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Degassing dynamics at Mount Etna inferred from radioactive disequilibria (^{210}Pb-^{210}Bi-^{210}Po) in volcanic gases

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Volcanic gases are significantly enriched in the last short-half-life radionuclides of the ^{238}U series, namely the so-called Radon daughters ^{210}Pb, ^{210}Bi and ^{210}Po. Because of their contrasted volatilities, these isotopes are strongly fractionated upon degassing, which gives rise to significant radioactive disequilibria between them in the gas phase. These disequilibria carry precious information on shallow degassing processes beneath active volcanoes: they remarkably constrain the magma residence time in the degassing reservoir and the duration of gas extraction from magma to surface. On Mount Etna (Sicily), where the study of these disequilibria was initiated thirty years ago (Lambert et al., EPSL, 1985-86), no measurement of ^{210}Pb, ^{210}Bi and ^{210}Po in the gases has been performed for the last twenty years.

Here we present new ^{210}Pb-^{210}Bi-^{210}Po radioactive disequilibria measurements in volcanic plume gases of Mount Etna. Samples were collected in the bulk diluted plume at kilometric distance from the summit area during the May 2015 eruption, then in more concentrated plumes arising from each summit crater of Etna during quiescent degassing in July 2015. We found values of (^{210}Bi/^{210}Pb) = 7.0 $\pm$ 0.3 and (^{210}Po/^{210}Pb) = 80 $\pm$ 6 during both periods. These results suggest that ^{210}Pb, ^{210}Bi and ^{210}Po are not significantly fractionated during the transport of the plume from the crater rim to close-downslope sites ($<$1 km).

None of the previous degassing models (Lambert et al., EPSL, 1985-86 ; Gauthier et al., JVGR, 2000) satisfactorily explain measured activity ratios. We propose here a new degassing model based on the previous conceptualization designed for basaltic open-conduit volcanoes, like Stromboli. This model considers extreme Radon enrichments in volcanic gases as a source of ^{210}Pb atoms produced by radioactive decay of ^{222}Rn within gas bubbles travelling to surface. We constrain a magma residence time of 470 $\pm$ 170 days and an extraction time of the gases of 4.9 $\pm$ 0.8 days. Along with SO_2 fluxes, we also derive a volume of the degassing reservoir of 0.2-0.6 km^3 in good agreement with previous estimates. Results gathered from these campaigns have intriguing implication for potential routine survey of the plume radioactivity, as part of the monitoring network of active volcanoes.