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Eruption of the Nyiragongo Volcano on 22 May 2021: Chemical Composition of the "Volcanic Salt" and Collateral Risk

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ABSTRACT

The present study aims to assess the chemical composition of the NaCl-like salt identified on the lava flows of the Nyiragongo volcanic eruption of May 22, 2021, in Kibati not far from the N02 road, in the Bukumu chiefdom; in order to determine its positive or negative impact on the health of the population (for consumers). Samples of these salts are subjected to organoleptic and chemical analysis at the laboratories of the CEEC (Center of Expertise for the Evaluation and Certification of Mineral Substances,) and the OCC in Goma. The results obtained obtained the presence of major elements whose content is greater than 100ppm (mg / kg) and other trace elements whose contents are below 1000ppm, other than certain radioactive elements. These elements come from the magma in a high temperature molten silicate bath, which has given rise to rock (salt) on the surface by rapid cooling of the lava. The high content of silicon and potassium and sodium alkalis clearly shows the alkalinity of the magma of this volcano. It is not in any way the NaCl consumption salt put rather alkalized silica rich in potassium and sodium.

Keywords: Volcanic salt, chemical composition, Nyiragongo Volcano

RESUME

La présente étude vise à évaluer la composition chimique du produit minéral à apparence de NaCl identifié sur les coulées de lave de l'éruption volcanique du Nyiragongo du 22 Mai 2021, à Kibati non loin de la route N°2, dans la chefferie de Bukumu ; afin de déterminer son impact sur la santé de la population qui en consomme. Les échantillons de ce produit ont fait l'objet d'analyse organoleptique et chimique aux laboratoires du Centre d'Expertise d'Evaluation et de Certification des substances minérales (CEEC) et de l'OCC à Goma.

Les résultats obtenus indiquent la présence des éléments majeurs dont les teneurs sont supérieures 1000 ppm (mg/kg) et des éléments en trace dont les teneurs restent inférieures à 1000 ppm, ainsi que de certains éléments radioactifs. Ces éléments proviennent du bain silicaté résiduel (magma) de haute température dont la cristallisation par refroidissement relativement rapide a donné en surface ce « sel » de lave. La teneur élevée en silicium et en alcalins (K+ et Na+) montre bien le degré assez élevé de l'alcalinité du magma de ce volcan. Il ne s'agit nullement pas de sel de consommation (NaCl), mais plutôt de la silice alcalisée riche en potassium et sodium.

Mots clés: Sel volcanique, composition chimique, Volcan Nyiragongo

1. INTRODUCTION

It is estimated that there are at least 1500 active volcanoes in the world, with an average of 50 to 70 eruptions per year. The majority of these volcanoes are located in Central and Latin America, Asia, North America, Southern Europe, and finally in Central Africa (Deguibe, A. 2018).

In Central Africa, the Virunga volcanic massif has 8 volcanoes of which two are very active, Nyiragongo and Nyamulagira. These two volcanoes, located on the axis of the East African continental rift), are related to the opening of the rift and is an expression of the regional tectonics of the Lake Kivu basin (KASAHARA et al, 1992; FIAMA, S. et al, 2011).

The Nyiragongo, located at 15 km north of the city of Goma, is known for its large eruptions of 1977 and 2002 and its permanent lava lake (TAZIEFF, 1977; TEDESCO et al. 2007; FIAMA, S, et al., 2011), accompanied by intense seismicity, characteristic of volcano-tectonic (VP) earthquakes, long-period and very long-period earthquakes.

These volcanic eruptions are usually accompanied by ejection of primary particles (aerosols) and sulfurous gas (SO2) into the atmosphere (DEGUIBE, A., 2018). These water-insoluble mineral particles are usually made up of alumina (Al2O3), silica (SiO2), ferric iron oxide (Fe2O3), etc. (KOKHANOVSKY, 2008). The size, shape and density of the different particles ejected by the volcano depend on the type and duration of the eruption. Thus, an effusive eruption of basaltic composition is likely to produce at least 10^5m3 of ash while an explosive eruption ejects an amount greater than 10^9m3 into the atmosphere (DEGUIBE, A., 2018).

The chemical composition of magma is dominated by silicon (Si) and oxygen (O). The content of silica (SiO2) in an ash produced from basaltic eruptions is about 45 to 55%; moreover this type of ash often appears rich in iron and aluminum (DEGUIBE, A., 2018).

Volcanic eruptions are sometimes accompanied by the late crystallization of magmatic juice into a mineral product improperly called "volcanic salt" that surrounding populations tend to substitute for cooking salt. The consumption of this "salt" raises several important health or medical issues (BURNIER, M., 2014). Indeed, despite its taste and flavor appreciated by many people, it is observed these days that excessive consumption of this product appears harmful to health because it can promote the development of high blood pressure and cardiovascular and renal complications (WHELTON, 2012; BURNIER, M., 2014).

Gemstonesalt (halite) extracted from salt mines contains 93 to 99.8% NaCl), sea salt contains between 98% and 99.8% NaCl; and ignigenic salt (from the Latin ignis: fire) obtained by artificial evaporation (thermal method) in saline (ROLAND CROS et al, 1998) contains more than 99.9%.

In order to deduce the number concentration, size and chemical composition of particles released from active volcanoes, especially "volcanic salt", the optical properties must be known in advance. However, the literature is not abundantly rich in information on the variations of chemical properties in certain volcanic particles emitted, it is imperative to carry out more recent analyses in laboratories well equipped for this purpose. With this in mind, in this study, we proceeded to analyze the chemical composition of the "salt" of the volcanic lava collected in one of the villages surrounding the Nyiragongo volcano.

2.STUDY SITE

Nyiragongo volcano, a stratovolcano of the East African Rift, erupted on May 22, 2021, at 15 km north of the city of Goma in eastern DRC, and lava flows poured eastward toward Rwanda. Another flow headed towards the city of Goma and stopped at 300 meters away from the Goma International Airport13 (Fig. 1), Figure 2 locates the sampling site of this "volcanic salt" at 7.3 m from the national road no. 2.

The sampled volcanic product (rock), which is the subject of this study, was collected in the lava flow of eastern direction, at the edge of the road No2, at the point of geographic coordinates: S 01'57 1440; E 029'276947; at an altitude of 1983m in Kibati village, in Nyiragongo territory.

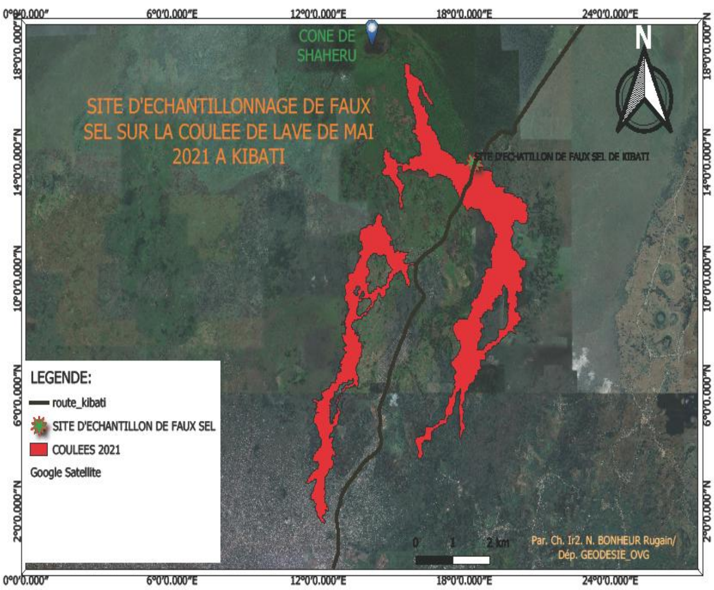

Fig.1 : Kibati lava flow,

Fig. 2 : Volcanic Sampling product site

3. MATERIALS AND METHODS

a) Materials:

Two representative samples were collected with a hammer on the flow, not far from the national road N°2, at the point of coordinates (S 01'57 1440; E 029'276947; Altitude 1983m). These samples (Fig.2) were naturally taken with the hammer in the form of small particles (powder) for the first one and in the form of a rock coherent at the same place. After a quick observation, the samples were packed in clean plastic bottles and labeled before being transported under acceptable conditions to the CEEC and OCC laboratories in Goma town.

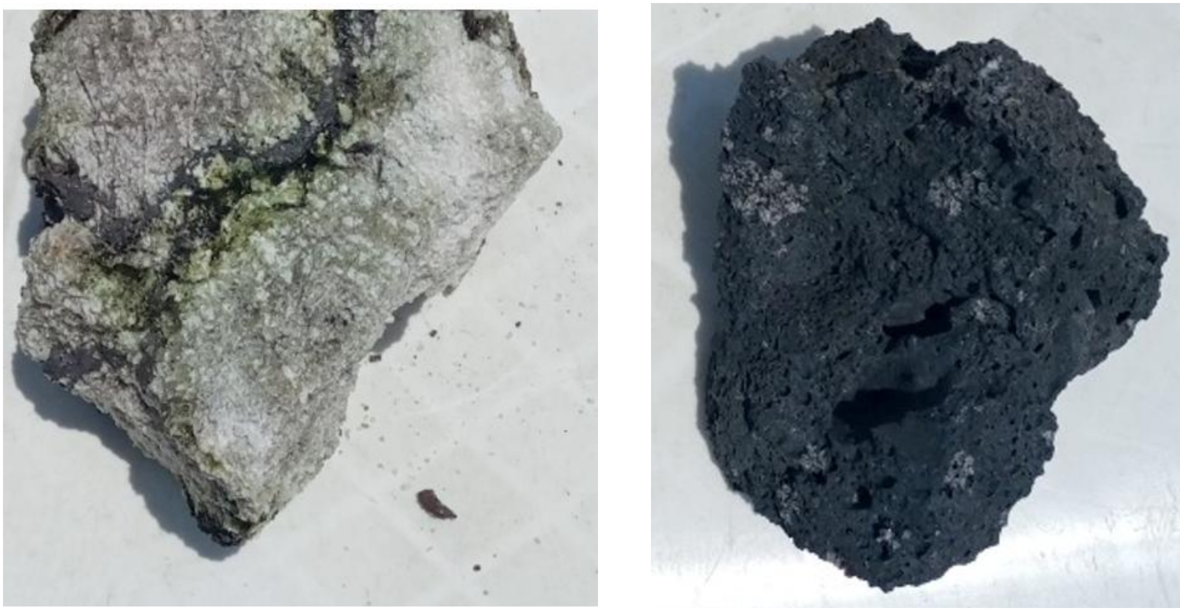

Fig. 3: The studied materials

b) Analytical methods

At the OCC laboratory in Goma, the samples were first subjected to the routine protocol (sensorial method of control of the label, packaging and contents). Then followed the physicochemical analysis by steaming, silver, iodometry and dissolution in water respectively, which allowed to determine the humidity, to measure the chlorine, sodium, iodine and to determine the solubility of this salt in water.

The major trace elements were analysed on thin powder of the samples, previously pulverized, at the CEEC laboratory of Goma by the X-ray fluorescence spectrometry method of which protocol of analysis is given in the appendix.

4. RESULTS

4.1 The physicochemical nature of the "volcanic salt":

The various physicochemical analyses of the materials studied (Table 1) showed excessively low NaCl contents of the order of 0.96% instead of the 97% required at least for rock salt (cooking salt), 0 ppm in iodine whereas cooking salt is supposed to have a minimum of 20ppm; finally, it is a product that is very insoluble in water, unlike cooking salt, which is perfectly soluble despite its crystalline appearance and whitish hue. This product does not reflect the nature of NaCl and does not appear at first sight to be cooking salt.

Tableau 1 : Physicochemical Analyses

	Requirements	Results	Analytical method
Humidity	Max. : 5%	0,01%	Steaming method
NaCl	Min. : 97%	0,96%	Argentometric, Mohr's method
Iodine	Min. : 20ppm	0,00ppm	Iodometric
Solubility	Perfect	Not soluble	Dissolution of water

4.2 Chemical composition

The whitish substance from the consolidation of the late silicate magmatic fluid from Nyiragongo (sample 1) was divided and processed into three parts: the thin ground powder (OVG 1), the precipitate (OVG 2) and the pellet (OVG 3).

Both qualitative and quantitative analytical results obtained on the three parts of sample 1 and the lava taken from the same location (sample 2) are shown in Table 2. Examination of these results reveals the presence of major elements (levels above 1000 ppm) and trace elements with levels below 1000 ppm. It should be noted that some elements commonly classified as trace elements show the levels above 1000 ppm, and are therefore considered major insofar as they control the crystallochemical structure of their mineral support. This is the case of tin. On the other hand, some others have despite their high concentrations considered as trace elements because they appear without their own mineral support.

4.3 Major elements:

Table 2 gives the chemical composition of the major elements.

- Silicon shows relatively high contents ranging from 66.92 to 67.87% in the magmatic fluid sample against only 35.72% in the lava;
- Aluminum shows a range of contents from 14.79 to 15.49% in the magmatic fluid, practically the same order of magnitude as that of the lava (15.22%);
- The iron content varies from 1.03 to 1.08% in the fluid, it is 9.56% in the lava;
- The magnesium content varies from 0% in the residual magmatic fluid to 3.47% in the lava;
- Calcium concentration varies from 2.07 to 2.15% in the fluid, it is 14.09% in the lava;
- Titanium contents vary from 0.11 to 0.15% in the fluid, while they reach 3.47% in the lava;
- For potassium, the contents are from 12.93 to 14.03 in the residual liquid, and 9.56% in the lava;
- The phosphorus contents range from 0.17 to 0.20% in the residual magmatic liquid to 3.74% in the lava;

A quick exam of data shows that if we compare the element contents in these two types of materials (samples), we can distinguish:

1) Elements enriched in the residual liquid compared to the lava: Si, K;
2) Elements depleted in the liquid and therefore enriched in the lava: Fe, Mg, Ca, Ti, and P.
3) Al is the element that appears to be constant or invariant in this late crystallization process of Nyiragongo magma.

The high content of silicon and potassium demonstrates the increase in acidity and alkalinity of the residual liquid as the magma crystallizes.

Table 2: Chemical composition of different parts of the magma fluid sample (sample 1) and the magmatic lava sample (sample 2) in ppm of major elements.

Elements	Thin Powder OVG1	Precipitate OVG2	Fluid pellet OVG3	Lave
Si	669229	673914	678720	357212
Al	152313	147886	154943	152194
Fe	10588	10781	10286	95634
Ti	1578	1399	1050	34724
Mg				
Ca	21234	21529	20749	140907
K	140346	139631	129302	150907
P	1864	2040	1742	37405
Mn	-	-	-	3557

4.4 Trace elements:

Table 3 gives the chemical composition of trace elements (ppm) and their variation in the studied materials.

- Cu, Co and Zn accumulate in the lava, but devoid in residual liquid;
- Sr, Ba, As and Sn seem to accumulate in the lava unlike Rb ;
- Pb, Tl are depleted in the lava and relatively enriched in the residual liquid;
- unlike Ta which appears depleted in the lava, Nb, Zr, U and Th show an enrichment in this material at the expense of the residual liquid.

Table 3: Chemical composition of different particles of the magmatic fluid sample (sample 1) and the magmatic lava sample (sample 2) in ppm of trace elements.

Element	OVG1	OVG2	OVG3	Lava
Cu	-	-	-	296
Co	-	-	-	288
Zn	-	-	-	188
Rb	459	440	448	378
Sr	371	353	297	6503
Ba	-	-	-	4530
Pb	56	47	54	-
Sn	800	865	706	3102
Tl	6	8	7	-
As	-	6	-	44
Ta	557	478	502	238
Nb	202	147	183	757
Zr	183	181	152	759
Th	28	26	22	40
Se	-	6	-	18
U	-	-	24	48
W	-	17	48	-
Sb	-	-	100	-
Bi	-	-	-	13
Cd	-	-	-	4

5. INTERPRETATION, DISCUSSION AND CONCLUSION

The behavior of major and trace chemical elements argues for a crystallization of residual magmatic juice into a whitish aluminosilicate product highly enriched in alkali and silica, similar in appearance to cooking salt without being one, as indicated not only by its composition but also by its physical and chemical properties (its insolubility in water, its alumino-silicate composition and the absence of iodine and chlorine)

By comparing the results of qualitative and quantitative analyses carried out in the laboratories (OCC and CEEC in Goma), it is revealed that:

- The salt-like product is insoluble in water and has no trace of iodine in its composition to be used as cooking salt (NaCl); it is rather a volcanic rock;

- It is important to note that the salty flavor would be related to the presence of sodium, which, along with potassium, accompanies the late crystallization of silica;

- Moreover, in the composition of this volcanic substance insoluble in water that the population confuses with the salt of household, are observed very harmful and dangerous radioactive elements, as the uranium and the thorium apart from the other metallic trace elements known as (heavy metals: Manganese, Iron, Cobalt, Copper, Titanium...), very harmful to the environment.

- It is therefore not a salt for human or animal consumption, but rather a volcanic rock whose consumption must be forbidden to the population in order to avoid the worst. This substance therefore constitutes a collateral volcanic risk that must absolutely be taken into account for the good of the surrounding population.

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