Abstract

Nyiragongo and Nyamulagira, in the Virunga Volcanic Province, in the western branch of the East African Rift, are the most active volcanoes in Africa, providing numerous recent historical records to study volcanism in an extensional setting. Located in a densely populated area of Central Africa, these volcanoes also represent a threat for human activities and their environment. However, despite the major interest they would represent for scientific investigations, volcano monitoring and hazard assessment, Nyiragongo and Nyamulagira remain little known for several reasons associated with the local context (socio-political instability, field accessibility, local climate conditions, local infrastructures, etc.).

In the present work, we focus on understanding the main mechanisms that control the eruptive activity of these two volcanoes. In a first part, the structural setting of the Kivu rift segment, where the volcanoes developed, is investigated in order to describe the interaction between tectonic rifting and magmatism and characterize the influence of existing fault networks on the distribution of volcanism. This study suggests that magma underplating might have influenced the development of the Kivu rift segment and that deep inherited Precambrian structures influenced the development of transfer zones, where volcanism next concentrated. These reactivated structures still influence the location of volcanic eruptions in the Virunga Volcanic Province.

In a second part, the historical eruptive activity of Nyiragongo and Nyamulagira is reconstructed from the late 19^{th} century up to now. It allows highlighting the mechanisms that influence the location, duration and emitted lava volume of eruptions. The historical activity of Nyamulagira indicates that edifice loading strongly influence the characteristics of eruptions, while rift structures also influence the location of eruptions. The detailed study of the 2010 eruption of Nyamulagira allowed the detection of eruption precursors in geodetic, seismic and SO_2 monitoring data up to 3 weeks prior to the eruption onset. The reconstruction of the eruptive history of Nyiragongo revealed that the existing literature might be misleading, highlighting the need to critically consider previously published information and develop new methods for systematically documenting key volcanic events. The evolution of the Nyiragongo lava lake since the 1950s and the characteristics of the 1977 and 2002 eruptions suggest that flank eruptions and the associated drainage of the lava lake result from a combination of events that promoted a deep dyke intrusion and the destabilization of the upper magmatic system. Two types of intracrateral eruption were historically observed: a persistent lava lake activity and an ephemeral lava lake activity. The variations of the lava lake level should be seen as a natural manometer indicating the pressure state of the upper magmatic system.

Finally, in the third part, close-range photogrammetric techniques are setup, tested and exploited to provide first quantitative insights into the lava lake dynamics in the main crater of Nyiragongo. An innovative Stereographic Time-Lapse Camera (STLC) system is developed to acquire stereo-pairs of images of the lava lake, allowing measuring and monitoring its level variations. The acquired data revealed metric variations of the lava lake level associated with a mechanism of gas piston, as already suggested for other persistent lava lakes. STLC data complemented with images acquired during helicopter flights also revealed a long-term decrease of the Nyiragongo lava lake level of almost 70 m between 2012 and 2014. This lava lake level decrease occurred through sporadic lava lake level fall events, which were for the first time measured and correlated with increasing long-period seismicity, suggesting that crustal magma intrusions may regularly occur at Nyiragongo. The ~70 m drop of the lava lake level also coincides with a metric subsidence of the central part of the main crater. This subsidence was accompanied with the formation of ring fissures around the lava lake pit.

In conclusion, the present thesis provides new results allowing improving the interpretation of variations in the eruptive activity of Nyiragongo and Nyamulagira and the associated signals measured with ground-based and remote sensed geophysical techniques. These results will contribute to improve further volcano monitoring and scientific investigations in the Virunga and elsewhere in youthful rift settings.