Magma Sources Involved in the 2002 Nyiragongo Eruption, As Inferred from an InSAR Analysis

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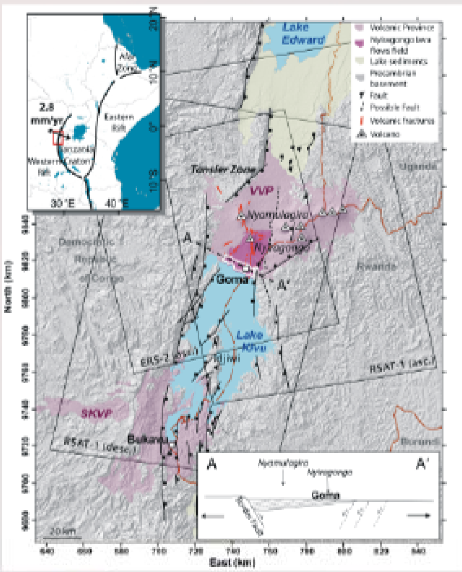
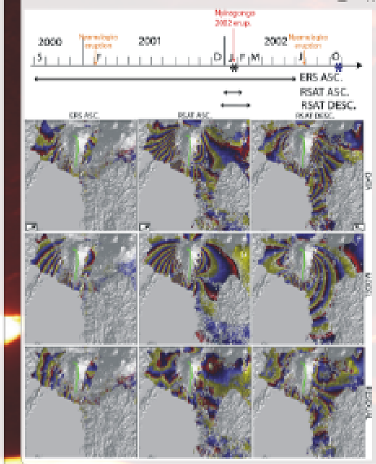
1 - TECTONIC SETTING

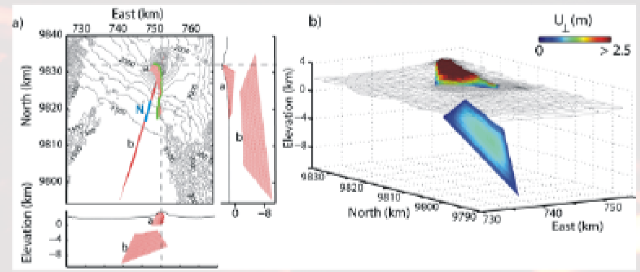


Up: Nyiragongo volcano lies in the Virunga Volcanic Province (VVP). The rift trend in the VVP is NNE with localized NE trends. The rift is probably a half-graben with a marked normal fault on the western side and no clear bounding fault on the eastern side.

Left: On 17 January 2002, Nyiragongo erupted along a 20 km-long fracture network extending southward from the NW flank of the volcano towards the city of Goma. The eruption lasted for 12 hours and the summit lava lake drained. The erupted volume is ~ 14 - 34 10^6 km^3 while the mean surface opening is 1-3 m.

2 - MODELING OF INSAR DATA

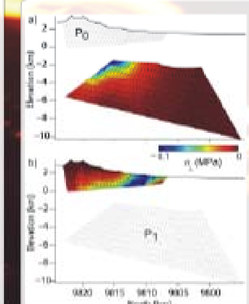




Left: Three wrapped interferograms (upper row) showing the deformation associated with the 2002 Nyiragongo eruption. One color cycle represents a 2.8 cm Line Of Sight (LOS) range change with positive fringes (red-blue-yellow) corresponding to a range increase. The arrows show LOS direction. The 2002 eruptive fissures are drawn in green. 1st column: ERS-2 ascending ifg, 2nd column: ascending RADARSAT-1 ifg and 3rd column: descending RADARSAT-1 ifg. Modeled (middle row) and residual (lower row) interferograms are obtained with the best fit model considering two-dike intrusions. This model also gives the lowest Akaike Information Criteria.

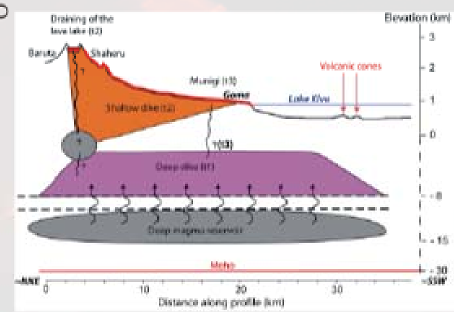
Up: a) Three views of the geometry of the preferred two-dike model. The view with contour lines is a map view. The dashed lines in the map view indicate the locations of the vertical cross-sections shown to the right of, and below, this view. The view to the right is the north-vertical cross-section and the view below is the east-vertical cross-section. The 2002 eruptive fissure is mapped in green and Ngangi old fissures in blue. b) Topographic mesh used for the modeling and 3D view of the two-dike intrusions. The opening of each element is adjusted so that it fits the constant stress boundary condition in the boundary element computation.

3 - ERUPTION SCENARIO



Left: Normal stresses induced by one dike on the other along a north-south cross-section of both dike intrusions: a) Normal stress (σ) in MPa induced on the deep dike by pressure from the shallow dike. b) Normal stress (σ) in MPa induced on the shallow dike by pressure from the deep dike.

Right: Schematic magmatic plumbing system beneath Nyiragongo volcano and the northern part of Lake Kivu, and possible eruption chronology inferred from the modeling and consistent with a previous study by *Tedesco et al.* [2007]. The topographic profile (black bold line) is obtained from the topographic and bathymetric data along the trace of the deep dike. The figure is not scaled for depth below sea level.

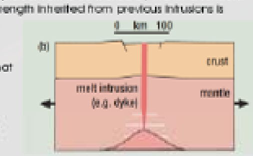


4 - CONCLUSIONS

- The best fit model describing the 2002 co-eruptive deformation, corresponds to two subvertical dike intrusions. The first, shallow dike, 2 km high on average, is associated with the 20 km-long eruptive fissure. The modeled mean surface opening is 3 m, which corresponds to field measurements. This dike volume is consistent with magmas originating from the summit lava lake combined with deeper sources. The second, deeper dike, 6 km high and located 3.3 km beneath the city of Goma, has a rift-parallel strike, and a basal length of 40 km. It is consistent with a deep magma source of the southernmost fissure. As this dike extends for about 20 km beneath the lake, it could have represented a considerable hazard if magma had reached the lake since its waters contain high concentrations of dissolved carbon dioxide and methane.

- Given the precursory seismicity, it is likely that magma was first supplied to a deep reservoir ten months before the eruption. From a stress transfer analysis, we find that the deep dike intrusion might have triggered the failure of a shallow reservoir and magma column beneath Nyiragongo lava lake, inducing the injection of lavas from the lava lake, magma column and shallow reservoir into the shallow dike. Our analysis indicates that the deep dike favored the opening of the southern part of the eruptive fissure, suggesting that magma from the deep dike was transmitted to the southern part of the eruptive fissure, through a dike too narrow to be detected. This model is consistent with geochemical analysis, the lava rheology, as well as the pre-eruptive and post- eruptive seismicity triggered on shallow faults by the intrusion of the deep dike. With the exception of the October 2002, 6.2 M_s earthquake, these fault motions are not detectable on the interferograms, which could be explained by them occurring in the areas of decorrelation or below Lake Kivu.

- Low overpressures are determined for both dikes, corresponding to crustal stresses which are close to being lithostatic and isotropic. The rift-parallel directions of the dikes, as well as their sub-vertical dips, indicate that their direction of emplacement is controlled by the rift extension. Because stresses are lithostatic, a low tensile strength inherited from previous intrusions is probably responsible for the intrusion direction. The alignment with numerous cones indicates that this direction is a preferential intrusion direction. The lithostatic crustal stresses show that the rift extension has been relaxed by the successive dike intrusions. Even if the rift is immature, it should be magma-driven (see a companion poster from Cayol et al. for further details)



Acknowledgements

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References

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