Magma - rock interaction: influence on eruption dynamics

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The interaction of magma with its surrounding host-rock is an inevitable process during a magmas journey from depth to Earth's surface. Especially the interaction with carbonate-bearing lithologies on short-term or syn-eruptive timescales is of major interest, since the thermometamorphic reactions taking place the magma-carbonate contact release CO_2 and affect the magma differentiation trend. An increase in externally derived CO_2 in the volatile budget of a magma will result in faster magma ascent, more explosive eruptive behaviour and a prolonged duration of the eruption. Thus, precise knowledge on the mechanisms and timescales of magma-carbonate interaction, also called limestone assimilation, occur is key to understand how it might influence eruptive dynamics.

For this study, Somma-Vesuvius (S-V) was chosen as reference volcanic system, as it is built on a km-thick Mesozoic carbonate platform (up to ~10km bsl.). Hence the whole eruptive feeding system, as well as the magma chambers, are exposed to direct contact with carbonate-bearing rocks. Furthermore, in the eruptive deposits of all major explosive eruptions of S-V witnesses of intense interaction with the carbonate host-rocks can be found, either as skarn-xenoliths or as carbonate-xenoliths enclosed in juvenile pumices. To date, no experimental study has been conducted using a S-V phonolite as magmatic starting material for interaction. Also, the influence of various internal and external parameters (like magma composition and viscosity, H_2O content of magma, limestone composition, pressure, temperature) on the efficiency of limestone assimilation in short-term or syn-eruptive settings is poorly constrained. Here we present the results of the first experimental study of phonolite-carbonate interaction at mid-crustal pressure conditions (600 MPa). The experiments have been conducted in a piston cylinder apparatus at 950°C and 1200°C, and with two different limestone compositions (high-Ca limestone and dolomitic limestone). The limestone assimilation in these experiments is much slower than in lower viscosity melts, demonstrating the influence melt viscosity has on limestone assimilation. Furthermore, the limestone composition strongly affects how the limestone is being assimilated: i) dolomitic limestones get assimilated by an assimilation and fractional crystallization process (AFC), during which a skarn-like assemblage of periclase-bearing dolomite, forsterite, clinopyroxene and Ca+Mg-enriched melt forms, while ii) high-Ca limestones tend to melt and mix with the phonolite melt at high temperatures. The melting of the high-Ca limestone is facilitated by the presence of hypersaline melt that interacts with the limestone and forms Ca-rich melt and a Na-K-Ca chloride carbonate melt. The latter, to date, has only been found in melt inclusions in skarns and this study presents the first ever experimental evidence of this melt. This evidences that crustal limestone melting is possible, even with higher viscosity melts and the selective removal of Na from the phonolite melt may influence the Na_2O/K_2O ratio of Campanian magmas at a crustal level.

Keywords: Magma-carbonate interaction, limestone assimilation, Somma-Vesuvius, Phonolite