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The evolution of the plumbing system of Nevado de Toluca (Mexico) over 1.5 million years

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The rate of magma input in Earth's crust controls the thermal evolution of magmatic systems and the rate of accumulation of potentially eruptible magma. Thus, proxies tracing the thermal evolution of magmatic systems in time provide essential information to estimate the magnitude of future volcanic eruptions. Here, we take advantage of a dataset of more than 10000 analyses of clinopyroxene, orthopyroxene and amphibole collected on products spanning 1.5 million years of eruptive activity of Nevado de Toluca volcano in Mexico, to trace the temporal evolution of its plumbing system. We use a machine learning based approach to thermo-barometry calibrated between 0 and 2GPa and 973 and 1873K. The standard error of the estimate for single analyses is around 0.2GPa for all phases and vary between 38 and 60 K for amphibole and cpx and opx, respectively. The coefficient of determination (R^2) for pressure is 0.75 and 0.85 for amphibole and cpx and opx, respectively and larger than 0.8 for temperature for all phases. The results show that the plumbing system occupies the entire crust already after a few hundred thousand years of volcanic activity. The temperature estimated for the three phases is constant for pressures between 0.4 and 1 GPa and decreases between 0.4 and 0.15 GPa, which is the minimum estimated pressure at which magma resides over the eruptive history of Nevado de Toluca. These results suggest that the magma feeding volcanic activity is sourced from a range of depths. We perform 1D thermal modelling, simulating the random injection of magma throughout the crust. Comparing these modelling and thermo-barometric results allows us to estimate the average rate of magma input in the crust. Thermal modelling shows that persistent magma storage regions shallower than about 6-8 km are not thermally viable. As we make no assumptions on magma chemistry or the physical properties of the crust, we suggest that the recurrently observed pressure of magma storage at 0.2 GPa might not be related to magma chemistry but rather be an unavoidable consequence of heat dissipation to the Earth's surface.