Reactive transport of partial melt with solid solution

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Lithological heterogeneities in the Earth's mantle are thought to play an important role in the localization of partial melts into high-porosity channels. Melt localization via the reaction infiltration instability occurs only if reactions increase porosity. Therefore, melt localization is not controlled by the initial porosity created by partial melting within the heterogeneity, but by the porosity of the reacted zone that forms as fertile melt infiltrates the ambient mantle. This porosity is determined by the coupling of mass and energy transport through the major element phase behavior and can be determined through a non-linear chromatographic analysis. Here we consider the special case of a partially molten porous medium with binary solid solution, which leads to the formation of a single reaction zone between the advancing reaction front and the initial lithological contact. The porosity profiles of the advancing reaction zone can have two distinct morphologies: sharp or spreading. Sharp reaction fronts occur when the reaction zone causes an upstream increase in reaction front velocity. Spreading reaction fronts that widen with time are observed in our new chromatographic analysis. These widening fronts may explain gradual changes in bulk composition near reactive mafic features on mesoscopic scales. Furthermore, the comparison of reaction fronts shed insight into whether reactive-instabilities and melt localization may occur. Localization of the melt emanating from the heterogeneity into high-porosity channels is most likely when the porosity of the reacted zone is high and the reaction front is sharp. The chromatographic analysis allows a graphical representation of the reactive melt transport behavior in the form of a map of composition paths in the phase diagram. This allows the identification of heterogeneity melting scenarios that are most likely to give rise to localization of the melt flow. The graphical tools developed here also help predict the direction of reactive flow based on the morphological sequence of reaction fronts.