Very short timescales from heating to eruption: Using diffusion chronometry to understand rapid-onset eruptive events

EDUARDO MORGADO[1,2], DAN J. MORGAN[1], JASON HARVEY[1], MIGUEL-ÁNGEL PARADA[2,3], ANGELO CASTRUCCIO[2,3], SUSANNA K. EBMEIER[1], RAIMUNDO BRAHM[2,3], RICHARD WALSHAW[1], BOGOMIL GEORGIEV[1]

[1] School of Earth and Environment, University of Leeds, UK.
[2] Andean Geothermal Center of Excellence, CEGA, Chile.
[3] Department of Geology, University of Chile, Chile.

During 22nd-23rd April, 2015 a rapid-onset eruption occurred at Calbuco Volcano, Southern Chile and consisted of two eruptive pulses separated by 7 hour interval. Up to 36 hours before the eruption no deformation was observable from satellite radar, and the first precursor was a seismic swarm, which started only 3 hours before the first eruptive pulse. Here we examined eight samples (from fall and PDC deposits) using diffusion chronometry to ascertain the pre-eruptive magmatic conditions.

All the samples have basaltic andesite composition (55.6 – 56.9 SiO_2 wt.%). The vesicularity ranges from 15 to 50 vol.% and crystallinity from 34 to 63% vol.%. The mineral phases comprises clinopyroxene ($En_{43-47}Fe_{9-15}Wo_{40-45}$), orthopyroxenes ($En_{67-72}Fe_{24-31}Wo_{2-4}$), plagioclase ($An_{46}$ to An_{89}), amphibole (pargasites and edenites), olivine (Fo_{60-75}), apatite, titanomagnetite (X_{usp}: 0.42-0.46; X_{usp}: 0.10-0.17), and ilmenite (X_{ilm}: 0.77–0.85). Several silicate-related (long-term) thermometers were applied, giving temperatures of 960-978 ± 39 °C. The textural and thermal features recognized suggest the presence of a stock-like shape of a mush reservoir beneath Calbuco Volcano.

Traverses crossing in-contact Fe-Ti oxides allow us to use (short-term) thermometry and oxygen barometry. In some high crystallinity samples (~ 60%) a heating event was recognized: rim (close to the grain interface) temperatures are higher (average 1018 °C, σ = 44 °C) than those from the cores (average 870 °C, σ = 18 °C). The elemental exchange as a response to the heating-formed diffusion profiles, which allow us to model timescales in titanomagnetite crystals. The calculated timescales range from few hours to four days between the heating event and the eruption. Our results are consistent with the timing recorded by geophysical data: InSAR, seismometers, and tiltmeters.