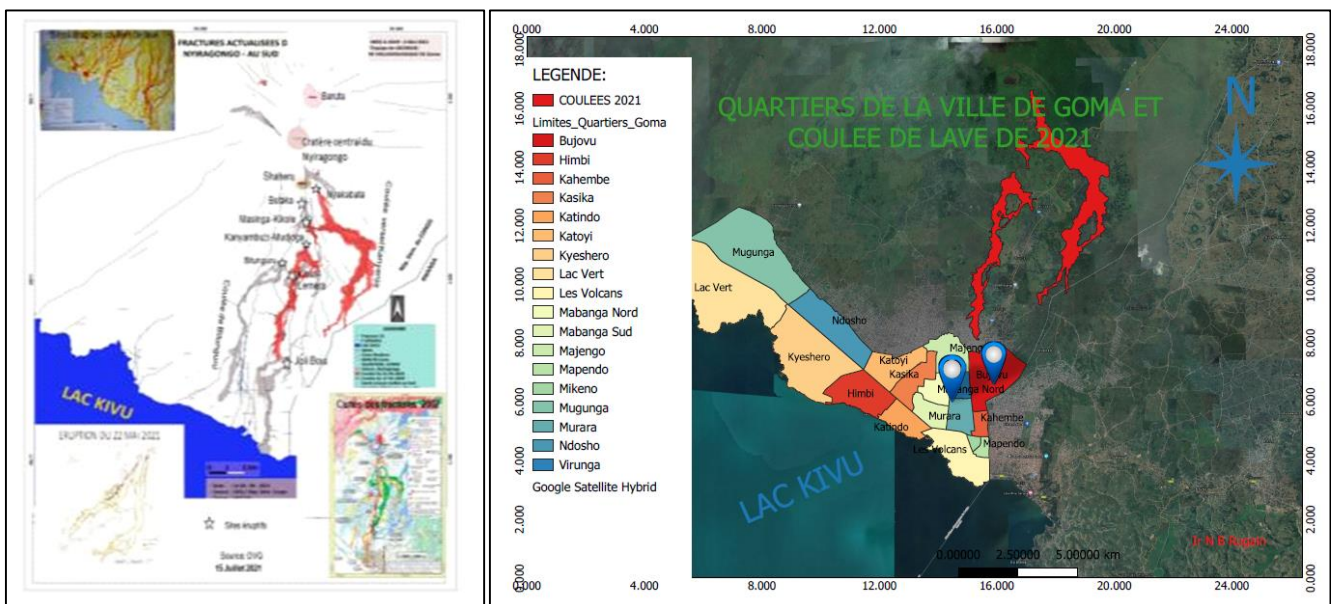


Fig 1: Illustration of the opening of fractures and fissures during the 2002 and 2021 eruptions

**2. Study Environment**

Nyiragongo is a stratovolcano rising to 3470m above sea level, located about 18km north of the city of Goma and Lake Kivu in the Democratic Republic of Congo. Part of the Virunga volcanic chain, it is one of the volcanoes of the western branch of the Great East African Rift Valley and is located in the Virunga National Park. It is surrounded by the

Nyamulagira volcano to the northwest and by the Karisimbi and Mikeno volcanoes to the east, Lake Kivu, the city of Goma and Rwanda (Gisenyi part) on the southern flank at the foot of this volcano. It represents a great risk for the population of the city of Goma and its surroundings but also in the world.



**Fig 2:** Figure of the Nyiragongo volcano and the city of Goma at its flank

These cracks, a few tens of centimetres wide in places, fractured the ground in the middle of the city, fuelling the psychosis of a new eruption of the volcano in the east of the Democratic Republic of Congo (DRC).

On Tuesday, as on the previous day, strong earthquakes continued to shake the region every ten to twenty minutes, some of them very strong. Under the force of the tremors, a three-storey building partially collapsed, leaving at least seven people seriously injured, according to the police on the spot.

A crack a few centimetres wide but several hundred metres long split the ground in the western part of the city, between the general hospital and Mount Goma, a mountain that marks the northern boundary of the city, further fuelling the psychosis. Many house facades and partitions cracked.

The Kaneza eruption site is located at the foot of Shaheru and this is the third time it has been called upon: 10 January 1977, 17 January 2020 and 22 May 2021. For the 2021 eruption the 2002 fracture was not reactivated much, another parallel to

this one towards the west was formed, fractured the Mudjoga 2 cone further north and exited to the southwest of this cone and extended towards the Kibati-Lemera cone

### 3. Materials and Methodologies

#### 3.1 Materials

The data used in this study comes from GPS (Global Positioning System) coordinates, for the determination of the geographical coordinates of the places where we observed the fracturing in the two districts: Mabanga and Bujovu. The Garmin GPS with an accuracy of 3m. The points collected were taken at the location where the cracks or large fractures were observed. We went through the places and quarters to follow with our GPS the general trend of these openings including the NNW - SSE as well as their orientation. Bujovu and Mabanga attracted our attention because they were the areas that were most affected by the different earthquakes that were felt in the Virunga region during the volcanic eruption of 22 May 2021.



**Fig 3:** Raising with the help of a GPS

#### 3.2 Methodology

GPS is set up either in degrees or in UTM (Universal Transverse Mercator). After turning on the GPS, it must first pick up the satellites which will send signals directly. These signals are directly in a straight line with no obstructions on the side of the satellites and the GPS, hence a place where the sky is clear. Once the sky is clear, we wait until the accuracy is displayed (3m) and the GPS gives us our position, i.e. Latitude, Longitude and altitude of all the points we have to cover. Our observations during the descent on the ground at the time of the many seisms felt after the volcanic eruption of

May 22, 2021, allowed us to take various points in order to determine and locate various places which were cracked in order to differentiate the new cracks and the old ones which were reactivated at the time of the eruption of May 22, 2021 at the time of the various seisms felt in the area.

#### 4. Discussion of the Results

The different districts we visited and which are the subject of our work are the Mabanga and Bujovu districts. Fractures resulting from old and recent eruptions are present everywhere in the city, some of them oriented North-South,

others linking the cones to the vents that have been destroyed. These fractures and fissures constitute a double danger. During this great volcanic activity, which produced lava and numerous earthquakes, a part of the city of Goma was stressed and presented a great danger for the population of this part of the city, who were forced to leave their neighbourhoods. Fractures resulting from old and recent eruptions are present everywhere in the city in a N-S orientation, others linking the cones to vents destroyed by man during construction. These fractures and fissures constitute a double danger. The presence of very active

volcanoes propelling fine pyroclastic products (volcanic ash) into the atmosphere, the dust coming from the intense traffic of cars, motorbikes and people increasing the condensation nuclei etc. As a result, the clouds in the atmosphere due to the emitted gases also constitute a greenhouse gas. Houses built on these cracks and fractures have been cracked and others destroyed in major earthquakes. With the heat flowing up with the gases some houses would have to be abandoned to avoid being asphyxiated but also this could be the path of the lava in case of a possible eruption.



**Fig 4:** The different eruptive sites (Mugoga, Kaneza, Shaheru)

Indeed, 10 of the 18 neighbourhoods are being evacuated due to the high risk of eruption with the help of humanitarian organisations present in the area. Almost one third of the city's inhabitants are affected.

Residents of these neighbourhoods were ordered to move to Sake, a town 24 km west of Goma, but others chose to go east to Rwanda. The city of Goma was devastated by the lava from the Nyiragongo volcano.



**Fig 5:** Destruction of houses by lava in May 2021

According to experts at the Goma Volcanological Observatory, gas from the Nyiragongo volcano dissolved in the deep waters of the lake, especially CO<sub>2</sub>, could asphyxiate all species living around Lake Kivu on the Congolese and Rwandan sides, and this could cause thousands of deaths in both countries. The interaction of the magma with the water of the lake, the destabilisation of the volume of gas dissolved under Lake Kivu and the emission of gas at the surface are potentially dangerous for the populations exposed to the fumes. In the city, some businesses remained open and there were no signs of immediate panic, but traffic is slow and residents, anxious about the repeated strong tremors and the appearance of these fractures in the road, are waiting.

#### 4.1 Bujovu neighbourhood

It was in 1989 under ministerial decree n°01/037/CAB/GP-NK/98 of 18/11/1989 that the Tyazo sub-district became the Bujovu sub-district, which was initially the sub-district of the Virunga district. It is bounded to the north by the Bukumu

chiefdom, to the south by the Kahembe district, to the east by the Rwandan Republic and to the west by the Goma international airport. This district is located at coordinates 01.661629/29.251146 at an altitude of 1530m,

The preferred orientation of the fractures was NNW/SSE and WNW/ESE. The fracture from these vents towards Birere and Rwanda. This fracture from the top through the Mujonga cone passes into the Bujovu district to Rwanda. A 35 cm opening in the road leading to the airport at the time of the numerous earthquakes felt during the Nyiragongo volcanic eruption, which worried the staff working at the airport as well as the inhabitants living in the neighbourhood.

While surveying in this area, we observed that the houses; the road, the cement workers were much affected. In some places, the fractures in the house were 1m, with the lack of support and help the population proceeded to fill these fractures by stone to allow them to still live in their house forgetting any danger.

#### Eruptions can destroy land and threaten people living on the sides of volcanoes



**Fig 6.** (a) Destruction of the wall, (b) airport road and (c<sub>1</sub> c<sub>2</sub>) the graves of the SEP CONGO cemetery

#### 4.2 Mabanga neighbourhood

The Mabanga - Sud district was created in accordance with presidential order n°089/197 of 25/05/1989 fixing the number and delimitation of the districts of the city of Goma, resulting from the territorial, political and administrative division of the DRC and then divided by the order of the Governor of the province of North Kivu into two districts, namely: Mabanga-North and Mabanga-South. The population of this district, after the volcanic eruption of 2002, had built on the fractures, volcanic tunnels and old vents.

During the big earthquakes recorded in the region after the eruption of Nyiragongo, we recorded several houses, schools, churches that were affected by these felt earthquakes. The population of this area still ignored the danger and allowed

themselves to build on old vents, fractures and other volcanic tunnels.

Volcanic tunnels are voids left underneath the flows during a volcanic eruption. Some families in Goma and Nyiragongo Territory use them as septic tanks for their toilets because they never fill up. The danger of these volcanic tunnels is that they can collapse if an earthquake passes. During an eruption, these tunnels constitute a privileged path for the lava flow and can reach a long distance from the main flow.

The opening of fractures and cracks as well as the reactivation of old ones frightened the population of this neighbourhood and they quickly called the team of the Goma Volcanological Observatory, which is in charge of monitoring. A survey was carried out to locate and map the cracks.



**Fig 7:** (3, 4) House cracks and (1, 2) Schools

#### 5. Conclusion

The intense seismic activity that followed the eruption reactivated some old fractures and created new ones on the southern flank, and these extended into the city of Goma. They were visible in the city, particularly in the Mabanga and Bujovu districts. This intense seismic and tectonic activity in the city of Goma and its surroundings led to a campaign to identify these new open fractures and the old ones reactivated after the eruption of 22 May 2021 using a GPS. It should be noted that fault reactivation has been observed many times in the Lake Kivu basin after major tectonic events (Munyololo *et al.* 1999; Ciraba *et al.* 2012) [9]. The observations show that with construction, man has hidden the cracks, fractures and vents created at the time of the 1977 and 2002 eruptions. Some of the seismicity felt had its epicentre in these areas. The mapping of these fractures and cracks shows the extension of these from the top of Nyiragongo to the city of Goma.

The Goma Volcano Observatory intends to keep a watchful eye on these areas as part of the monitoring of the volcano and future research, provided that everyone is involved in mitigating this volcanic risk which is part of our daily lives.

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