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Crustal heating and assimilation by LIP magmas: volatile perspectives from experimental petrology and thermodynamic modeling

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Assimilation of surrounding crust and associated fluids are effective in influencing volatile budget and redox state of LIP magmas and enhancing their atmospheric emissions. In addition, volatiles can also be released from crust that is not directly assimilated but is heated due to contact metamorphism induced by LIP magmatism. In this contribution, we present some recent results from heating and partial melting experiments on natural black shale samples and review a publicly available modeling tool, Magma Chamber Simulator (MCS), which quantifies thermodynamic and geochemical consequences of open magma systems.

In pristine black shales, carbon is often bound in various kerogens, i.e. hydrocarbon compounds, that gradually break down to more stable graphite by loss of H, O, and S due to up-temperature reactions (graphitization). Upon graphitization, the gas species are dominantly CH_4 and H_2S. In the experiments of this study, the lowest T at 2 kbar is 700 °C, which means that graphitization is complete. The subsequent process is further mobilization of the "residual" graphite-bound-carbon likely as CH_4 and CO_2 by reaction with H_2O released from dehydrating minerals. This provides a potential second-stage emission source.

The mass of country rock that can be heated to temperatures relevant to different stages of volatile release can be estimated using MCS. For example, if the magma flow (kg/yr) is known for sills being emplaced into sediments rich in organic materials, the mass flow (kg/yr) of greenhouse gases released from the sediments can be estimated. The MELTS engine of MCS also treats H_2O and CO_2 at supersolidus temperatures and volatile elements such as S, Cl, and F can be tentatively modeled using the trace element protocol. Future improvements for more versatile treatment of the fluid phase are possible so that for a given fluid bulk composition the full array of possible species and their concentration can be computed. Nevertheless, in its present state, MCS provides abundant opportunity to study the effects of assimilation on volatile budget and redox state of magmas and the release of volatiles to the Earth's atmosphere.