Basalt-limestone interaction at crustal conditions and implications for volcanic emission of CO₂

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Carbon dioxide released via volcanic systems is generally mantle-derived, but high degassing rates for some arc volcanoes (e.g. Merapi [1] and Colli Albani Volcanic District [2]) are thought to be influenced by magma-carbonate interaction in the continental crust [3]. Yet, systematic investigation on the effect of P-T on hydrous basalt-induced crustal decarbonation is limited.

Here we simulated basalt-limestone wallrock interactions at 0.5-1.0 GPa, 1100-1200 °C using a piston cylinder and equal mass fractions of pure calcite (CaCO₃) and a hydrous (~3 wt.% H₂O) basalt melt in a layered geometry contained in AuPd capsules. All experiments produce melt + fluid + calcite + cpx ± plagioclase ± calcic-scapolite ± spinel. With increasing T, plagioclase disappears and scapolite appears at 0.8 and 1.0 GPa, cpx becomes CaTs-rich, and fluid proportion increases. At 1.0 GPa, 1200 °C our hydrous basalt is superliquidus, whereas in the presence of calcite, the experiment produces calcite + cpx + scapolite + melt.

With the consumption of calcite with increasing T and decreasing P, melt, on a volatile-free basis, becomes silica-poor (69.0 wt.% at 1.0 GPa, 1100 °C to 34.9 wt.% at 0.5 GPa, 1200 °C) and Ca-rich (37.1 wt.% at 1.0 GPa, 1100 °C to 41.8 wt.% at 0.5 GPa, 1200 °C) whereas, with increasing T Al₂O₃ drops (e.g. 14.0 at 1100 °C to 10.6 wt.% at 1200 °C at 1.0 GPa) as cpx becomes more CaTs-rich.

Wall-rock calcite consumption is observed to increase with increasing T and decreasing P. At 0.5 GPa, our experiments yield carbonate assimilation from 10.8 to 24.6 wt% between 1100 and 1200 °C, similar to calculated ≤15 wt.% at Colli Albani [2]. Using a magma flux rate of 5.4×10¹² g/y estimated for Mt. Vesuvius [4], we obtain a CO₂ outflux of 5.1×10¹¹-1.2×10¹² g/y for T variation of 1100 to 1200 °C at 0.5 GPa. The lower T estimate appears similar to the observed flux of CO₂ in Vesuvius systems of 1.1×10¹¹ g/y [5]. Our experiments thus suggest that one volcano such as Vesuvius alone can generate excess CO₂ that amounts to at least 1-2% of the present-day global arc flux of CO₂ [6].