

Thermodynamic Modelling of Open-system Behaviour for Anatectic Metapelites

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Summary

Open-system processes, including fractional melting and fractional crystallization, may occur in rocks that have undergone partial melting and these processes must be accounted for when constructing isochemical phase diagram sections for anatectic metapelites. If fractional melting occurs, there are significant changes to the location of quartz, feldspar, and subsolidus phase boundaries, but there are almost no changes to the suprasolidus phase boundaries involving mafic phases. During fractional crystallization, the modality is dominated by quartz and feldspar, and the mafic phases that crystallize are different from those that crystallize if the melt is in equilibrium with the source. With the important exception of quartz and feldspars, the P-T condition of the peak metamorphic assemblage can be predicted even if fractional melting or crystallization occurred; however, retrograde reactions cannot be modelled unless open-system processes are taken into account.

Abstract

The use of isochemical phase diagram sections (pseudosections) to infer P-T histories of rocks requires knowledge of the chemical composition of the equilibrium volume during metamorphism. In anatectic pelites, however, melt extraction and fractional crystallization may alter the equilibrium composition. Because a change in composition affects where mineral assemblages are stable in P-T space, these anatectic processes must be accounted for to accurately infer P-T histories from migmatites.

Fractional melting and fractional crystallization are modelled using the equilibrium thermodynamic modelling software package TheriakDomino (de Capitani, 1994) utilizing the updated thermodynamic database of Holland and Powell (1998) and mineral activity-composition relations of Tinkham and Ghent (2005) and White et al. (2007). Modelling is carried out in the chemical subsystem MnNCKFe₂+Fe₃+MASHT using an average pelite composition. Two hypothetical P-T paths for anatectic metapelites are modelled; one is an intermediate-pressure "regional" loop and the other is a low-pressure "contact" loop.

Compared to the case where no melt is extracted, fractional melting can significantly alter the location of suprasolidus Kfs, Qtz, and Pl phase boundaries but other phase boundaries (e.g. Grt, Crd, Bt, Sil, Opx) are not affected. The topology of the subsolidus portion of the phase diagram is also substantially altered.

If melt physically segregates into lenses or veins that remain in the host rock, the melt may maintain chemical equilibrium with the adjacent solids during cooling, or it may undergo fractional crystallization in a closed chemical system. During fractional crystallization, the modal mineralogy is dominated by Qtz, Kfs, and Pl, whose ratio is dependent upon the composition of the melt. For K-poor pelites, it is possible to fractionally crystallize Qtz and Pl without Kfs, implying Qtz+Pl segregations may have an anatectic origin. Other phases (e.g. Grt, Crd, Bt, Opx, Sil) crystallized from melt may be used to characterize the retrograde portion of the P-T

path; for example, in some scenarios, counterclockwise P-T paths will crystallize Grt+Bt compared to Crd+Bt for clockwise paths.

Whole-rock composition analyses of migmatites may not represent the equilibrium volume. Although creating a phase diagram section with an unrepresentative composition will affect the location of Kfs, Qtz, and Pl-out phase boundaries, it has surprisingly little effect on other boundaries near and above peak metamorphic conditions. Below peak conditions differences in the phase diagram sections are significant enough that retrograde reactions cannot be accurately predicted.

References

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