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Geochemical evidence of volcanic plumbing system processes from fumarolic gases and diffuse CO_2 degassing of Taal volcano, Philippines, prior to the January 2020 eruption

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Significant temporal variations in the chemical and isotopic composition of Taal fumarolic gas as well as in diffuse CO_2 emission from Taal Main Crater Lake (TMLC) have been observed across the ~12 years of geochemical monitoring (Arpa et al., 2013; Hernández et a., 2017), with significant high CO_2 degassing rates, typical of plume degassing volcanoes, measured in 2011 and 2017. In addition to these CO_2 surveys at the TCML, soil CO_2 efflux continuous monitoring was implemented at Taal volcano since 2016 and a clear increasing trend of the soil CO_2 efflux in 2017 was also observed. Increasing trends on the fumarolic CO_2/St, He/CO_2, CO/CO_2 and CO_2/CH_4 ratios were recorded during the period 2010-2011 whereas increasing SO_2/H_2S, H_2/CO_2 ratios were recorded during the period 2017-2018. A decreasing on the CO_2/CH_4 and CO_2/St ratios was observed for 2017-2018. These changes are attributed to an increased contribution of magmatic fluids to the hydrothermal system in both periods. Observed changes in H_2 and CO contents suggest increases in temperature and pressure in the upper parts of the hydrothermal system of Taal volcano. The $^3He/^4He$ ratios corrected (Rc/Ra), and $\delta^{13}C$ of fumarolic gases also increased during the periods 2010-2011 and 2017-2018 before the eruption onset. During this study, diffuse CO_2 emission values measured at TMCL showed a wide range of values from >0.5 g m^{-2} d^{-1} up to 84,902 g m^{-2} d^{-1}. The observed relatively high and anomalous diffuse CO_2 emission rate across the ~12 years reached values of 4,670 ± 159 t d^{-1} on March 24, 2011, and 3,858 ± 584 t d^{-1} on November 11, 2017. The average value of the soil CO_2 efflux data measured by the geochemical station showed oscillations around background values until 14 March, 2017. Since then at 22:00 hours, a sharp increase of soil CO_2 efflux from ~0.1 up to 1.1 kg m^{-2} d^{-1} was measured in 9 hours and continued to show a sustained increase in time up to 2.9 kg m^{-2} d^{-1} in 2 November, that represents the main long-term variation of the soil CO_2 emission time series. All the above variations might be produced by two episodes of magmatic intrusion which favored degassing of a gas-rich magma at depth. During the 2010-2011 the magmatic intrusion of volatile-rich magma

might have occurred from the mid-crustal storage region at shallower depths producing important changes in pressure and temperature conditions, whereas a new injection of more degassed magma into the deepest zone of the hydrothermal system occurring in 2017-2018 might have favored the accumulation of gases in the subsurface, promoting conditions leading to a phreatic eruption. These geochemical observations are most simply explained by magma recharge to the system, and represent the earliest warning precursor signals to the January 2020 eruptive activity.

Arpa, M.C., et al., 2013. Bull. Volcanol. 75, 747. https://doi.org/10.1007/s00445-013-0747-9.

Hernández, P.A., et al., 2017. Geol. Soc. Lond. Spec. Publ. 437:131–152. https://doi.org/10.1144/SP437.17.