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The January 2002 Volcano-Tectonic Eruption of Nyiragongo volcano, Democratic Republic of Congo

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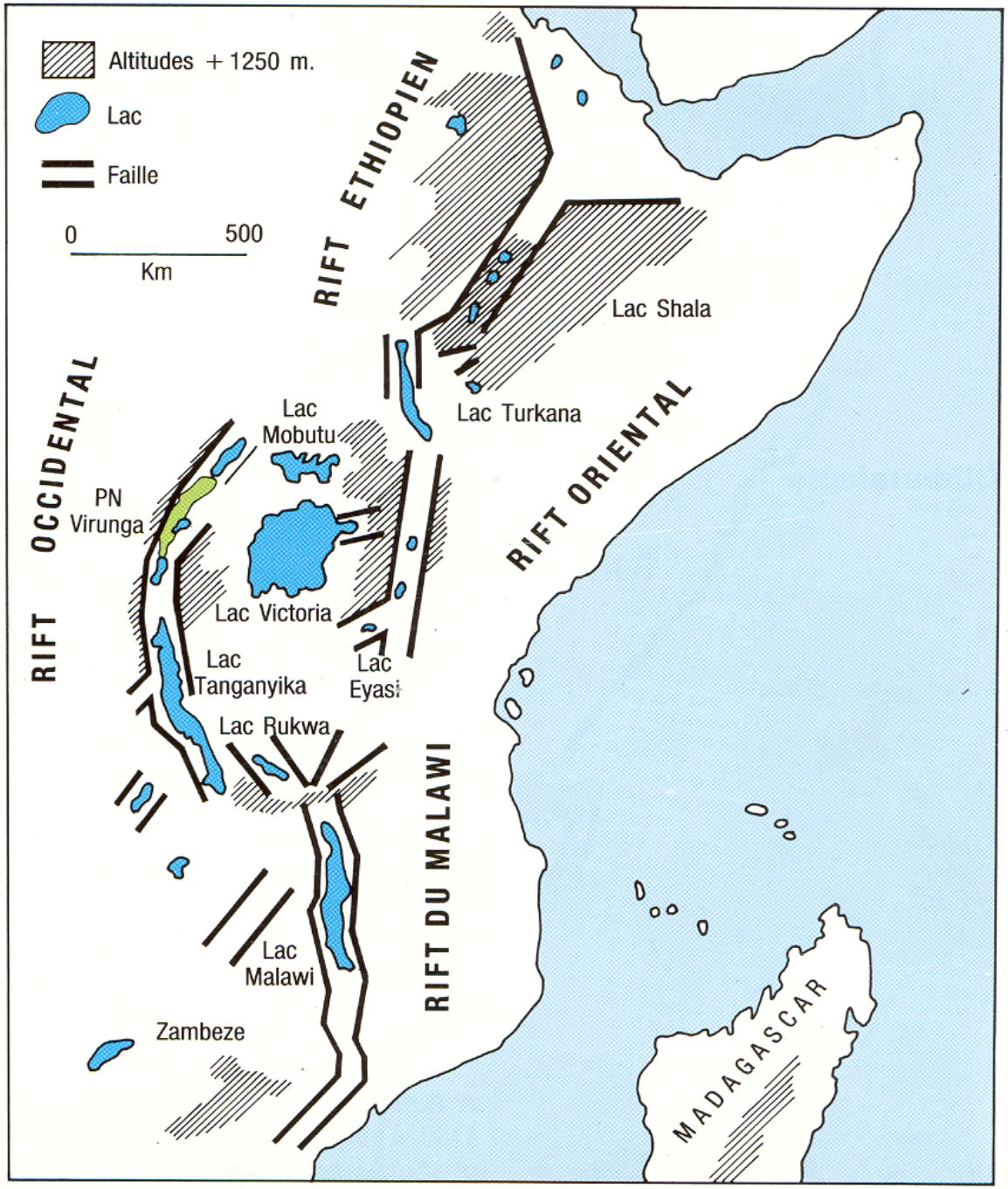
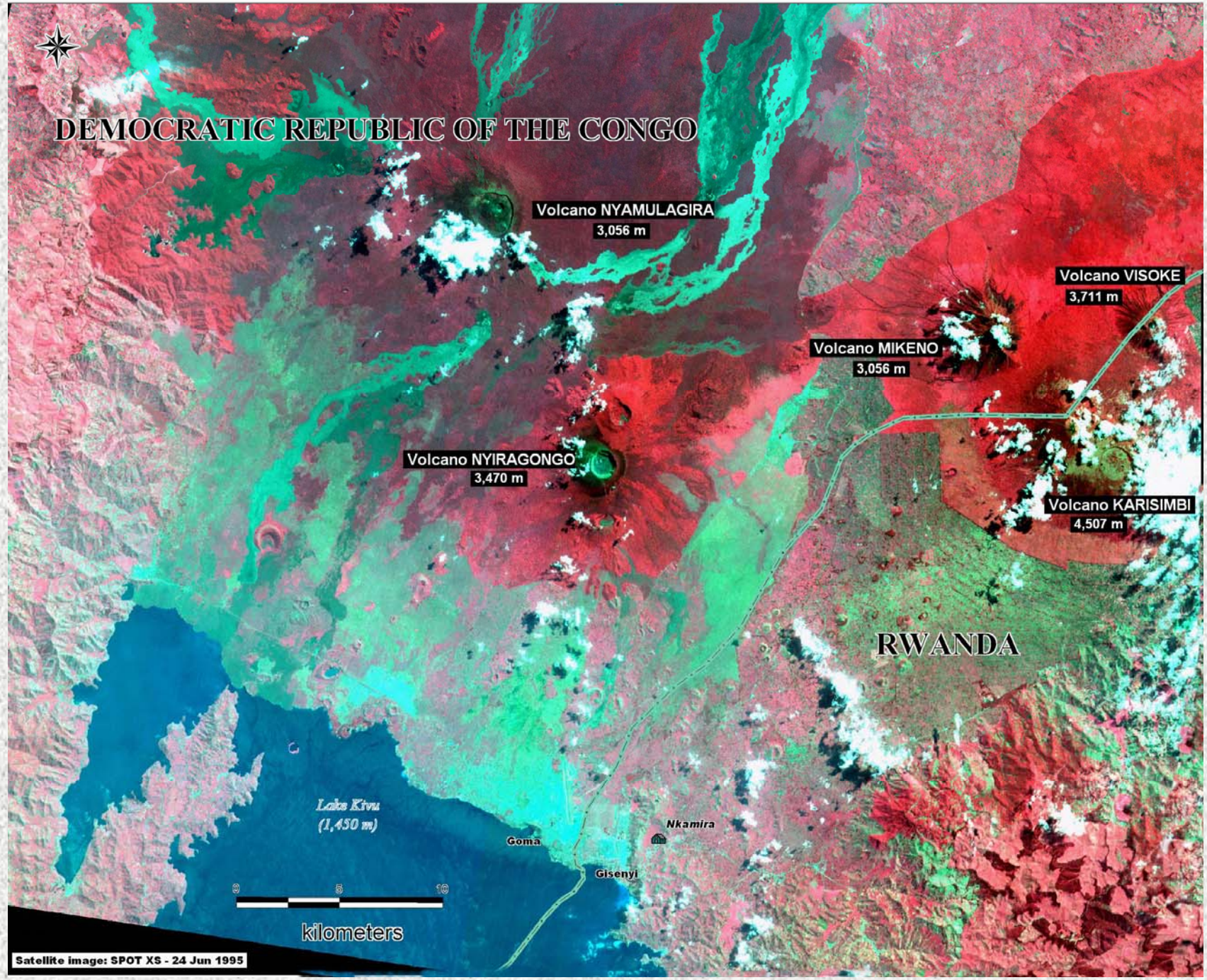
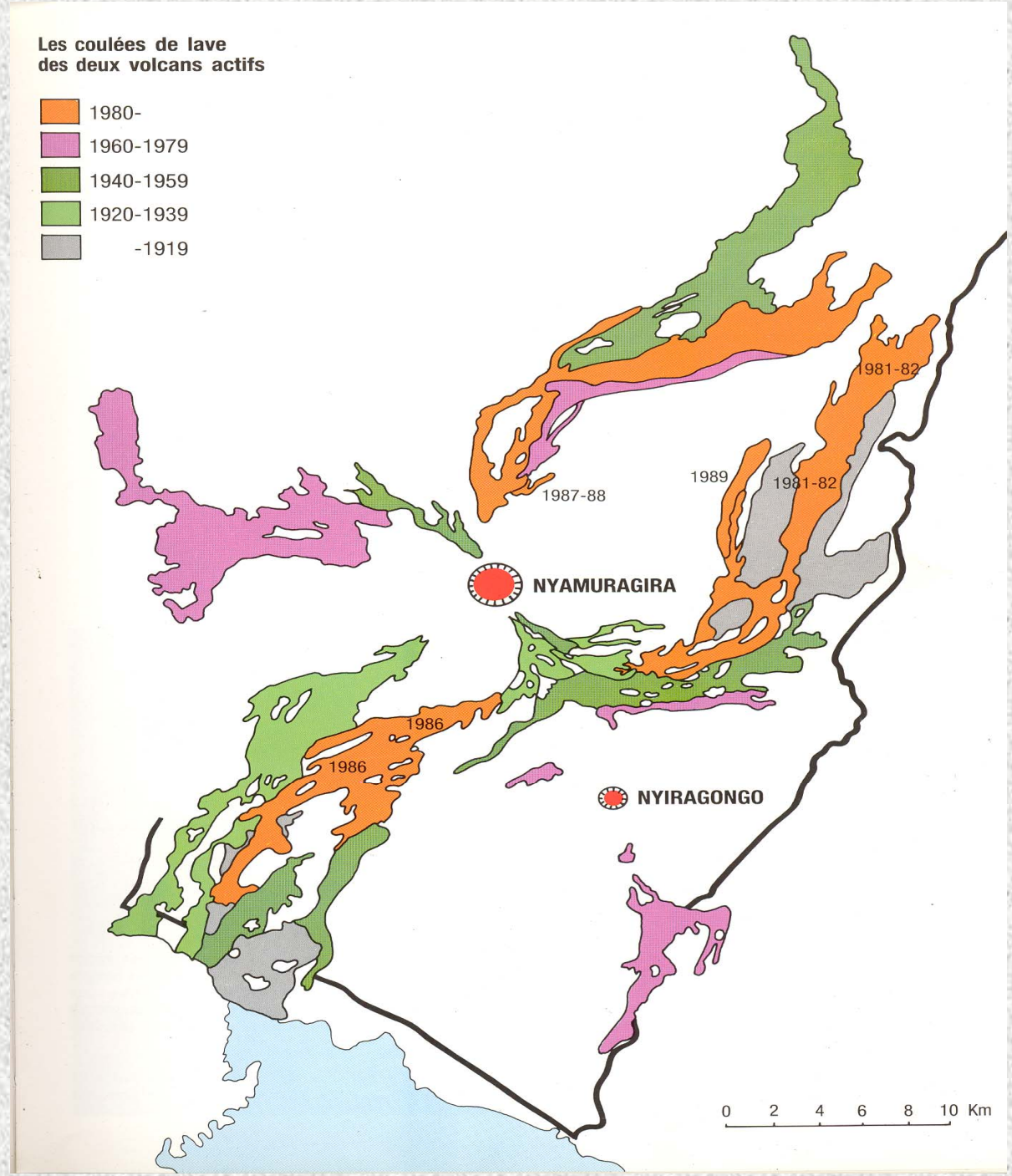
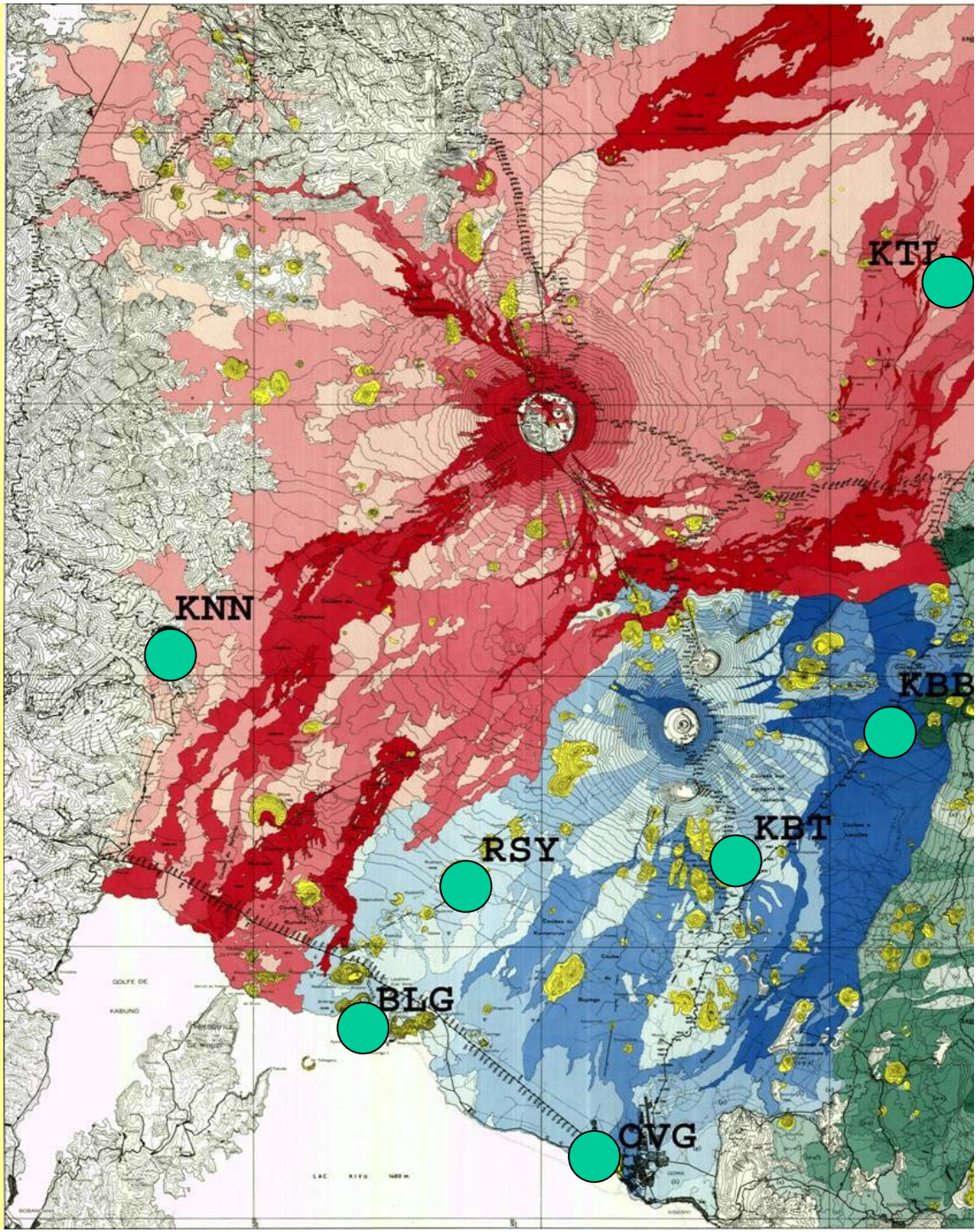
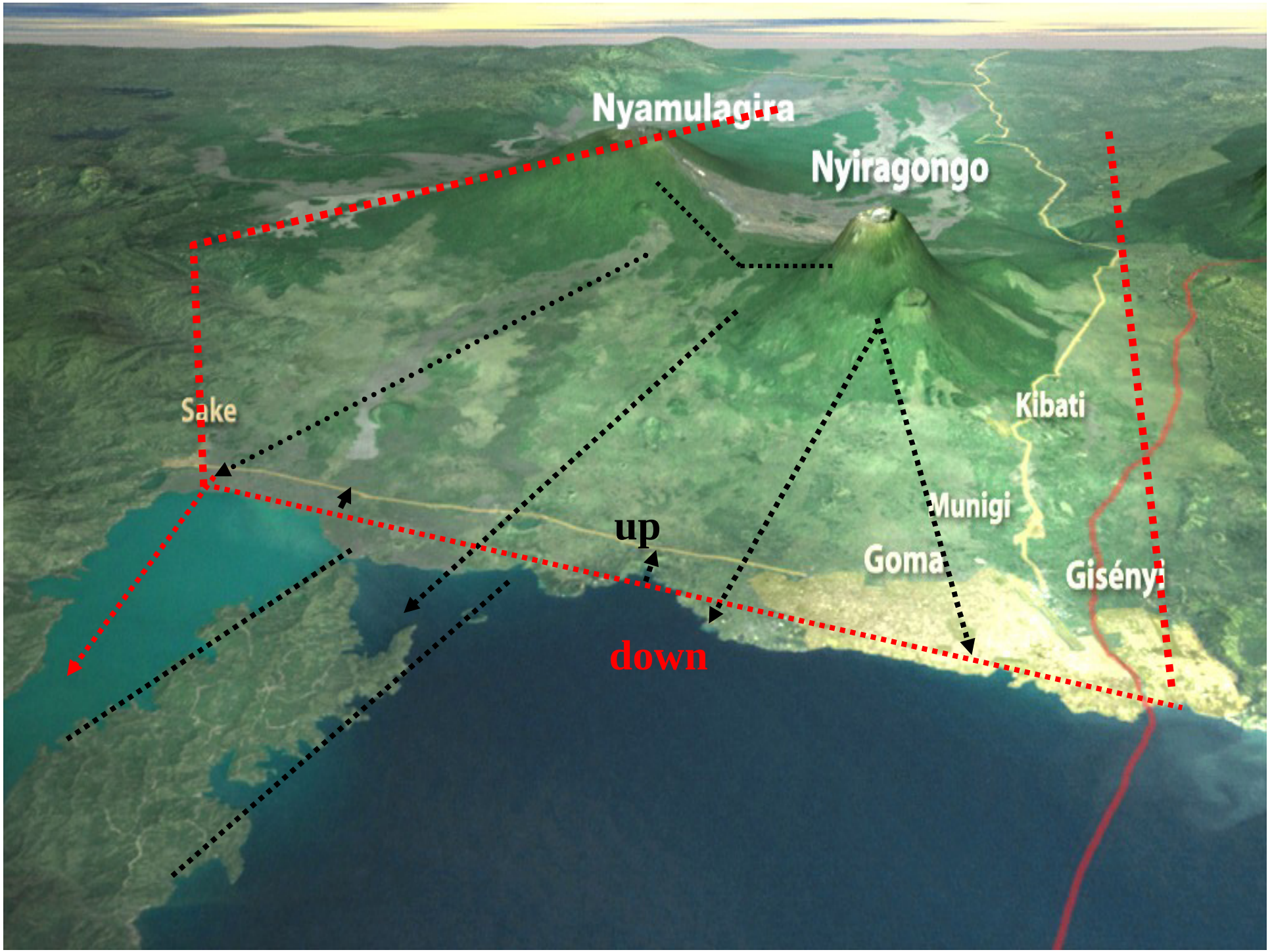

Altitudes + 1250 m.
Lac
Faille
0
500
Km
RIFT ETHIOPIEN
RIFT OCCIDENTAL
RIFT ORIENTAL
RIFT DU MALAWI
Lac Shala
Lac Turkana
Lac Mobutu
PN Virunga
Lac Victoria
Lac Tanganyika
Lac Eyasi
Lac Rukwa
Lac Malawi
Zambeze
MADAGASCAR


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
0
5
10
kilometers
Satellite image: SPOT XS - 24 Jun 1995


Les coulées de lave
des deux volcans actifs
1980-
1960-1979
1940-1959
1920-1939
-1919
1987-88
1989
1981-82
1981-82
NYAMURAGIRA
1986
1986
NYIRAGONGO
0 2 4 6 8 10 Km

Volcanological map of Nyiragongo and Nyamulagira volcanoes with the digital seismic network sourrounding the volcanoes. The north-western side of the volcanoes cannot be covered because of (i) a highly forested area and (ii) the presence of armed local militias bringing strong insecurity in the whole area.



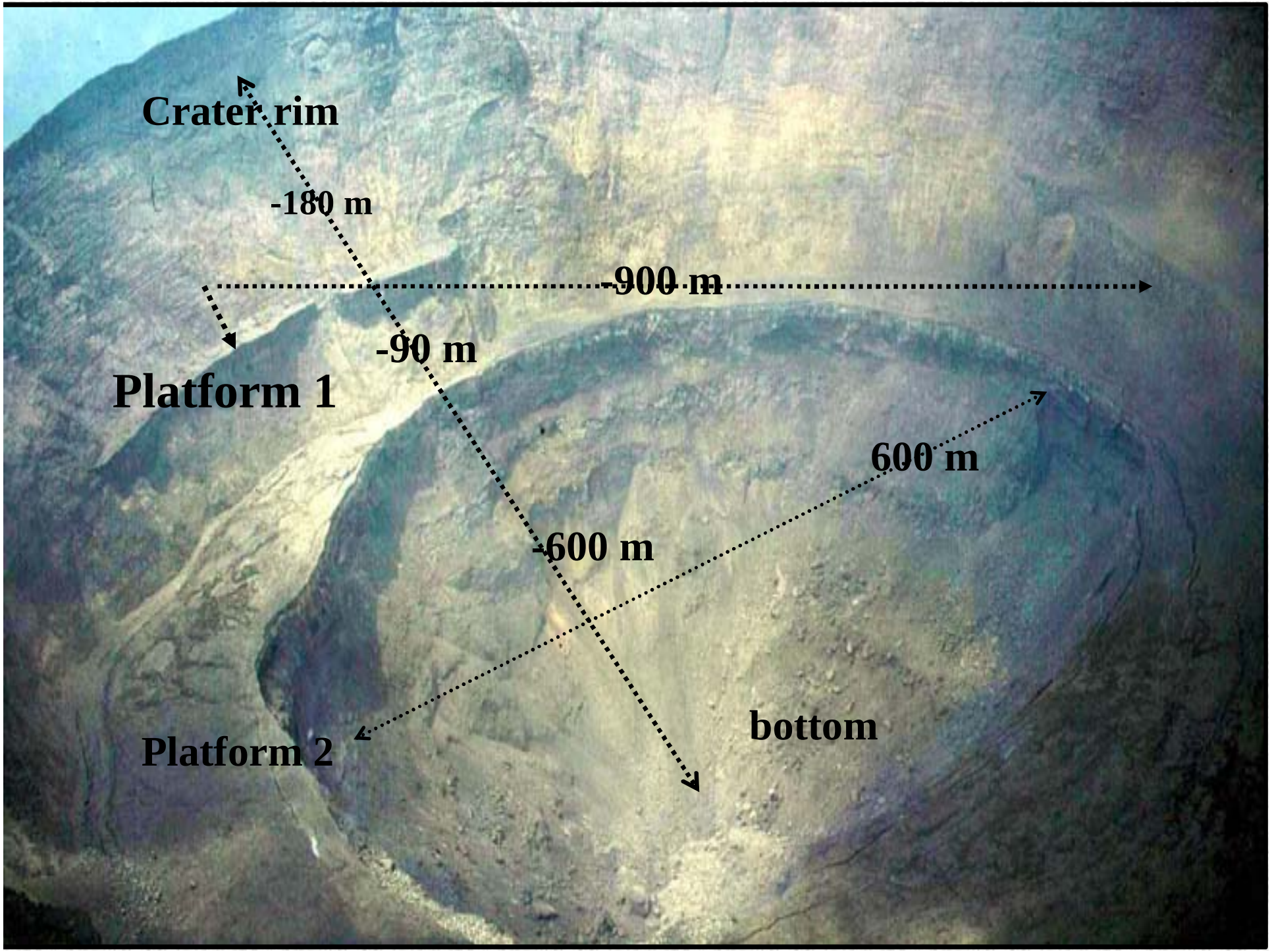

Nyamulagira
Nyiragongo
Sake
Kibati
Munigi
Goma
Gisényi
up
down

Goma Volcano Observatory and Nyiragongo volcano 15 km away.

View of the inside crater in 1995, showing on the crater floor the presence of a thick solified 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 circural fractures.

The situation, radically changes the day after.


Crater rim
-180 m
-900 m
-90 m
Platform 1
600 m
-600 m
bottom
Platform 2

Nyiragongo eruption, January 17 2002

The fractures system propagates from N to S at different time, not all fractures erupt while part of fracture system developed after the eruptive activity.

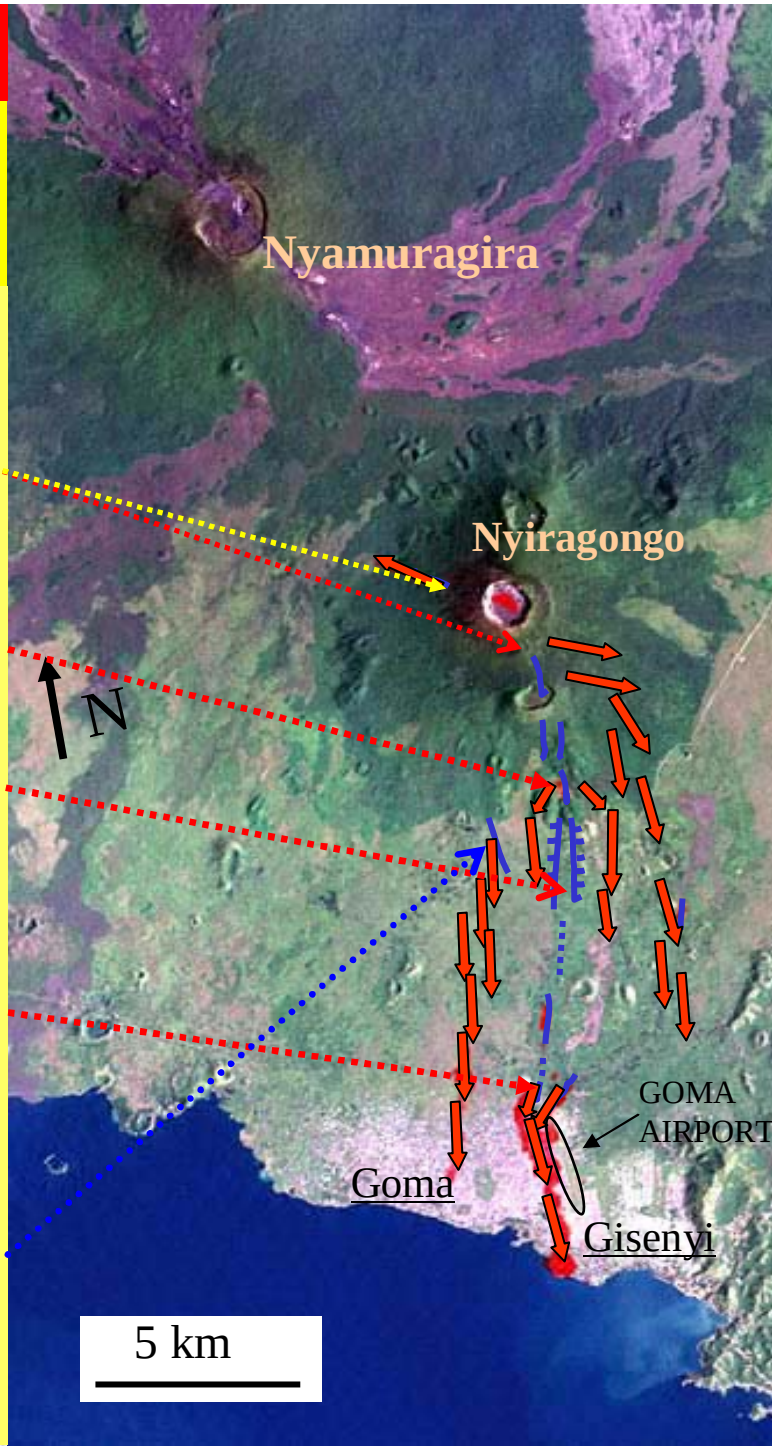
8h25: eruption starts. Seismograms saturated. Fracture open N of Shaheru crater, and N of main crater at about 2700 m. Lava flows inside and laterally the crater of Shaheru.

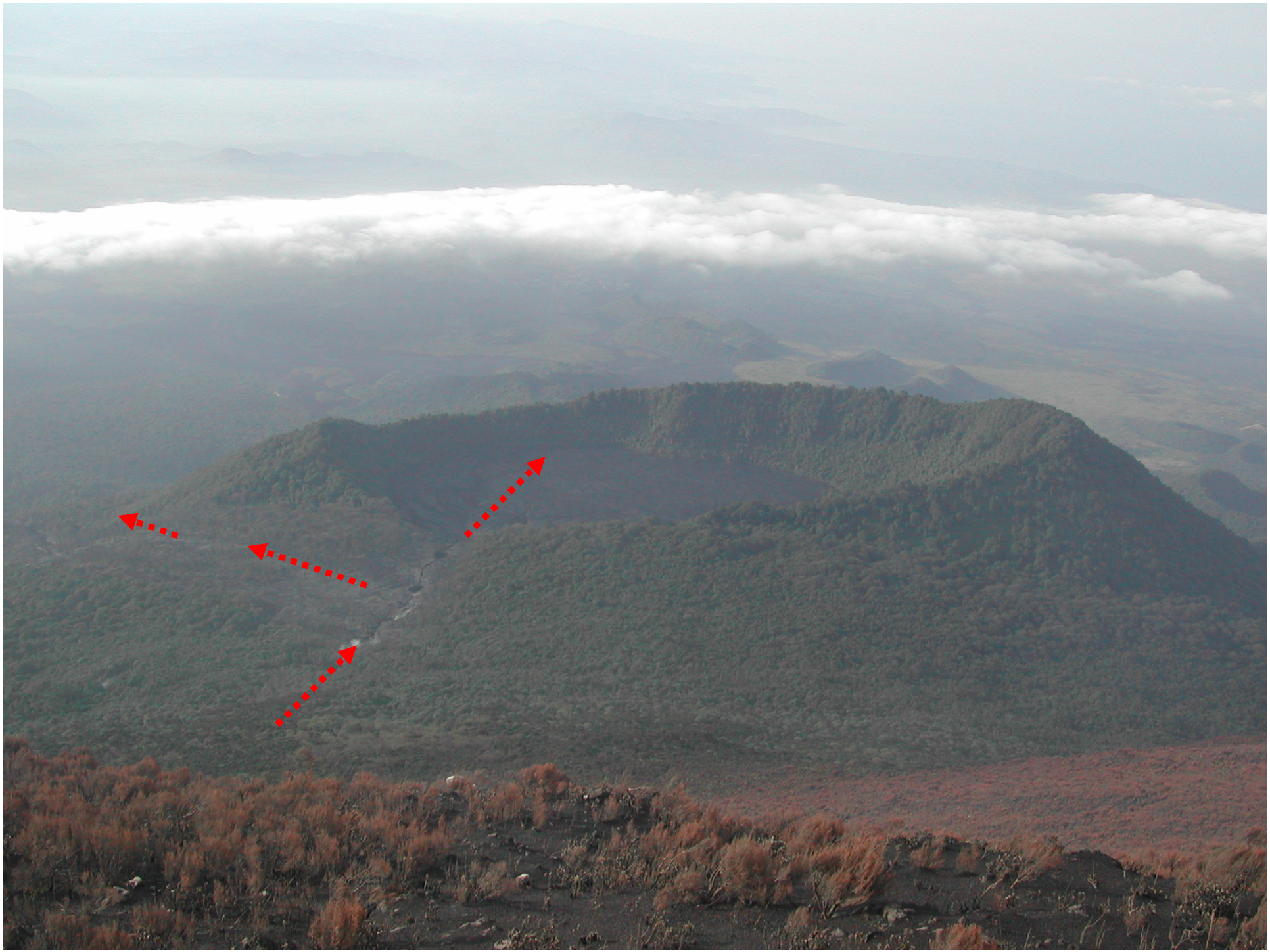
Around 10 am, lasting at least 2 hours: eruption begins between 1950 – 2000 m.

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

16h10: eruption starts in the suburbs of Goma at Monigi, 1570 msl – 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.

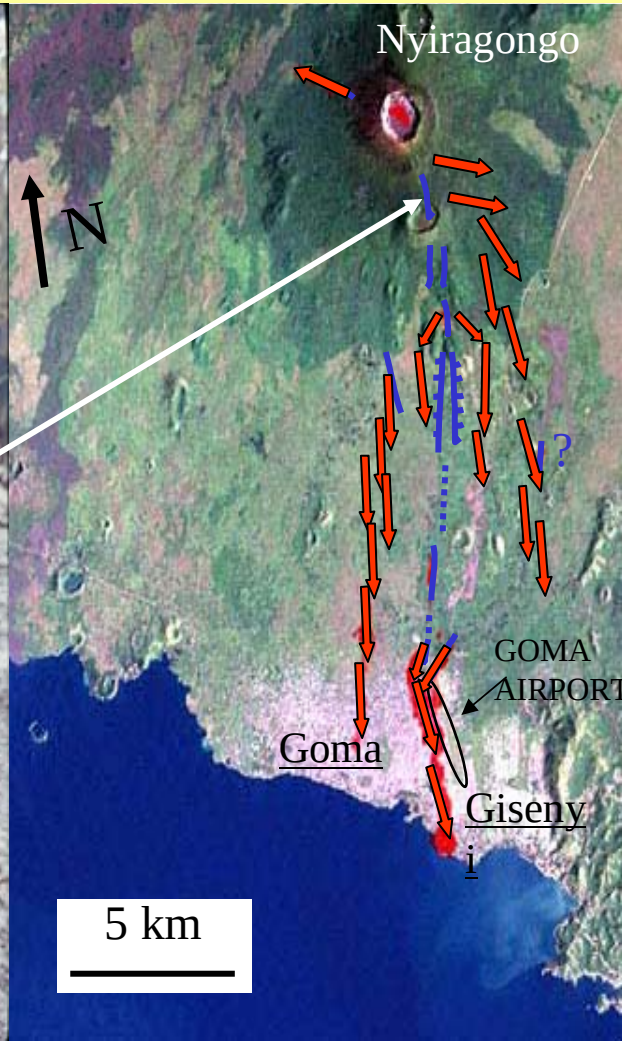




Along the eruptive fracture, up to a distance of less than 30 metres, abundant spatters of lava (lava nests) on tree branches suggest that the erupted lava was pushed through the fracture up to at least several tenths of meters. Witnesses said …"this activity was visible up to night time". The eruption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

***in this area**

The lava field around the Shaheru fracture is formed by a thin (5-15 cm) layer of lava appearing 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 fracture system appears to have been very fluid, able to surround obstacles (such as trees) leaving only thin layers, 1-4 cm, on them. The same feature occurred one January 6, 1977 eruption, from the same higher slope fracture.

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

Only 5 – 15 cm thick solified lava remained on the ground.

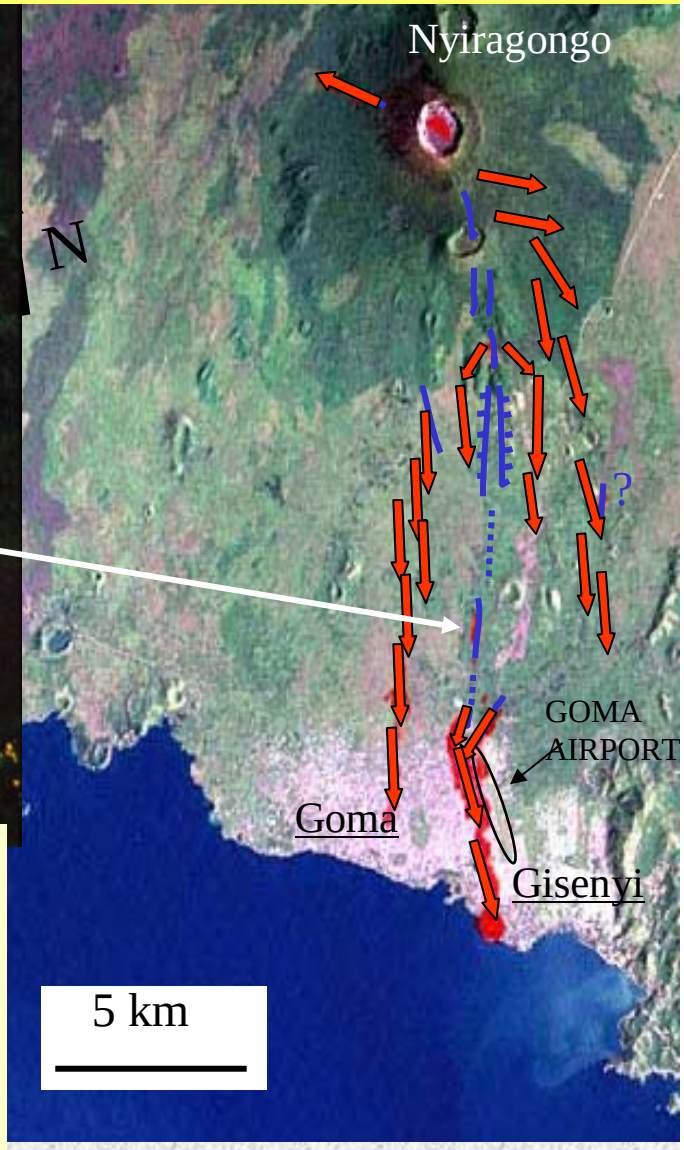
The total absence of vent structures like hornitos, spatter cones, or other typical eruptive features, suggests no typical lava fountain activity, but high pressure. Such an activity is commonly associated with discharge of gas-rich magmas, at least during the initial phases of an effusive eruption. The magma erupted on the higher part of the southern 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 evidences that part of the fractures only opened after the eruptive event.

Which means a tectonic more than a volcanic driven eruptive event.

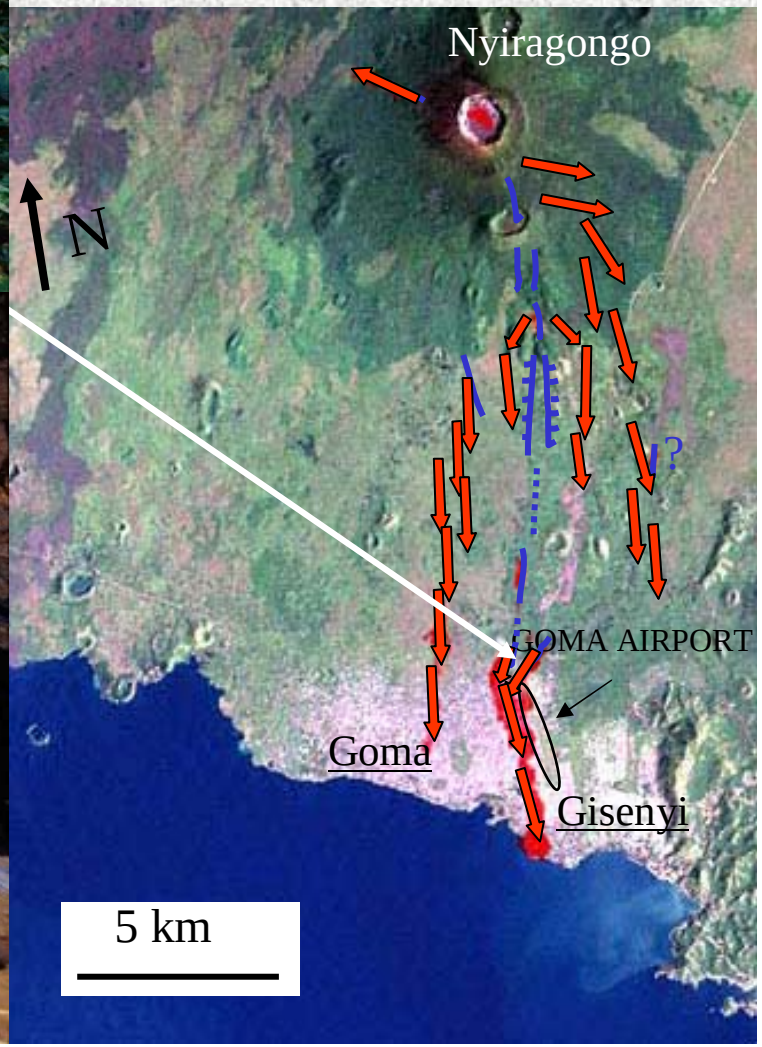
In fact…

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

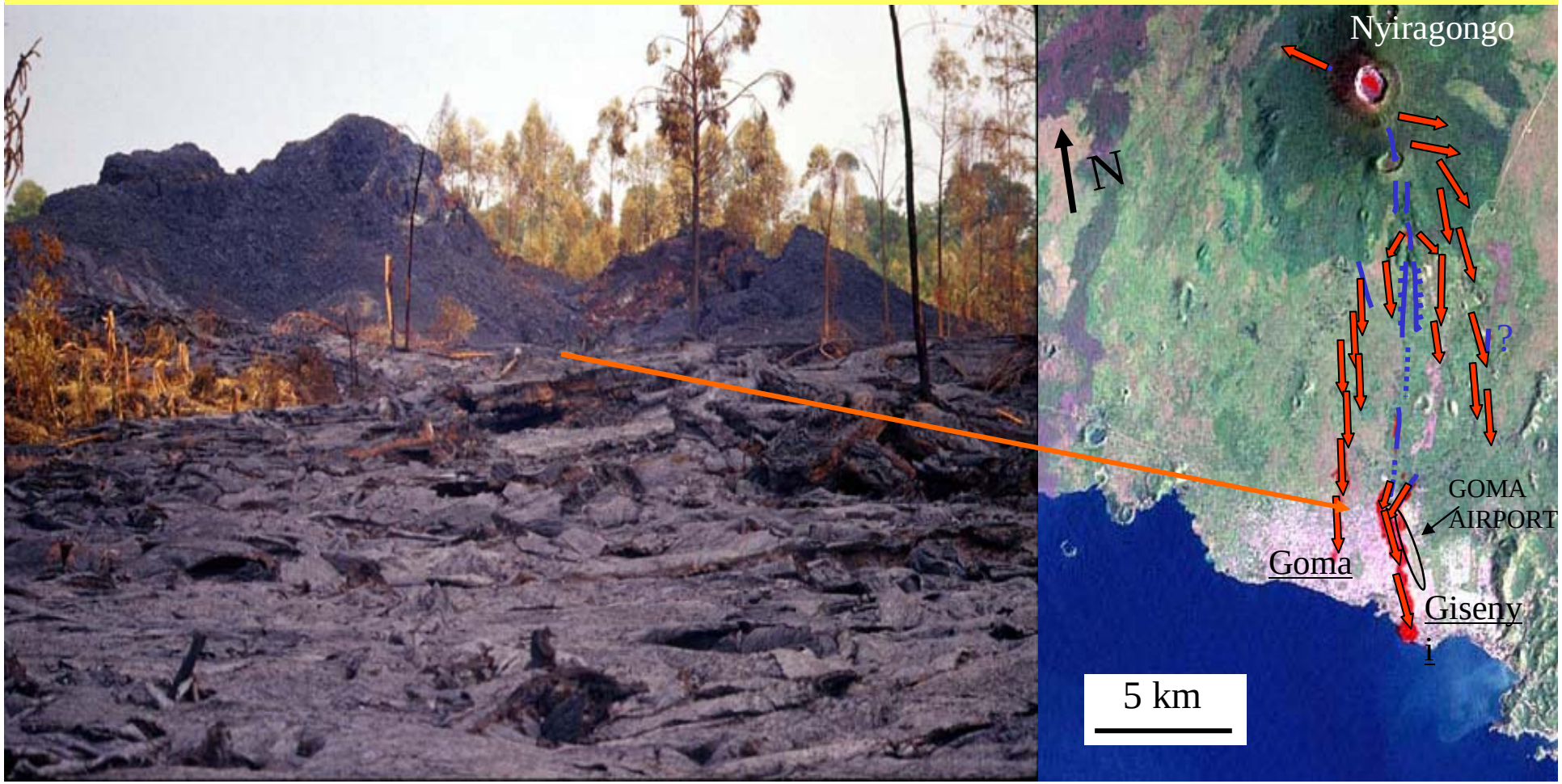


These fractures appeared at around 2pm. Lava eruption only started at 4.10pm, about 2 km to the South, at an altitude around 100 m lower.

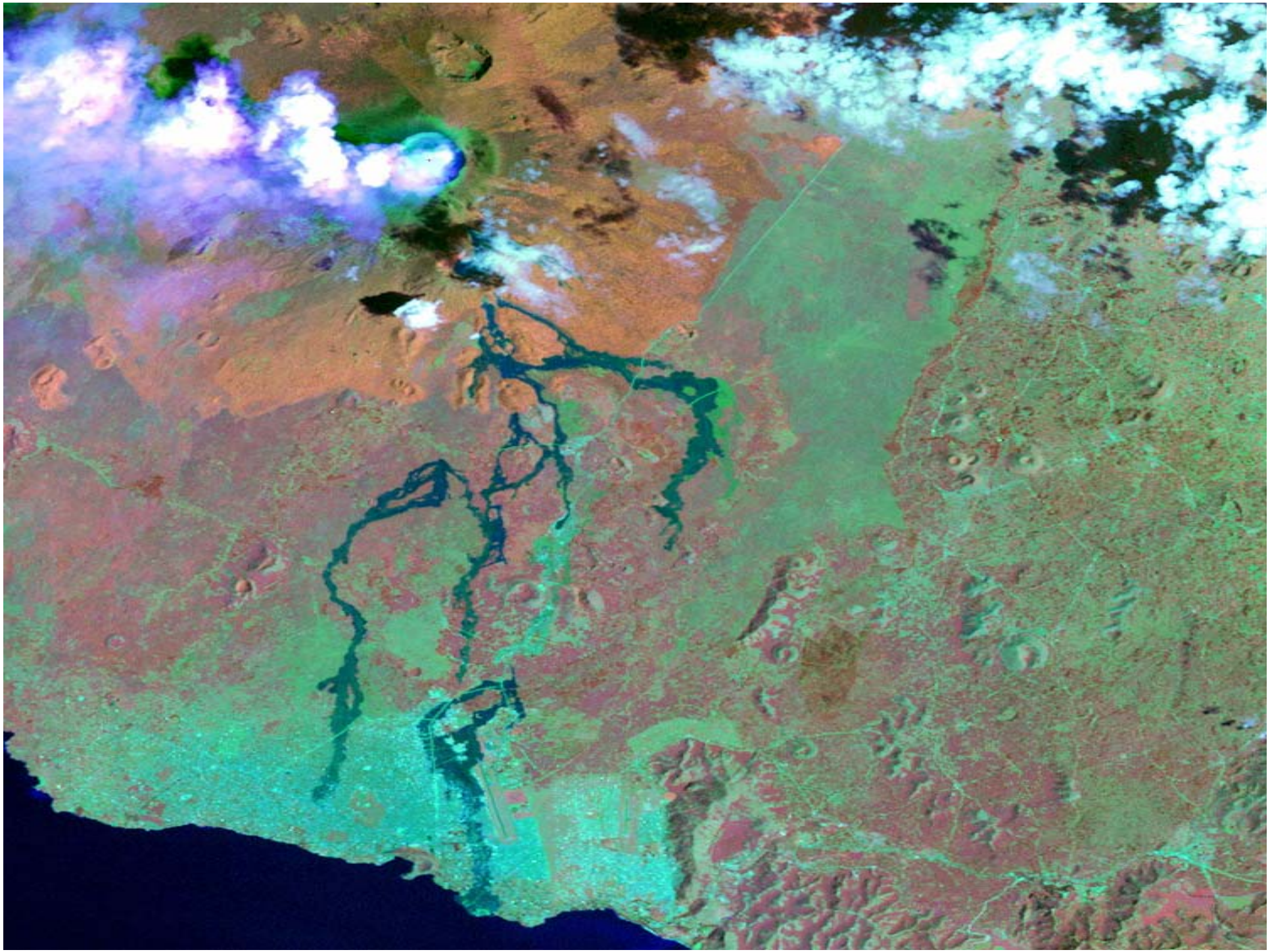
Munigi village. The solified top of a dike can be seen within fractures, sometimes less than 1 m below the ground level.



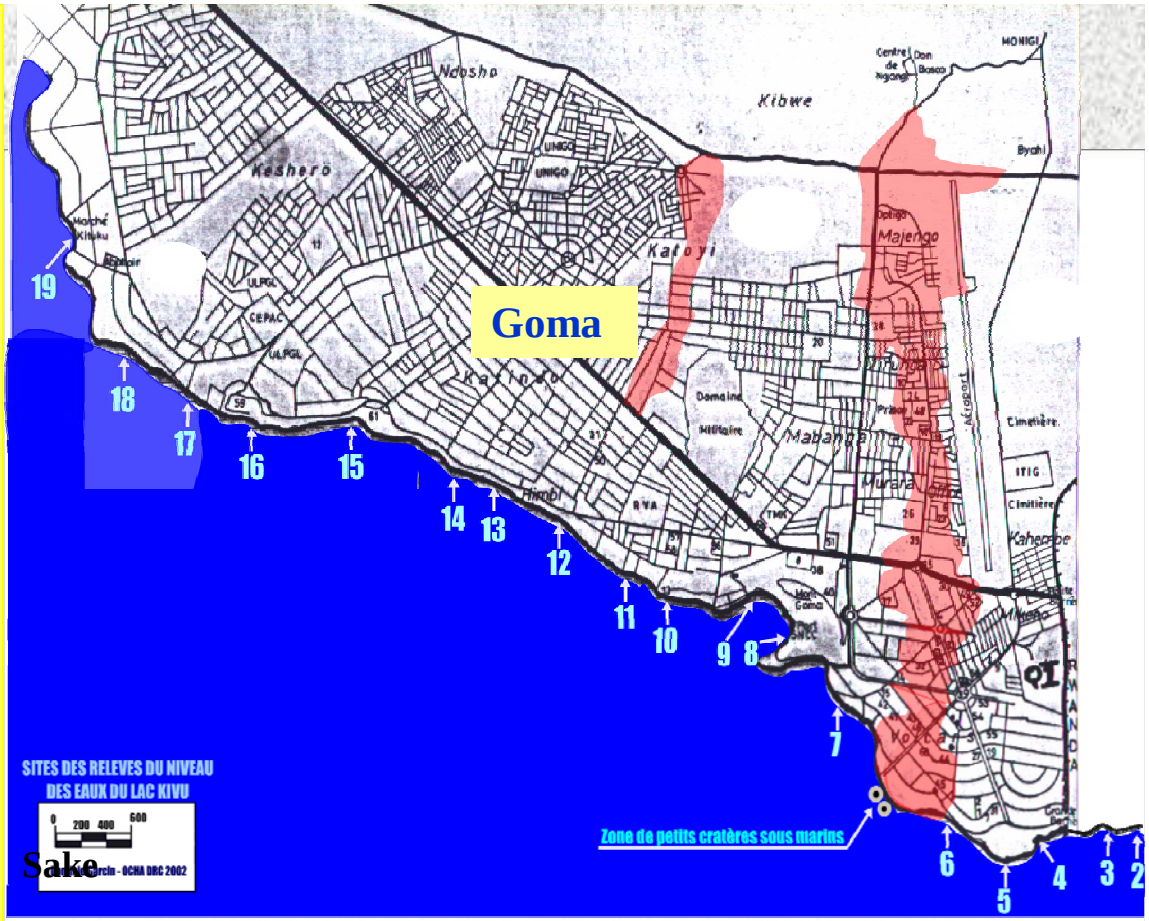
On the Northern outskirt of the city of Goma, an important new lava emission occurred. Here, the eruptive fracture is outlined by several hundred m long alignment, of up to 20 m high, of spatter cones and hornitos, testifying important undegassed lava (fountain) activity. Differently than in the higher 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 feeded by such an activity devastated the city of Goma and partially the Goma airport.

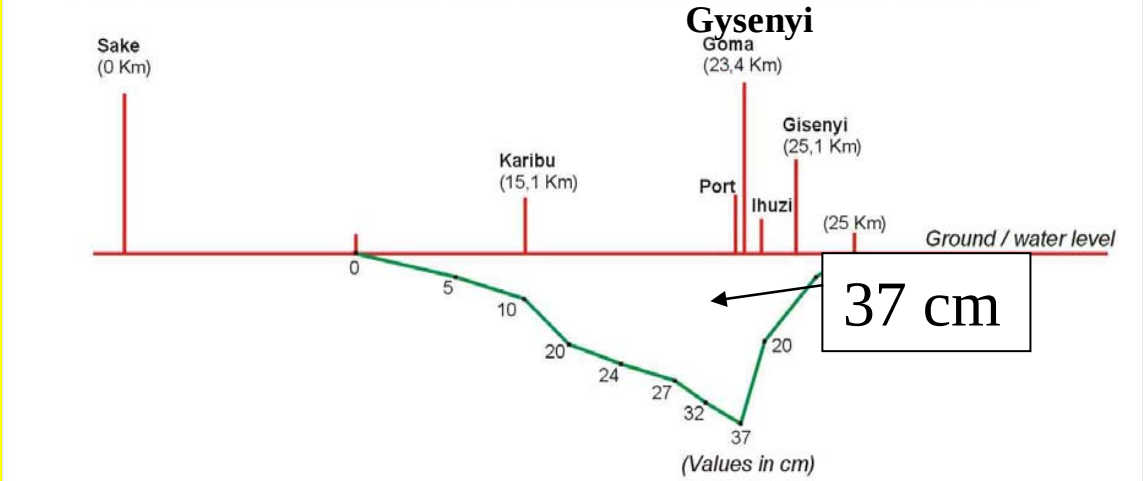


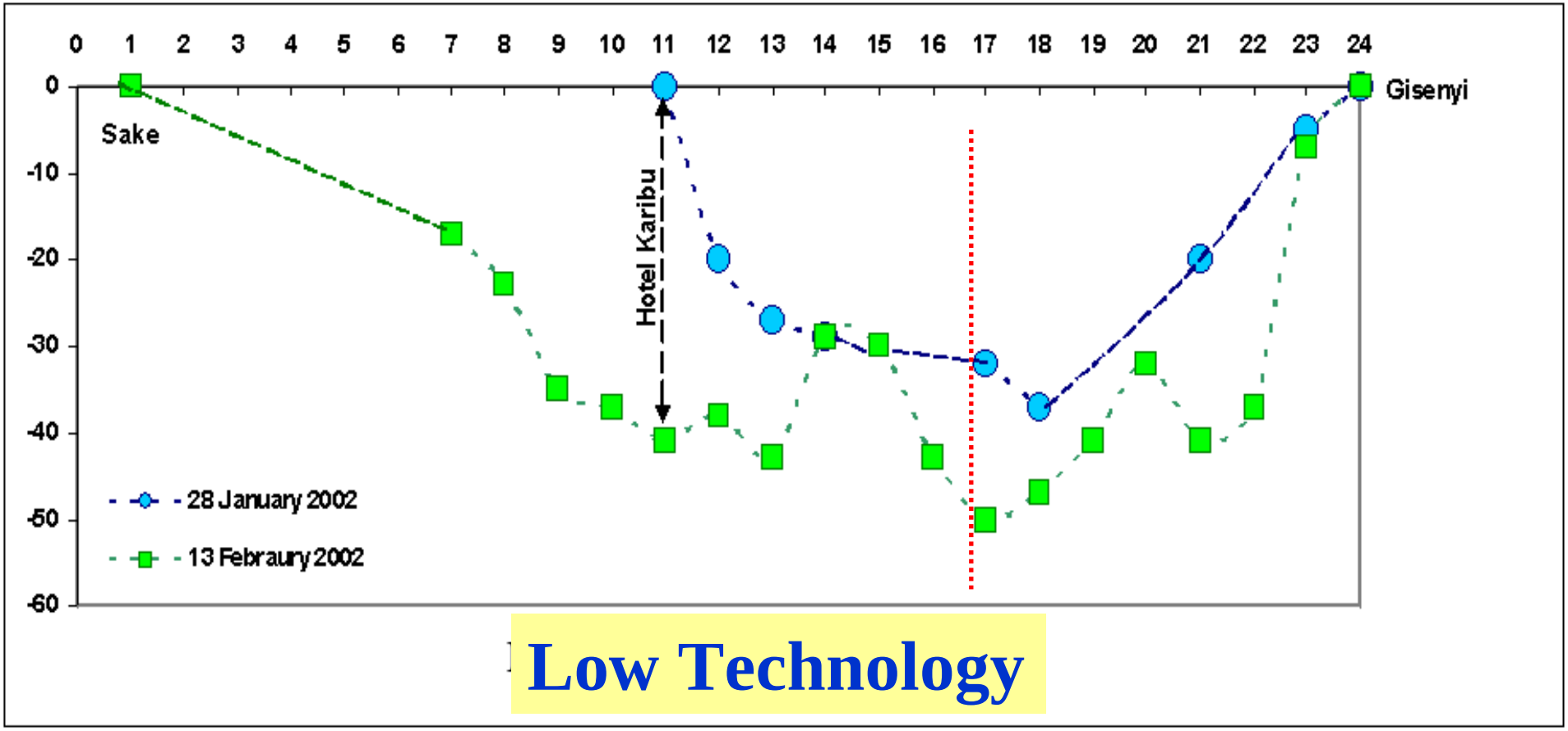
The scoria and spatters are glassy, highly vesicular, and very expanded. In this field gas vesicles of decimeter-size are common.



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.

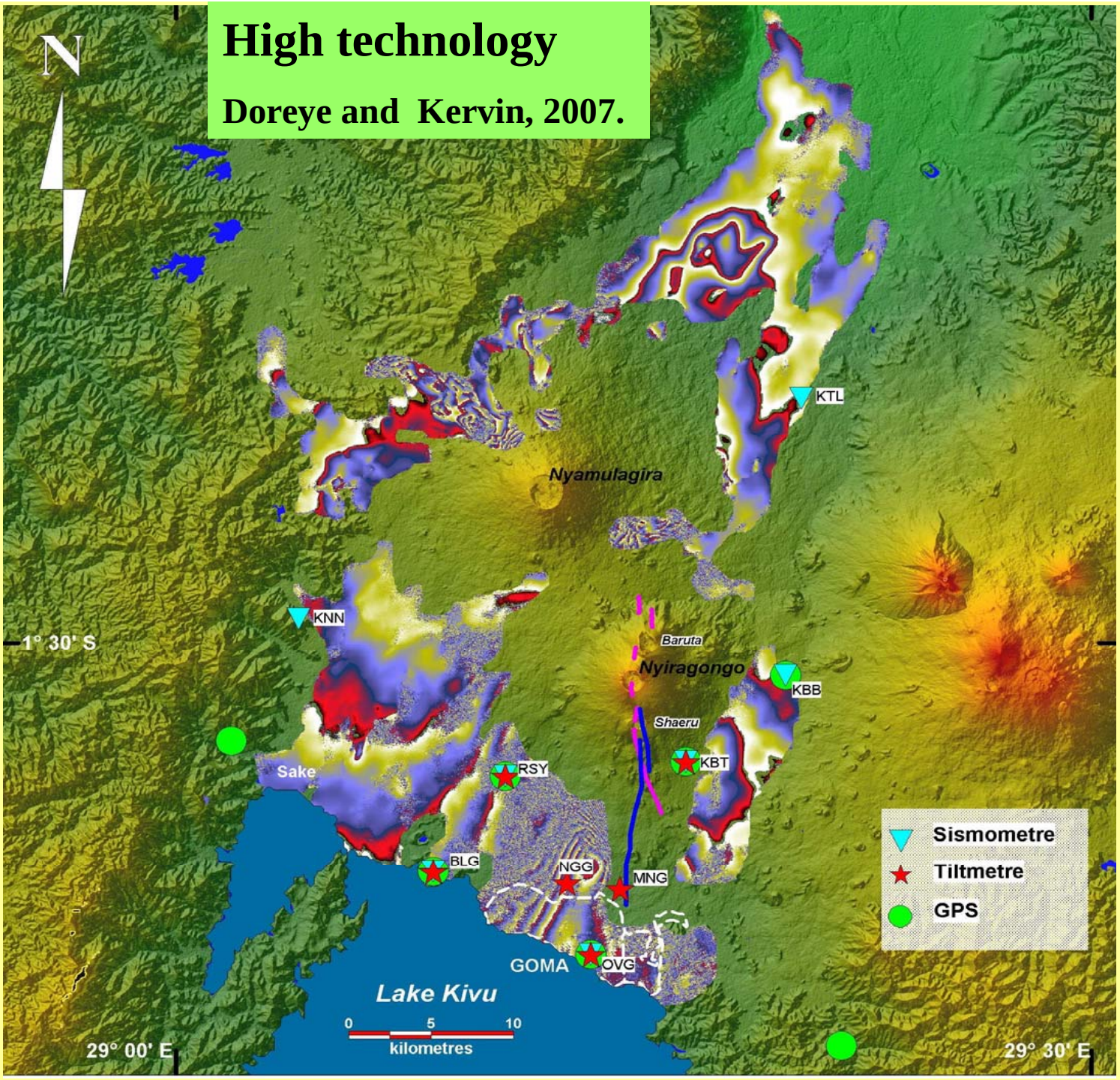


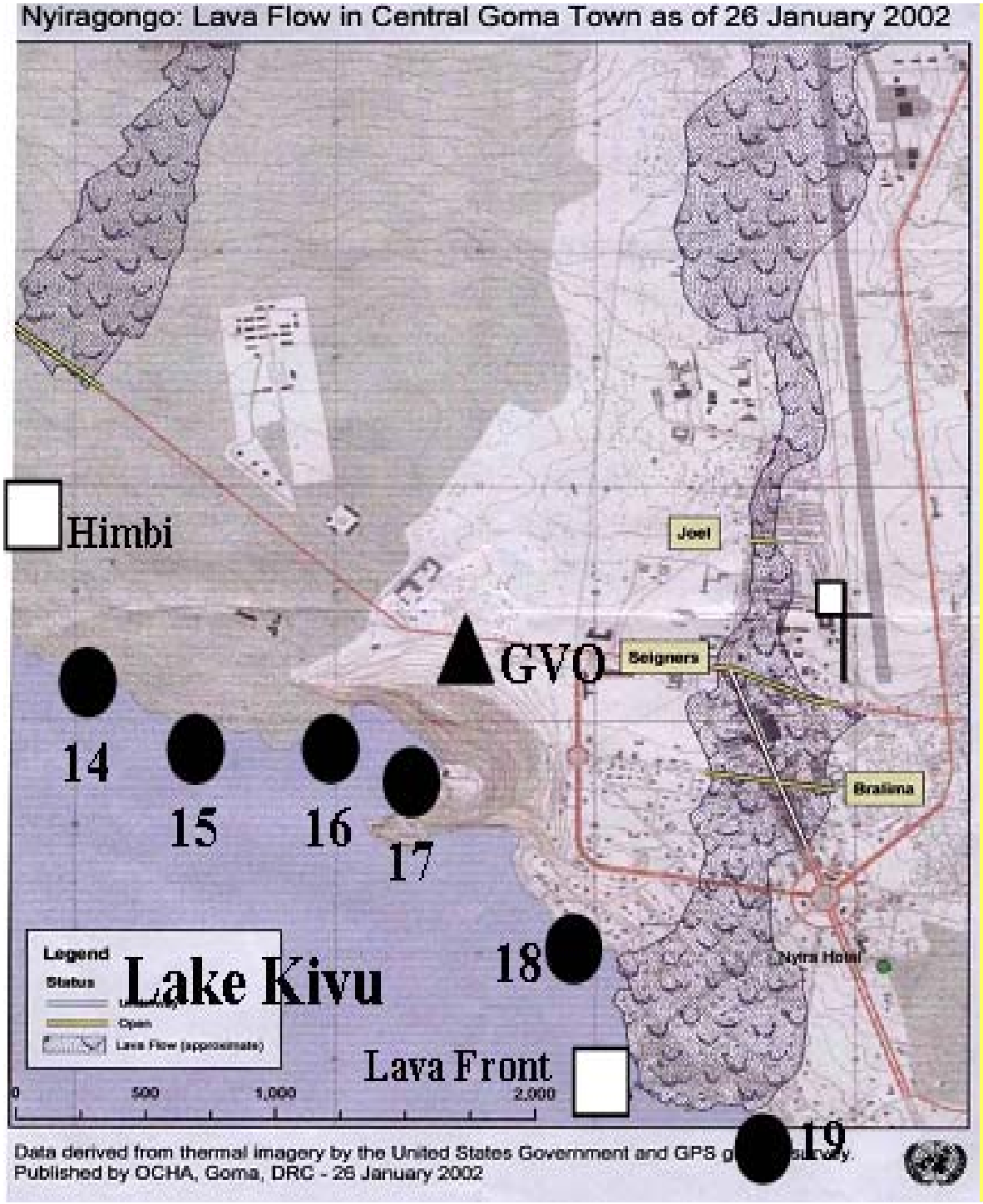




Low Technology

Vertical ground deformation as measured on the line between Gisenyi and Sake one week and three weeks after the eruption. Maximum deformation (sinking) has been recorded at the Goma Harbour (site 17).

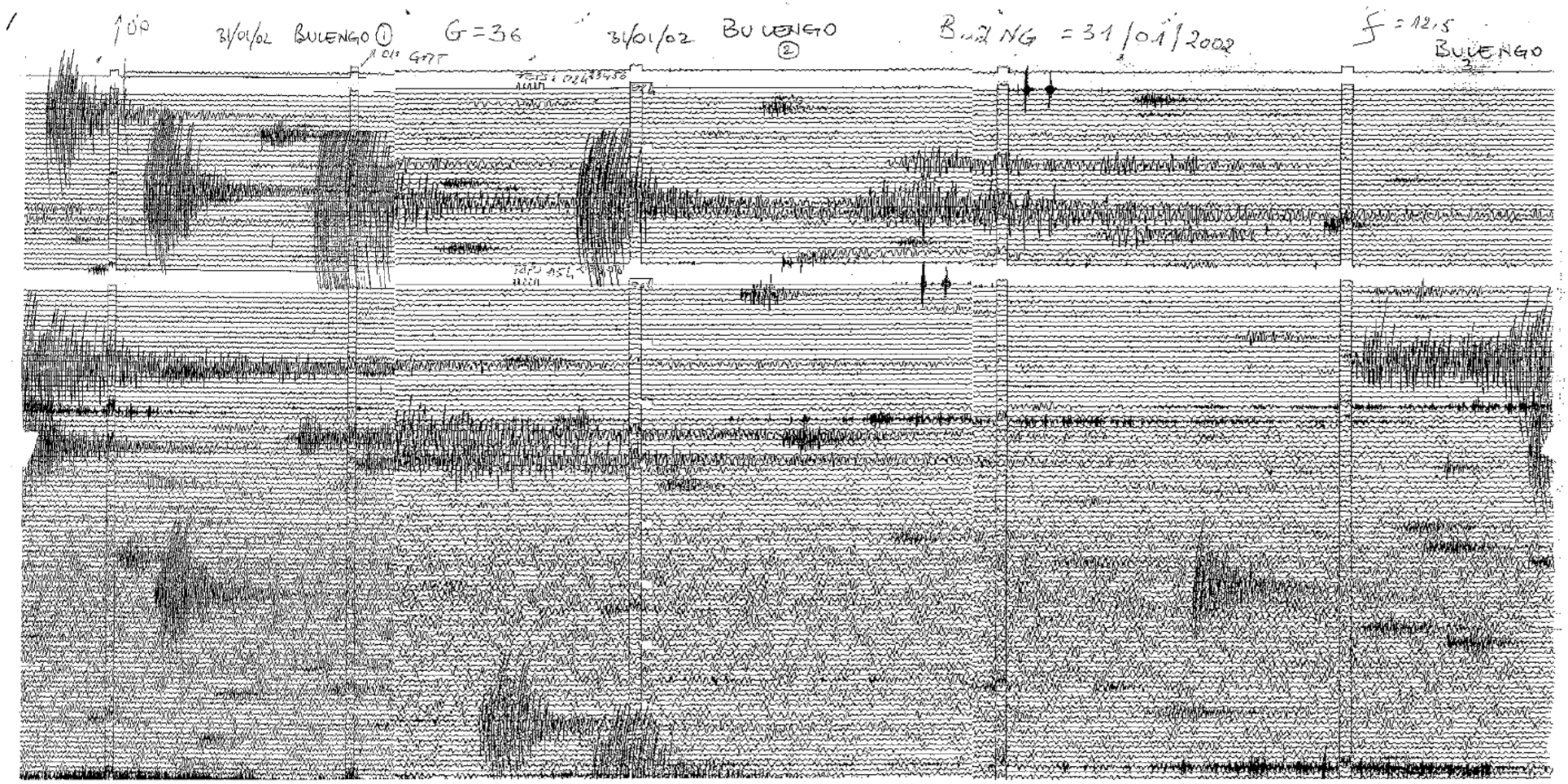

High technology
Doreye and Kervin, 2007.
N
KTL
Nyamulagira
KNN
1° 30' S
Baruta
Nyiragongo
KBB
Shaeru
KBT
Sake
RSY
BLG
NGG
MNG
GOMA
OVG
Lake Kivu
0
5
10
kilometres
29° 00' E
29° 30' E
Sismometre
Tiltmetre
GPS



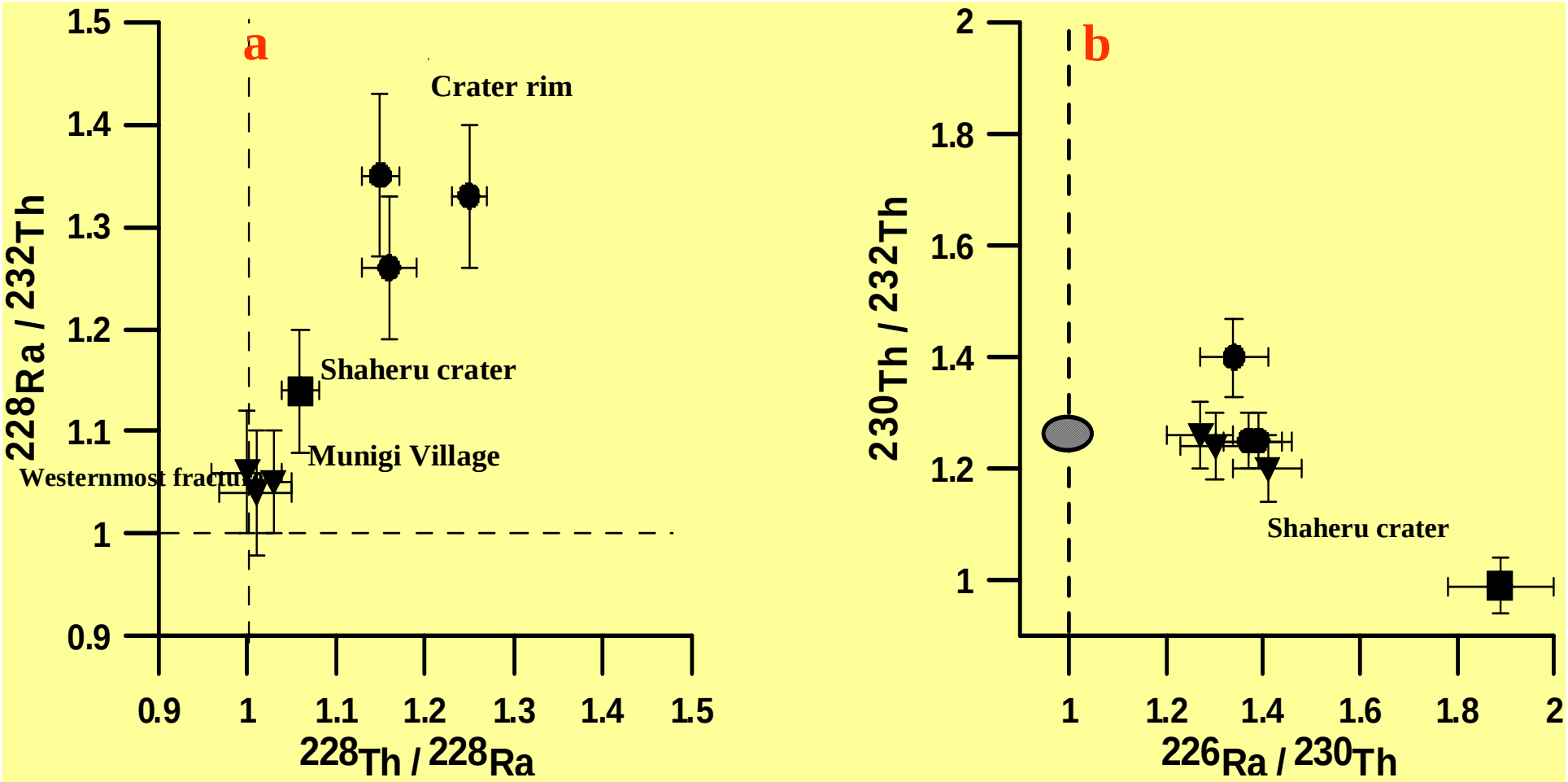
Particular of the two lava flows invading and devastating the city of Goma. The Eastern branch originated from 1550 m a.s.l. (Munigi vents), and reaching Lake Kivu. The Western branch originated from 1950 m a.s.l. stopping just on the Goma-Sake road. For few days, Goma was divided into two parts, Goma east and Goma west. 13% of the city was totally destroyed. More than 100,000 people became homeless.

Spontaneous evacuation from the city of Goma. The crowd walkingfrom Goma to Gisenyi next to the border of Rwanda.

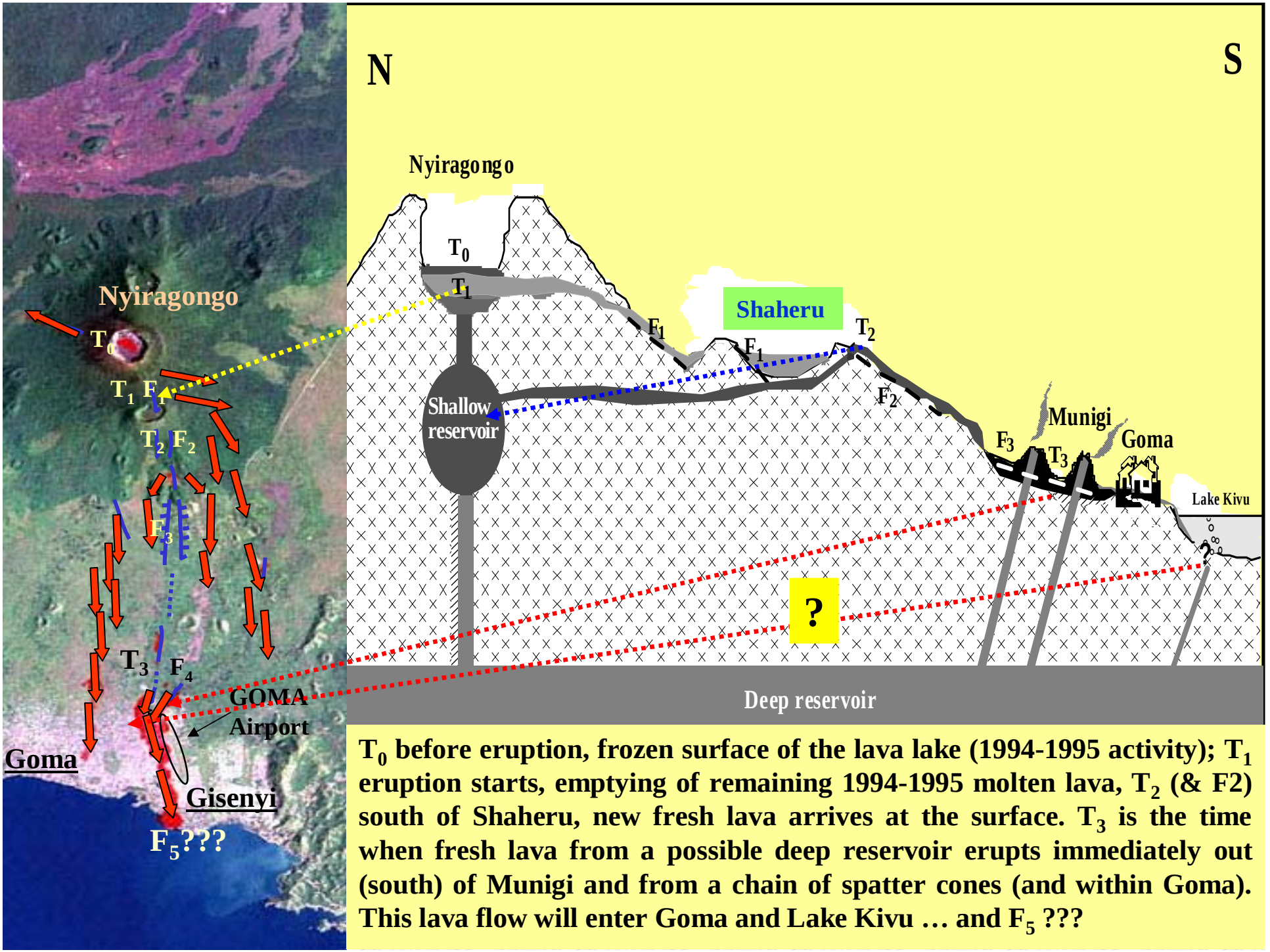
Spontaneous return to Goma only 24 hours from the beginning of the eruptive event. People walking on the “new” and still hot lava flow.



Typical, although extremely anomalous, seismogram a week after the eruption (01/31/2002). Three types of earthquakes are visible: (a) major tectonic shocks, (b) long period quakes and (c) volcanic tremor.



Equilines indicate values at radioactive equilibrium. It is worthy to note that in (a) values of lavas and scoriae erupted from the main Crater and fractures North of Munigi are clearly out of radioactive equilibrium if compared to those erupted in the southern part of the fracture system (from Munigi to Goma). This result shows two different feeding systems, central and peripheral, and possibly two different magmas. Figure b) shows that Shaheru lava sample displays a $^{230}Th/^{232}Th$ and $^{226}Ra/^{230}Th$ activity ratio distinct from all other samples, pointing to a different and older batch of magma likely related to the 1994-1995 Nyiragongo lava lake episode.



T_0 before eruption, frozen surface of the lava lake (1994-1995 activity); T_1 eruption starts, emptying of remaining 1994-1995 molten lava, T_2 (& F2) south of Shaheru, new fresh lava arrives at the surface. T_3 is the time when fresh lava from a possible deep reservoir erupts immediately out (south) of Munigi and from a chain of spatter cones (and within Goma). This lava flow will enter Goma and Lake Kivu … and F_5 ???

Destruction …

Conclusions (?) & Recommendations

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 (in terms of 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. Next one wont probably be similar ...!

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.

- **International Funding to OVG – E.U. (more likely), U.N. (less likely).**
- **Scientific projects from Universities and Scientific Institutions for specific funded programs.**
- **It is highly necessary to form/prepare a new generation of local scientists, through the organization of an International (pan-African) Master-Ph.D. course in Goma (inviting students from all African concerned countries).**
- **Request of new technologies … satellite – data transmission – e-mail fast connection … all at special rate (for humanitarian purposes) for data – sharing & fast – very fast early warning.**
- **The geochronology/dating of all/most cones around Nyiragongo and those south facing the city of Goma and Lake Kivu is a crucial step to decrease the enormous hazard of this region.**
- **A tomography of Nyiragongo, in particular southern flank up to Goma (and Lake Kivu) is of the most importance to each hazard model.**


Cooperation is needed and it means:
Assessment, Prevention and Mitigation.