

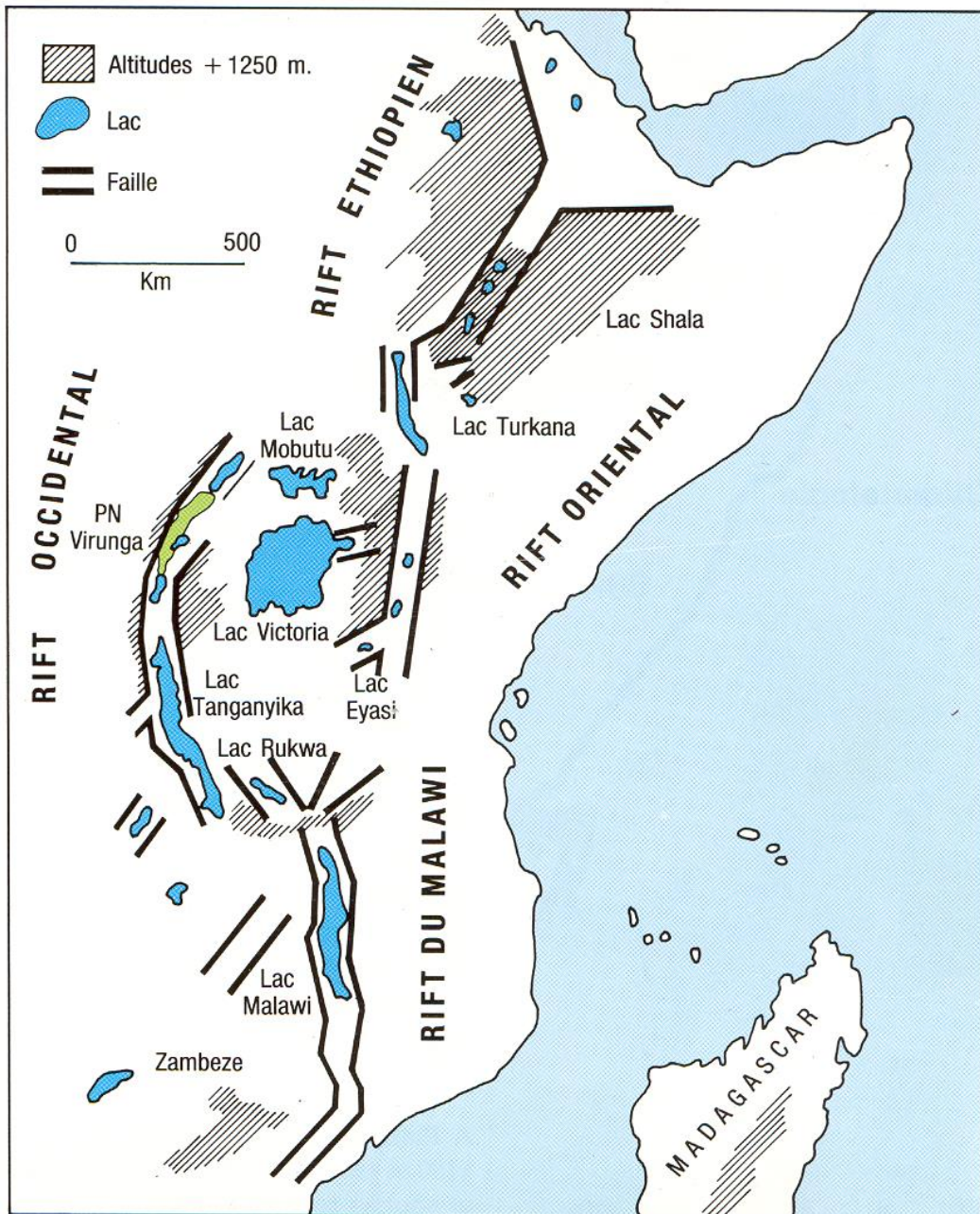


**D. Tedesco, J. Durieux, C. Kasereka, P. Papale, O. Vaselli and M. Yalire**

**UN-OCHA**

Office for the Coordination of Humanitarian affairs

**Eruptive Activity of Nyiragongo Volcano  
Goma, Democratic Republic of Congo**





# DEMOCRATIC REPUBLIC OF THE CONGO

**Volcano NYAMULAGIRA**  
3,056 m

**Volcano VISOKE**  
3,711 m

**Volcano MIKENO**  
3,056 m

**Volcano NYIRAGONGO**  
3,470 m

**Volcano KARISIMBI**  
4,507 m

# RWANDA

*Lake Kivu*  
(1,450 m)

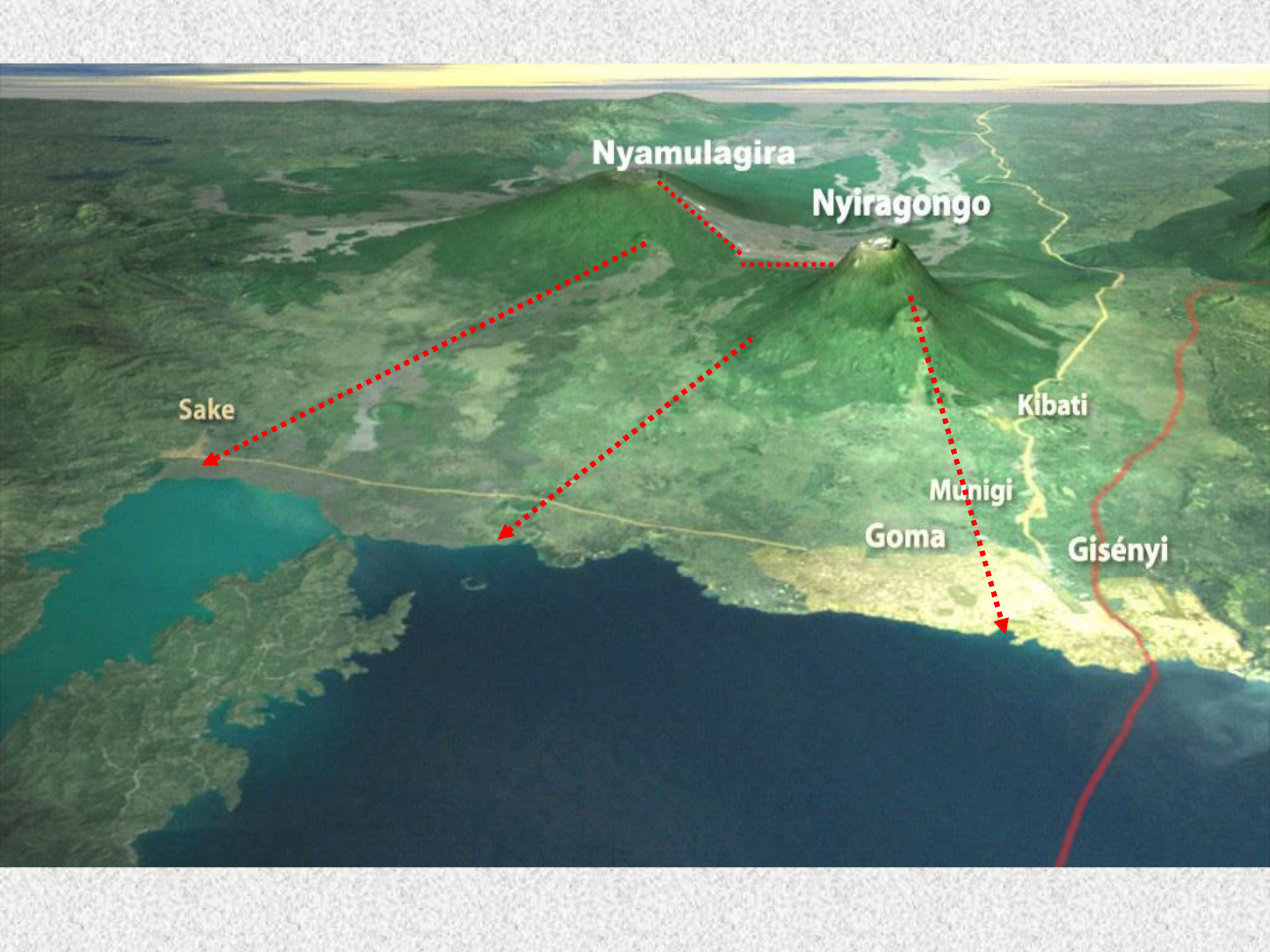
Goma

Nkamira

Gisenyi



kilometers



**Nyamulagira**

**Nyiragongo**

**Sake**

**Kibati**

**Munigi**

**Goma**

**Gisényi**

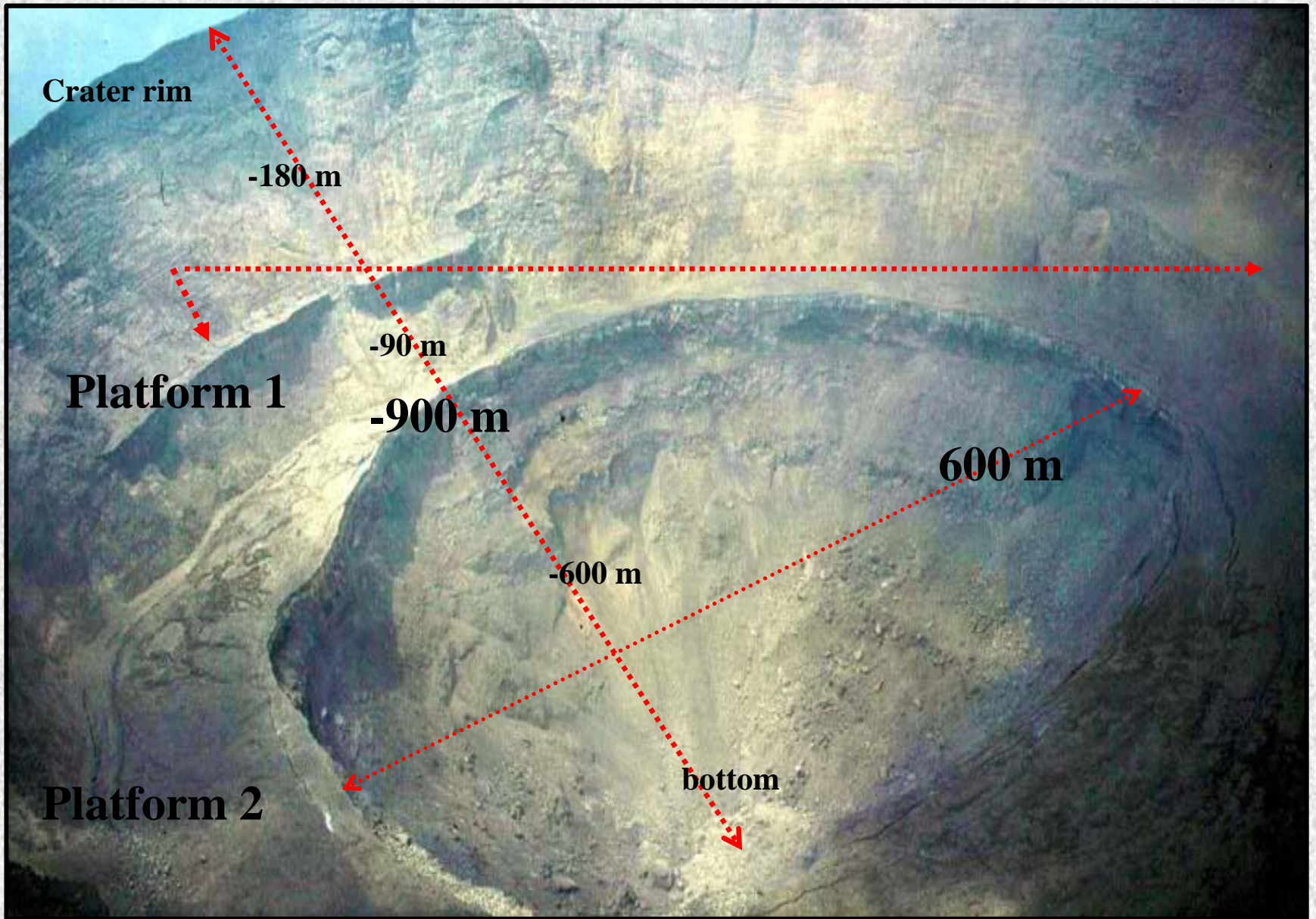
View of the inside crater in 1995, showing on the crater floor the presence of a thick solidified crust of the old lava lake. On January 2002, before the eruption, the situation was substantially unchanged



On January 21st, the central part of the crater was showing an intense fumarolic activity from circular fractures.

The situation, radically changes the day after.





















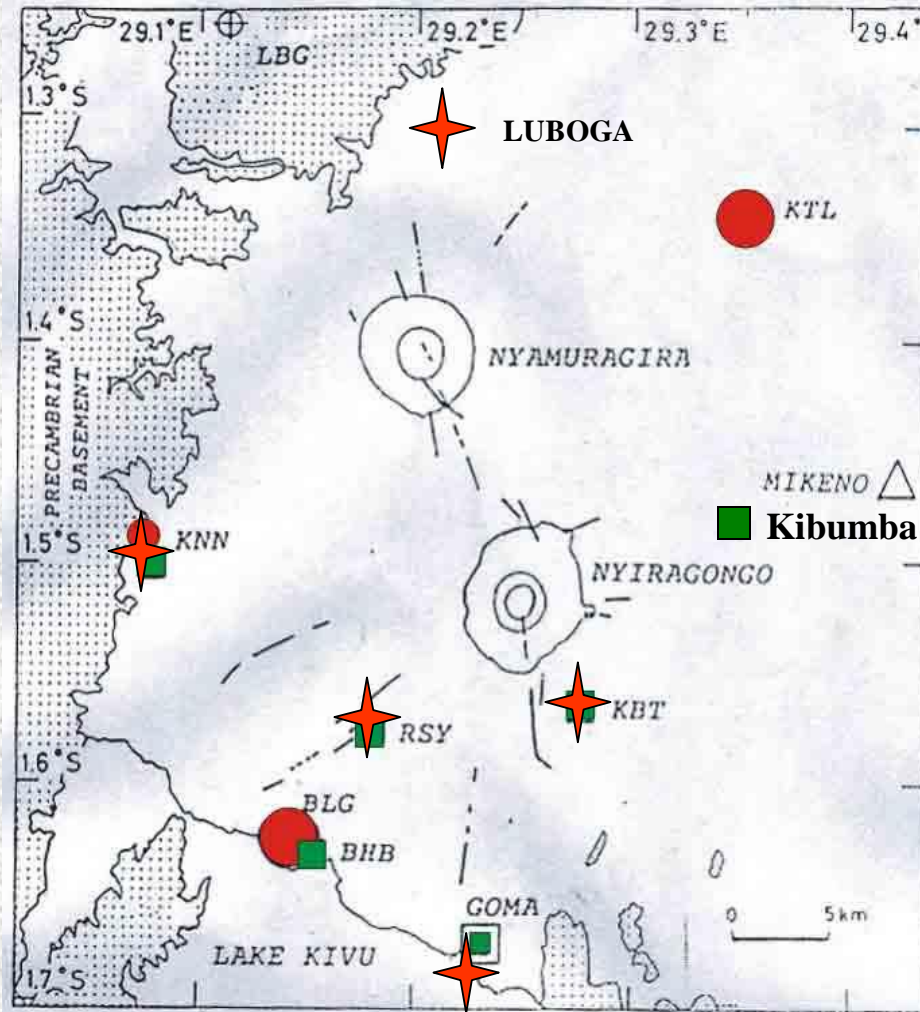
**Up to 54,000 Tons/day of SO<sub>2</sub> have been detected by satellite imagery (courtesy of Dr Simon Carn).**

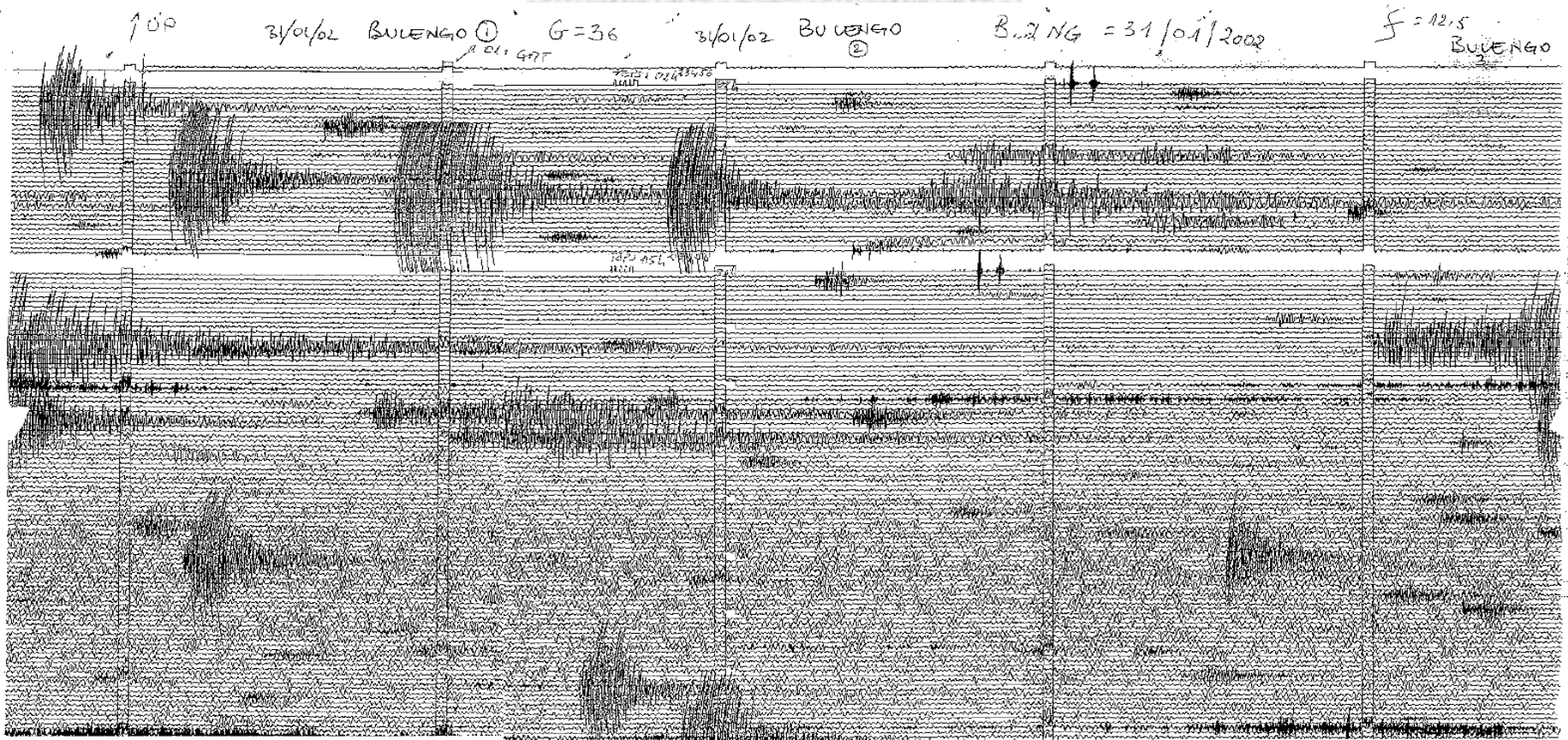
**Seismic studies have been for long time the only monitoring activities performed at GVO.**

**Anomalous activity was recorded after the January 17, 2002 eruption.**

**In the following months, seismic activity has still shown an anomalous pattern if compared to the last two decades activity. Felt quakes from very rare have become a constant feature, while tectonic/fracturing activity have been located in new areas, south of the volcanoes, much closer to the city of Goma and finally into lake Kivu.**

## Locations of seismic stations (1-component)





Typical seismic record during the days and weeks that followed the January 17, 2002 eruption, showing the main features of seismic signals. The typical sequence was constituted of major shocks, followed within minutes to hours by long-period events and volcanic tremor. The sequence in figure corresponds to 12 hours of recording.

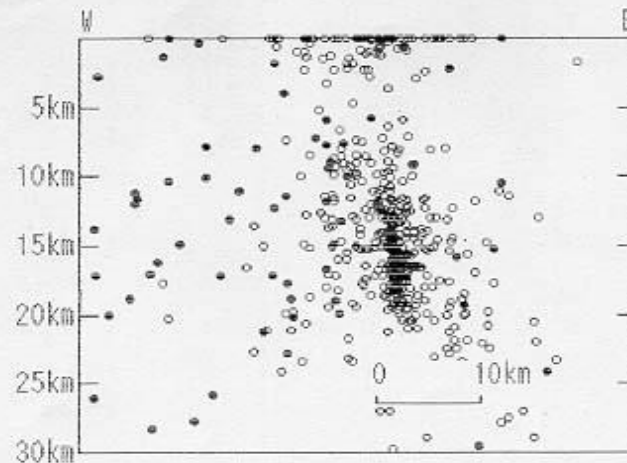
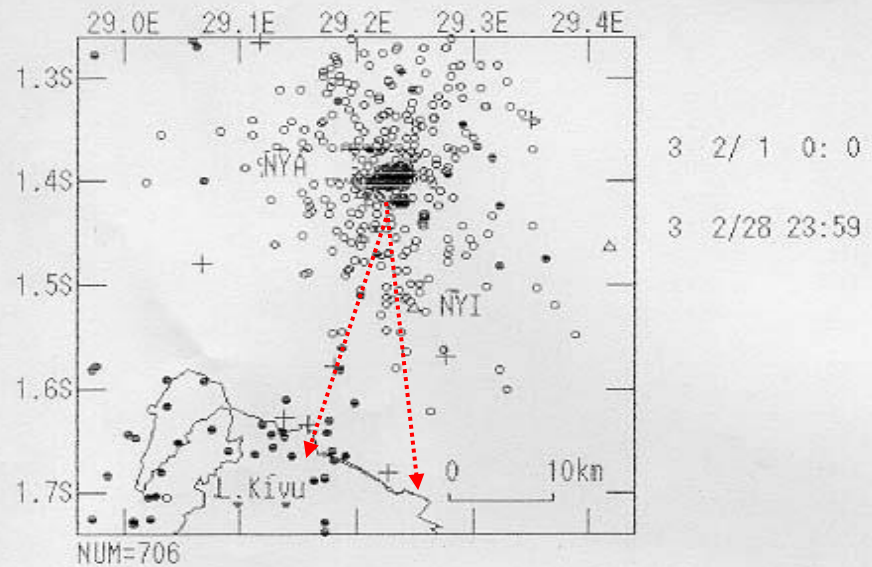


Seismicity in the Virunga region in the last two years has shown several variations.

It is worthy to note that an “unusual” tectonic activity with several felt earthquakes has been localized more south into lake Kivu.

Magmatic quakes (open circles) are usually scattered between Nyamulagira and Nyiragongo. Tectonic activity (black circles) related to fracturing has been mainly localized on a N-S line. Several of these quakes were felt by local population.

Seismic Data elaborated by G.V. Mavonga, G.V.O., 2002/2003.



In two occasions, “strange noises” have been recorded only at Mt. Goma seismic station. This noise, recorded during day and night, has not an anthropic origin; after being studied by several seismologists worldwide have been definitely recognized as magmatic tremors. Further studies are needed to better constrain this activity to understand future developments.



# Gas Plume: Ash and Gases



During 2003 ashes (Peleé's hairs and scoria) were falling along the city of Goma and all around the crater [from Kibati (east), to Mudja (south) to Rusayo (west)]. The south flank of the volcano has been continuously covered by ashes and consequently by gases). As a result vegetation has been seriously damaged.



**Plant damages due to ashes, scoria and acid gases were recorded up to Sake (25 Km S-W). Not only small “cultivars” but also big plants such as banana trees have been seriously affected.**





**Water stored in banana's trees is a typical water resource during dry season. The presence of ashes have strongly polluted waters.**



# OMS threshold for Fluoride is 1.5 ppm

ppm referred to the rock	Weight	F	Cl	NO3	SO4
OVG-Pelee+Ash 11/02/03	1.004	647	498	25	124
Nyiragongo-Pelee 6/10/02	2.47	121	142	871	850
Goma Pelee+Ash 15/02/03	2.072	772	265	5	362
OVG Pelee+Ash 13/02/03	1.196	711	2090	176	836
Goma Pelee+Ash 13/02/03	1.034	1306	1983	97	484
OVG at 7.20pm 14/02/03 Ash	2.289	437	1987	26	5678

After ONE week

N	ppm referred to the rock	Weight	F	Cl	NO3	SO4
1	OVG-Pelee+Ash 11/02/03	1.004	184	25	5	30
2	Nyiragongo-Pelee 6/10/02	2.47	63	8	30	71
3	Goma Pelee+Ash 15/03/03	2.072	198	17	1	19
4	OVG Pelee+Ash 13/02/03	1.196	355	29	3	46
5	Goma Pelee+Ash 13/02/03	1.034	421	68	5	87
6	OVG at 7.20pm 14/02/03 Ash	2.289	262	55	1	153

After TWO weeks

ppm referred to the rock	Weight	F	Cl	NO3	SO4
OVG-Pelee+Ash 11/02/03	1.004	81	20	4	17
Nyiragongo-Pelee 6/10/02	2.47	25	8	7	19
Goma Pelee+Ash 15/02/03	2.072	66	8	1	14
OVG Pelee+Ash 13/02/03	1.196	130	19	3	19
Goma Pelee+Ash 13/02/03	1.034	242	21	2	33
OVG at 7.20pm 14/02/03 Ash	2.289	79	7	1	38



**CO<sub>2</sub> gas emanations:  
“evil winds/mazuku,  
elephants graveyard**



**CO<sub>2</sub> concentration usually ranges from 20-30% up to 90% in atmosphere.  
15% is considered the lethal threshold**





**Rumoka crater, bats were found dead 40 meters above the CO<sub>2</sub> line ...**



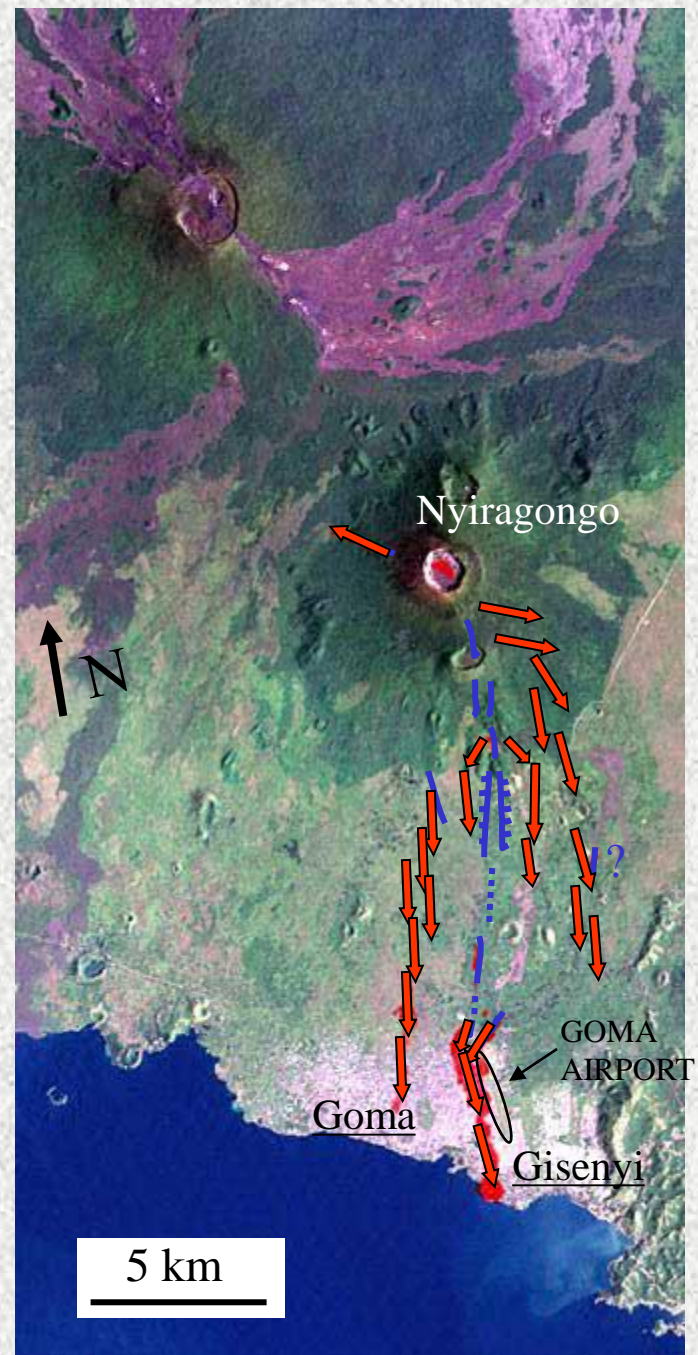


## Nyiragongo eruption, January 17 2002

The image combines data from the Shuttle Radar Topography Mission, Advanced Spaceborne Thermal Emission and Reflection Radiometer, or Aster, and Landsat to depict areas affected by the eruption of the approximately 3,469-meter (11,385 foot) volcano.

The volcano is one of eight located in the East African Rift Valley on the border of the Democratic Republic of Congo and Rwanda.

Background image from NASA.



**The fractures system propagates from N to S at different time, not all fractures erupted and part of fractures developed after the eruptive activity.**

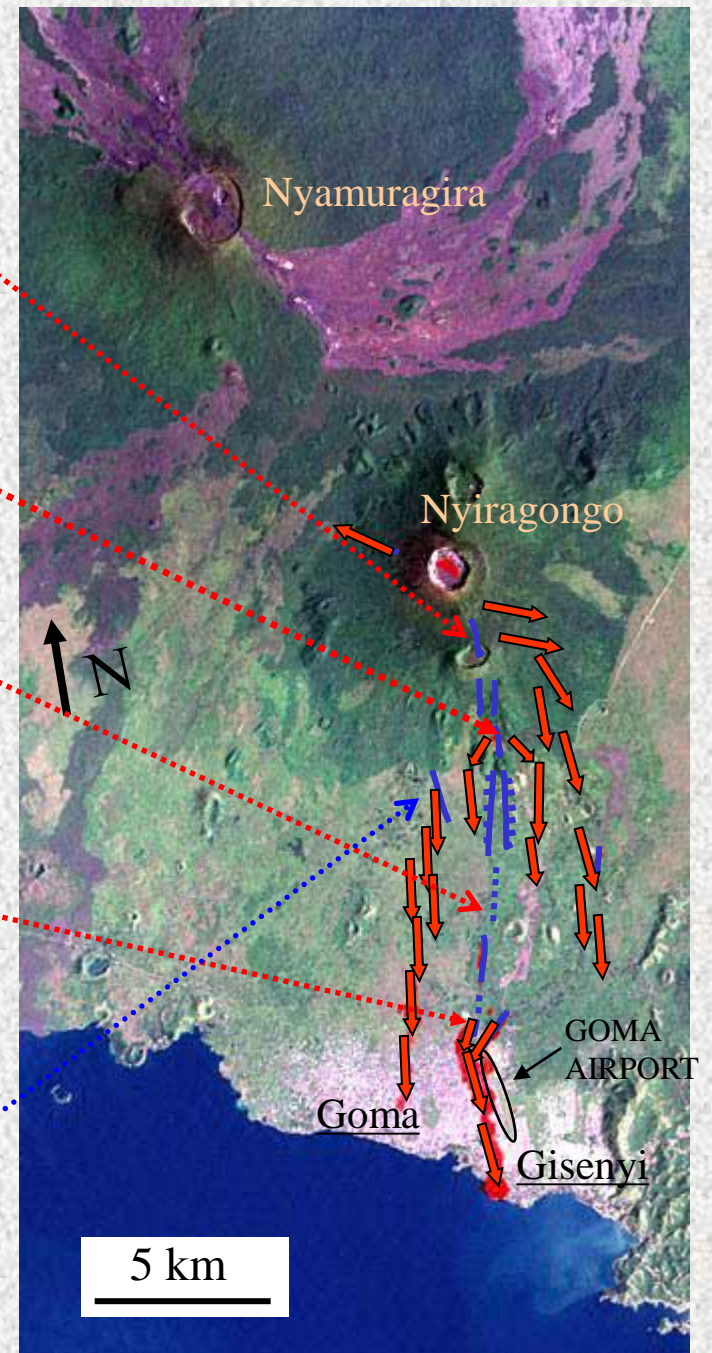
**8h25: eruption starts. Seismograms saturated. Fracture open N of Shaheru crater, at about 2700 m. Lava flows inside and laterally the crater of Shaheru.**

**Around 10 am, lasting at least 2 hours: eruption begins between 1950 – 2000 m.**

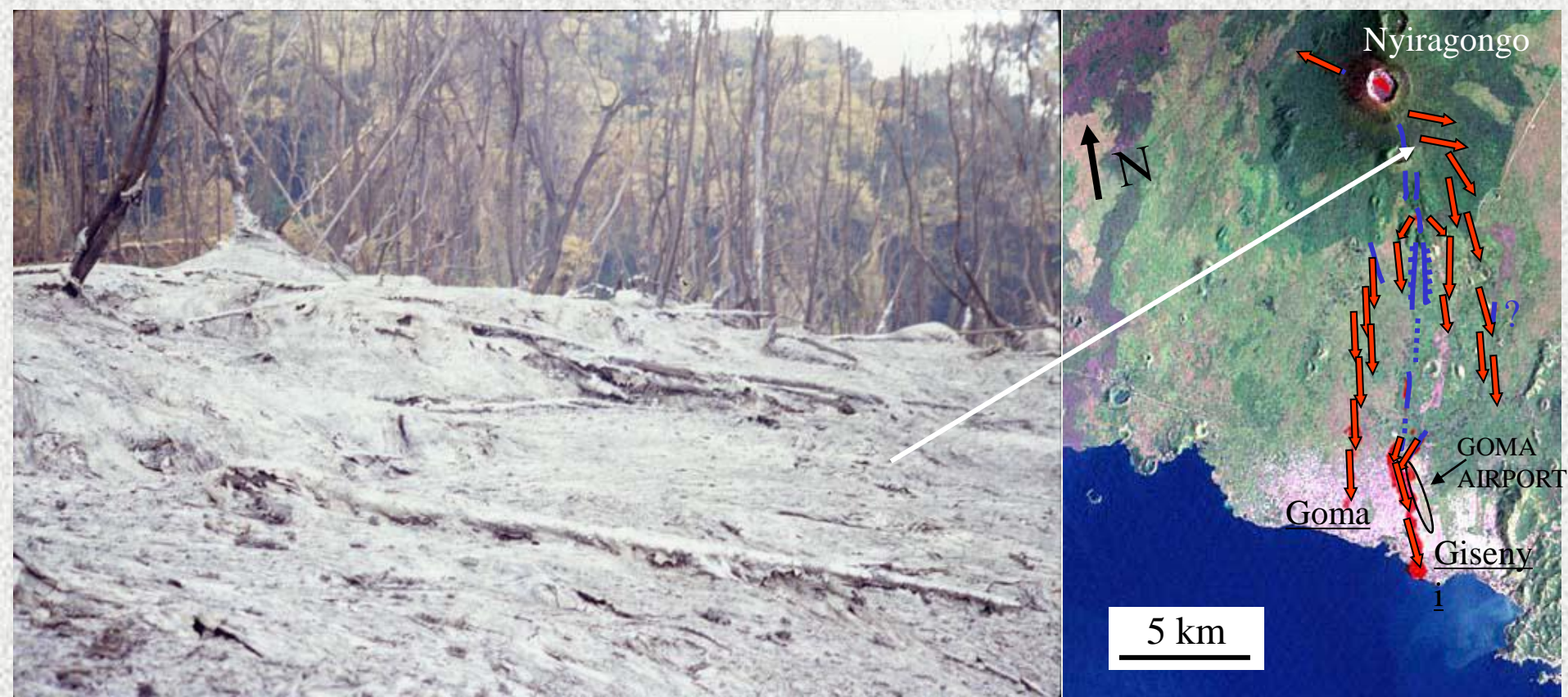
**Around 2 pm, non-eruptive fractures appear along the gentle slopes N of Goma.**

**16h10: eruption in the suburbs of Goma, 1570 m starts – Lava will destroy part of the city of Goma and its airport. The lava flow will reach lake Kivu late in the evening (arriving at a depth of about 70/80 meters).**

**At around 16h30: eruption at 1950 m starts from a fracture about 1.5 km West of the main system of fractures. This lava flow will also cause destruction of part of the city. The lava flow exactly stops on the Goma-Sake road.**



The lava field around the Shaheru fracture is formed by a thin (5-15 cm) layer of lava which appears as a single unit. No structural elements, such as ephemeral vents, lava tunnels, leveés, etc.. are present. Lava from fractures inside and above the Shaheru crater mechanically accumulated inside it, with an estimated thickness of 2-3 m.





Lava emitted from the Northern and higher fractures appears to have been very fluid, capable of surrounding obstacles (such as trees) leaving only thin layer, 1-4 cm, on them. A similar feature of the January 6, 1977 eruption, occurred from the same higher slope fracture.



**In this area the thickness of the active lava flow evaluated from the solidified lava on trees was between 80 and 150 cm depending on local morphology.**

**Only 5 – 15 cm thick solidified lava has remained on the ground.**



Along the eruptive fracture, up to a distance of less than 30 metres, abundant spatters of lava (lava nests) on tree branches suggest that the erupted lava was pushed through the fracture up to at least some tenths of meters. Witnesses said that this activity was visible up to night time. The eruption lasted in this case at least 12 hours.



**The total absence of vent structures like hornitos, spatter cones, or other features, suggests no typical lava fountain activity. Such an activity is commonly associated with the discharge of gas-rich magma, at least during the initial phases of an effusive eruption. The magma erupted on the higher part of the south flank of Nyiragongo seemed to be highly degassed. It is a likely feature of an “old-degassed” magma.**

**Fracturing dynamics is still a matter of debate. In fact there are field evidence that part of the fractures only opened after the eruptive event.**





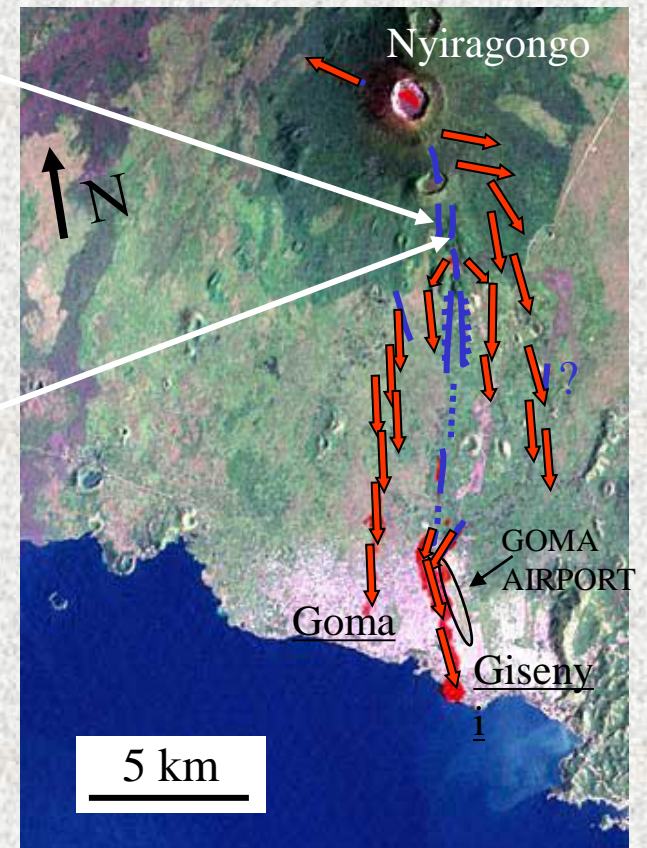
**Some fractures opened after the eruption**

Thin, centimetric, lava layer is visible in most of the different lava fields. The possible total amount of lava emitted during this eruption is of about 20/30 millions of m<sup>3</sup>. The eruption lasted at the most one day, although lava flown into the lake for several days. Being very thin, parts of the lava field on the crater slopes have been already colonized by plants.

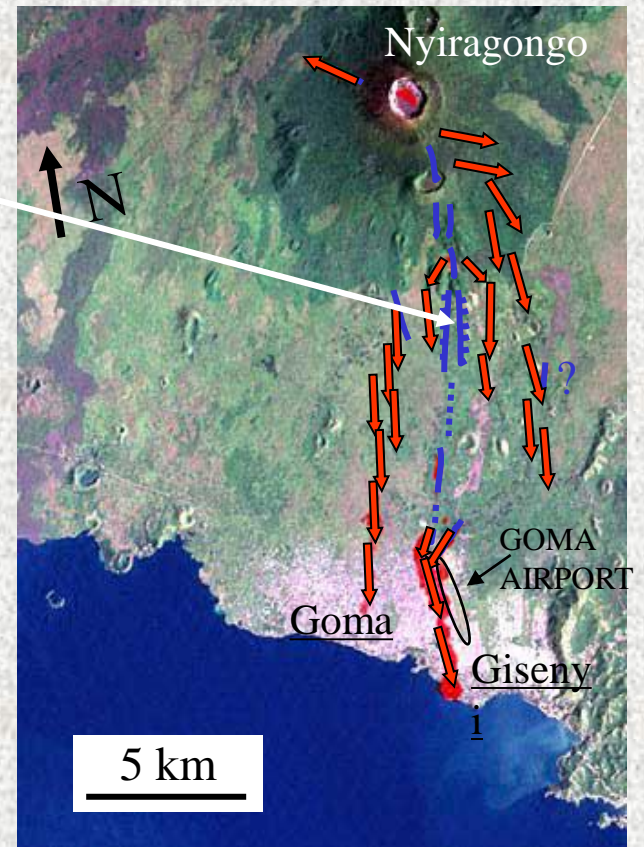




**Sub-parallel fractures, about 300 m apart, along the South flank of Shاهرu**



More to the South, the area between the two fractures was locally covered by a thin layer of lava...

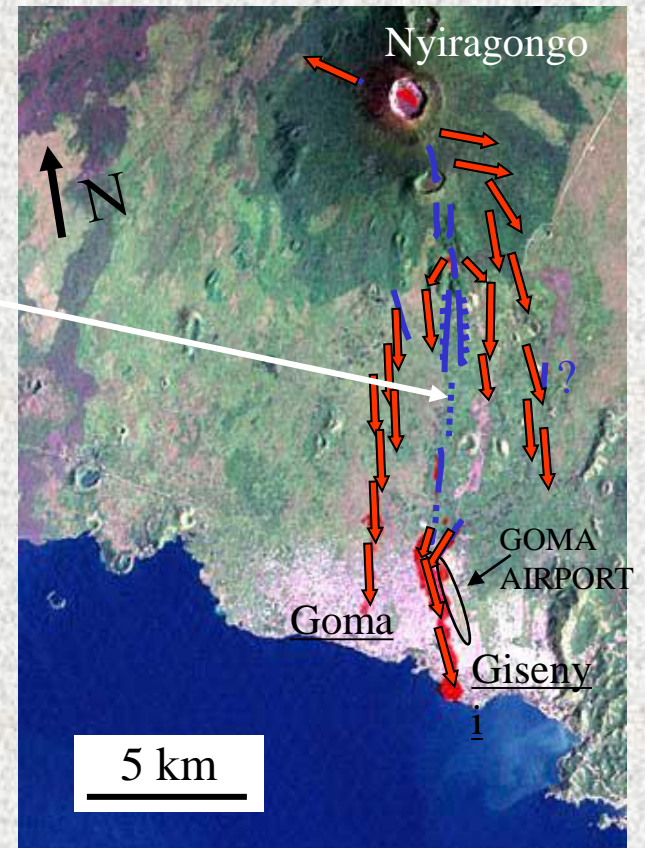




... but further south, in the cultivated areas North of Goma, the fractures were not associated to emission of lava.

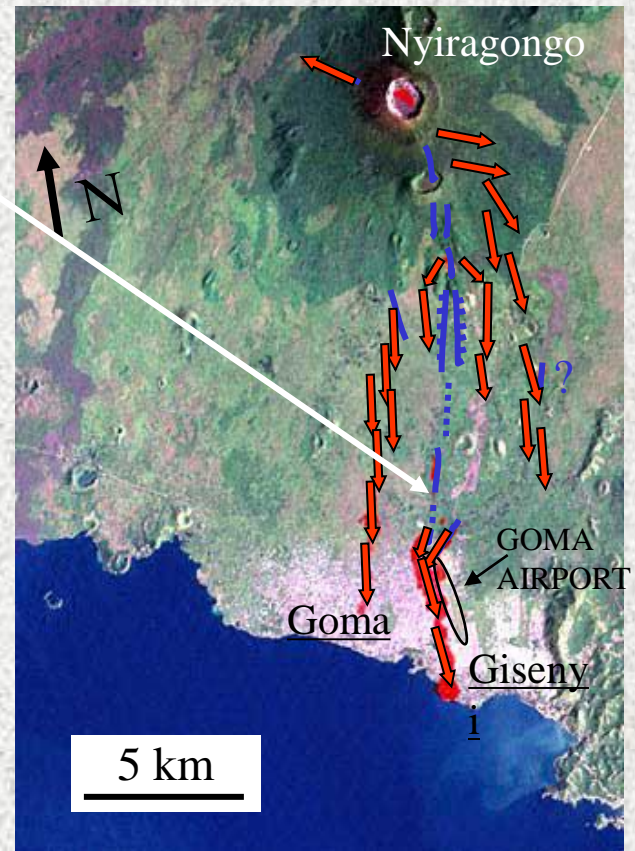


These fractures appeared at around 2pm. Lava eruption only started at 4.10pm, about 2 km to the South, at an altitude around 100 m lower.

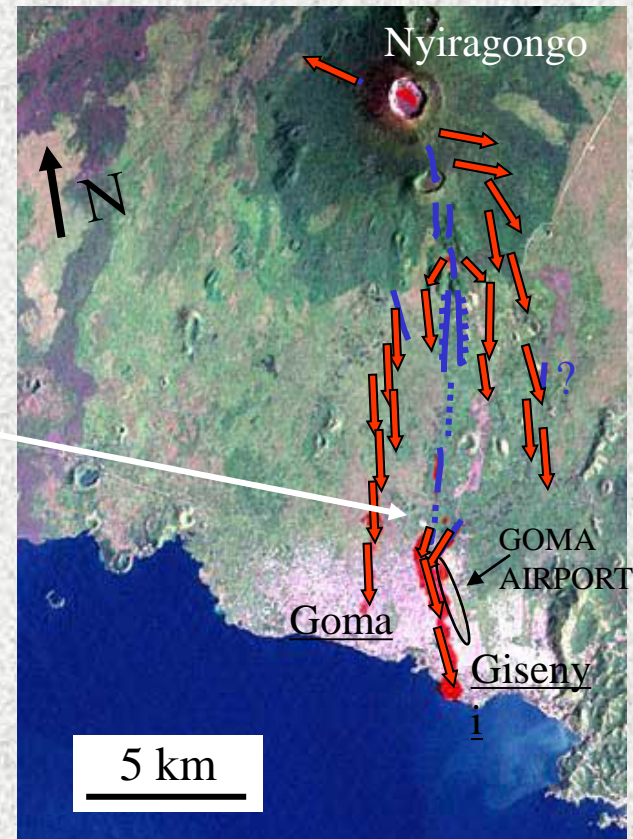




Munigi village. The solidified top of a dike can be seen within fractures, sometimes less than 1 m below the ground level.



**On the Northern outskirts of the city of Goma, an important new lava emission occurred. Here, the eruptive fracture is outlined by several hundred m long alignment, of up to 20 m high, of spatter cones and hornitos, testifying important undegassed lava (fountain) activity. Differently than in the higher part of the fracture system, lava erupted here looked fresh and gas-rich. It is of the most importance to trace at depth its source-region. The lava flows devastated the city of Goma and partially the Goma airport.**



The scoria and spatter are glassy, highly vesicular, and very expanded. Gas vesicles of decimeter-size are common.



**To confirm our hypothesis (of the existence of two different sources for the north-high slope and south-down slope lava flows), high resolution gamma analyses (Coaxial Ge) have given the following results:**

**Shaheru:  $^{228}\text{Ra}/^{228}\text{Th}$  (activity ratio) : 0.94 +/- 0.02 (up to 10-12 years old)**

**Munigi:  $^{228}\text{Ra}/^{228}\text{Th}$  (activity ratio) : 1.00 +/- 0.03 (recent lava – no age)**

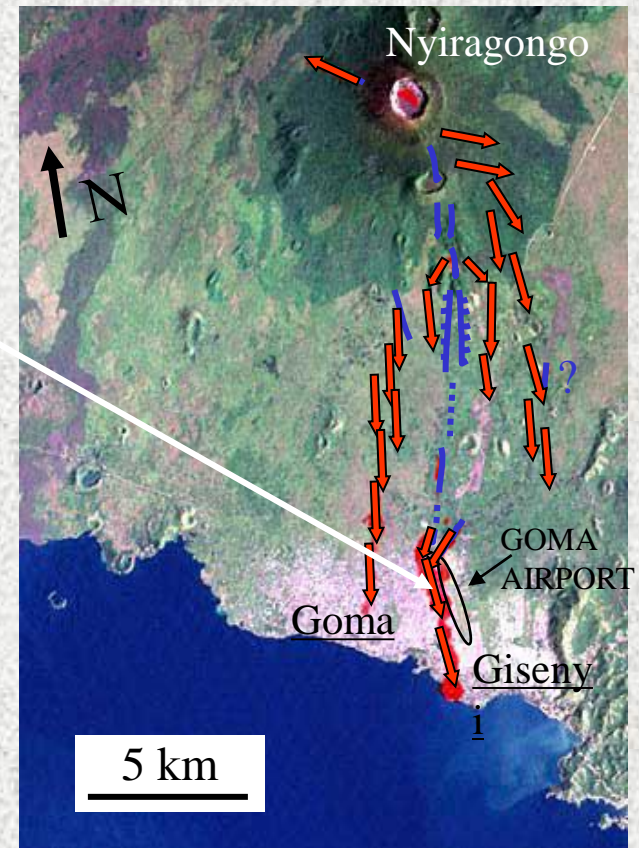
**Western Most fracture  $^{228}\text{Ra}/^{228}\text{Th}$  (activity ratio) : 1.03 +/- 0.03 (recent lava – no age)**

**These results suggest that magma feeding the Shaheru lava flow was affected by some phenomenon of differentiation which caused a significant radioactive di-sequilibrium between  $^{228}\text{Ra}$  and  $^{228}\text{Th}$ . The activity ratio between these two radionuclides tends towards the unity when the magma is fresh or without any differentiation process (such as the case of Munigi and W.F. samples). Therefore depletion of radium at Shaheru respect to thorium occurred in a previous period, that can be quantified in the order of 10/12 years (data performed by M. Voltaggio).**



The lava field across Goma is 100-500 m wide, of the aa type. Several ephemeral vents opened on the lava flow surface.

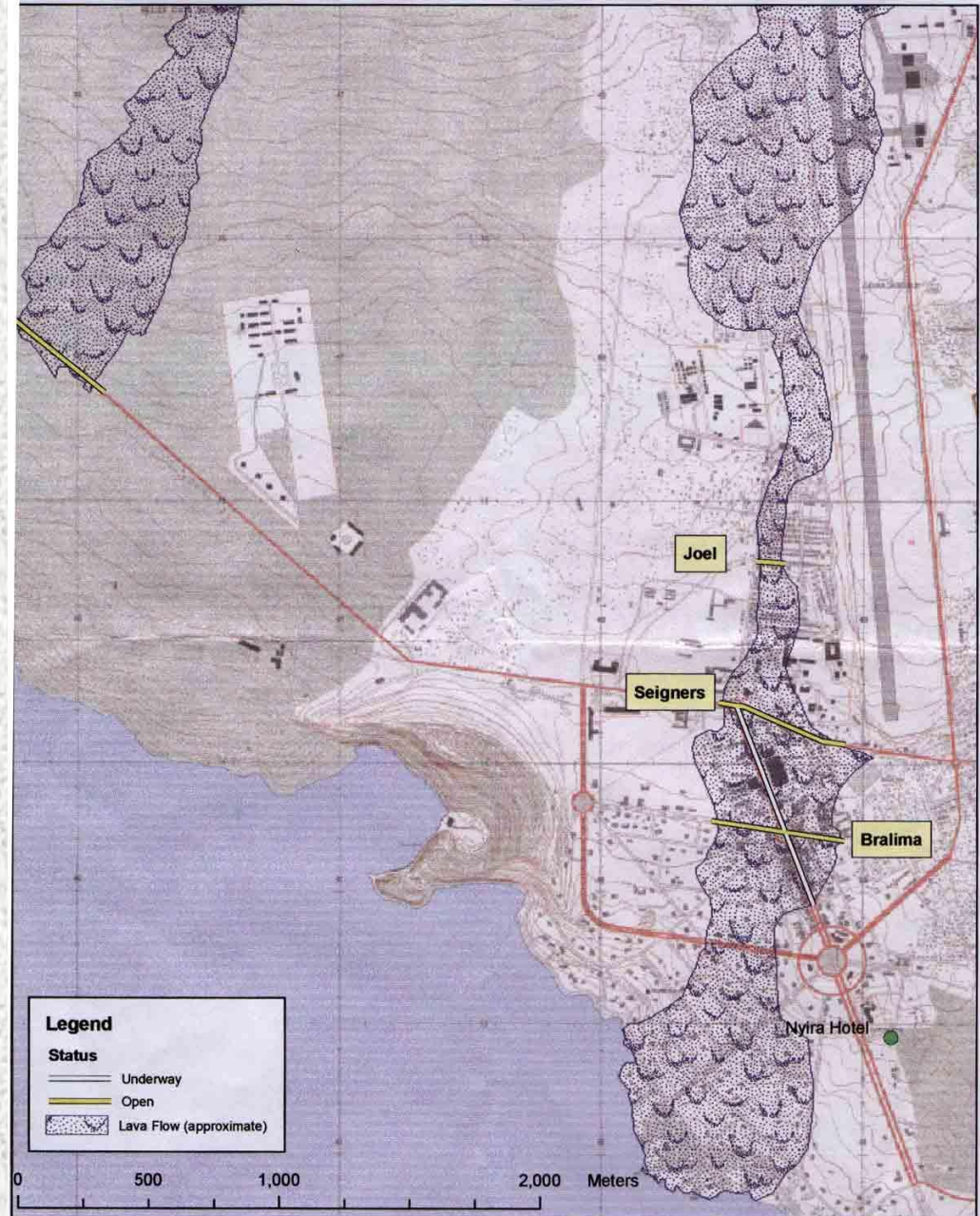
Field work evidences that fractures most probably opened also in the city of Goma. A video, recorded at night during the eruption, shows the opening of inside town vents.



The lava flows in central Goma, mapped a few days after the January 17, 2002 eruption.

The Eastern branch originated from 1550 m a.s.l. (Munigi vents), and took about 10 hours to reach the shore of lake Kivu. The Western branch originated from 1950 m a.s.l. stopped just on the Goma-Sake road.

13% of the city was totally destroyed. More than 100,000 people became homeless





Spontaneous evacuation from the city of Goma. The crowd walking from Goma to Giseniy next to the Rwandan border.

Spontaneous return to Goma only 24 hours from the startinf of the eruption. People walking on the new and still “**hot**” lava flow.





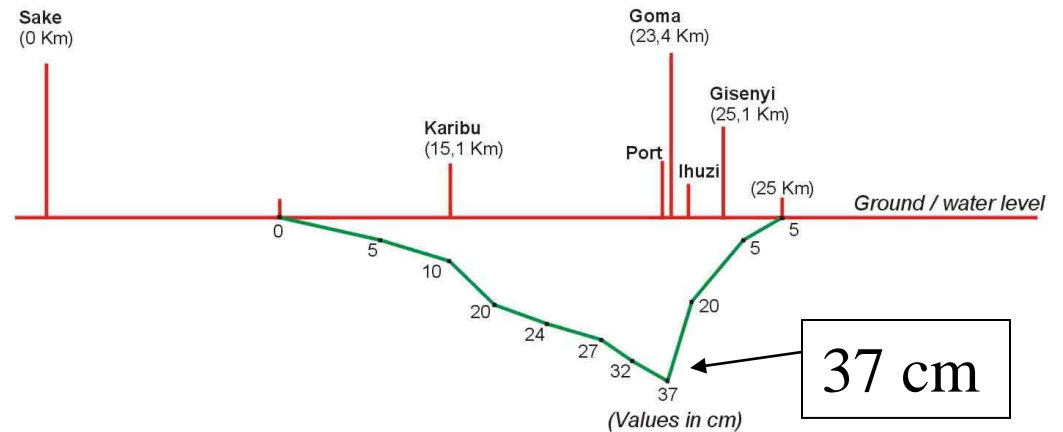
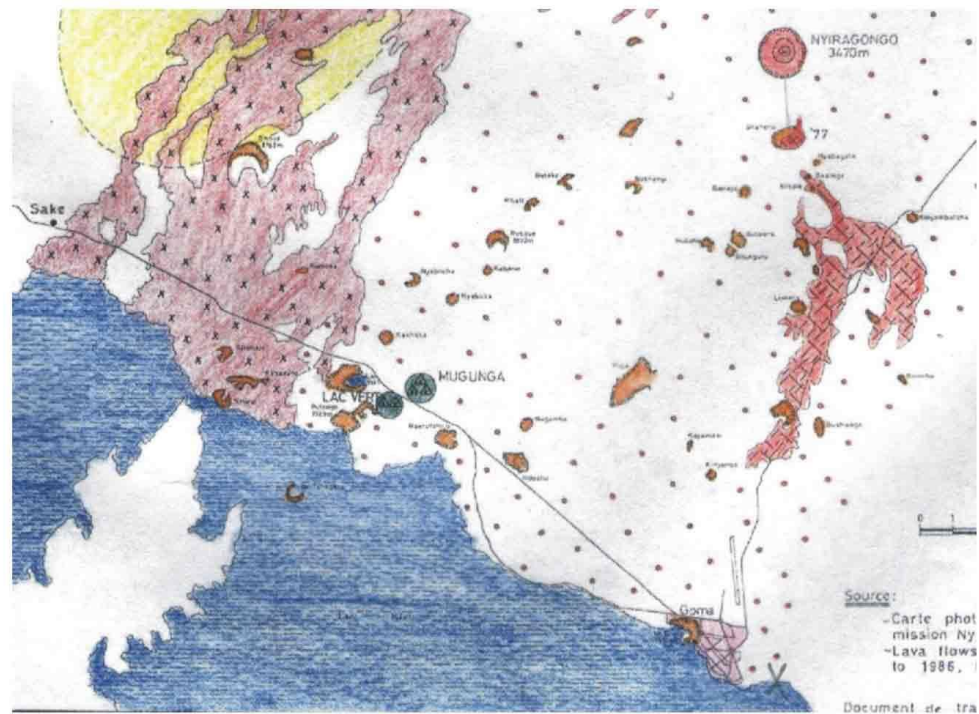


## Survey of January 28

Rumours of water level variations intrigued us to start measuring bench marks on the shoreline of lake Kivu.

Results revealed a marked subsidence in the central area of the rift, fading towards its borders.

The maximum subsidence corresponds to Goma harbour.



# Destruction ...















# **First Humanitarian Response: Re-starting of life-pipelines.**



**Reopening of Roads**

# Health Care Centers



# Water Distribution



## Food Distribution



## **Conclusions?**

**More questions than answers ... a lots have been done but more, much more, remains to do.**

**The local Goma Volcano Observatory needs a long term perspective in order to assure a continuous and correct evaluation of the activity of the two volcanoes.**

**Help (funds) and cooperation (projects and training) is needed in several fields for both low and high tech projects.**

**The January 17, 2002 eruption was a very small eruption, but its impact was enormous.**

**The Rifting episode we have witnessed and the following activity, volcanic (the activity is still very high) and non volcanic (environmental, *e.g.* water, and possible future health problems due to the gas plume) suggest that awareness have to remain very high.**

**Do not repeat this again! Cooperation  
means also: Assessment, Prevention  
and Mitigation.**

