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Pb-Sr isotope temporal variations on juvenile ash samples from the last eruptive period of Tungurahua volcano (1999-2016)

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Andean volcanic activity consists in long quiescence periods interrupted by violent explosive eruptions of diverse intensity, magnitude and duration. Anticipating these transitions between low energy eruptions and violent major explosions is a challenge for modern volcanology. Many parameters could play a role in explaining these fast transitions, such as the conduit process (degassing and microlite crystallizations) but also deeper processes (crustal assimilation, nature of the mantle-derived primitive liquids).

Geophysical methods (seismic, acoustic, heat flow, ground deformation, gas emissions) are currently used by volcano observatories in order to identify unrest phases at medium to short time-scale. Furthermore, the evolution of pre-eruptive magmatic reservoirs is often studied via micro-petrological techniques, such as the detailed study of growth-zoned crystals emitted during paroxysmal phases. These zonation patterns are related to changes in composition and/or P-T-XH2O conditions in the magma reservoir caused by its complex evolution through time (injection/recharge, crystallization, degassing processes). Thanks to these methods, a tight relation between mafic magma recharge and explosive volcanic reactivation has been constrained with delay time estimated from years to months. Yet, such petrologic methods are not efficient as predictive tools.

In this study, we performed micro-geochemical analysis (trace elements, Pb-Sr isotopes) on time-series of juvenile ash samples (69) emitted by Tungurahua volcano over its most recent period of activity (1999-2016). Geochemical time series display an oscillating pattern with good correlations between Pb-Sr isotope compositions evolution and most trace elements as well as between whole rocks and ashes compositions. Pb-Sr isotope cyclic signal seems to reveal that paroxysmal phases first emissions are the most radiogenic of each eruption phase. As the eruption goes on, we observe a rapid decrease in Pb-Sr isotope composition. Finally, it appears that both 206Pb/204Pb and 87Sr/86Sr ratios of juvenile ash samples decrease from 2013 to the last year of activity in 2016, leaving the final emissions with the less radiogenic Pb-Sr isotope compositions.

The oscillating geochemical pattern of juvenile ash samples has been meticulously compared to the well-known eruptive dynamics of the volcano through time, providing clues on the processes triggering the violent reactivation phases. Indeed, the rapid geochemical evolution of the magma reservoir with a high temporal resolution has been interpreted as the effect of deep magma recharges in the shallow reservoir of Tungurahua volcano.

Coupling continuous geochemical analysis to geophysical monitoring puts in evidence a geochemical precursor for eruptive phases, delivering a better understanding on the global stratovolcano system and assuring an improvement in volcanic monitoring.