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The mass balance constraints on the depletion of elements during metamorphic devolatilization and anatexis

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The consideration of mass balance to loss of elements from metamorphic rocks during devolatilization and anatexis reveals some principal constraints that must be considered in any model of element redistribution in metamorphic processes. During devolatilization, the changes in rock composition with the increase of metamorphic grade are a result of loss of fluid, produced by devolatilization reactions. Fluid, characterised by low viscosity and density, can be effectively extracted from a rock. Metamorphic devolatilization on average results in loss of 1-4 wt. % of the rock mass to the fluid and typically the average loss is <2 wt. %. This relatively small mass fraction mandates that in order to decrease the content of an element significantly (small percentage loss will not be visible on sediment heterogeneity) the concentration of an element in fluids must be much greater than in the protolith. For example, for 50% extraction of an element by 2% fluid, the fluid should have 25 times higher content than the protolith and loss of 50% of element with 0.5% of fluid require fluid with 100 times enrichment (Stepanov 2021).

Anatexis produce granitic melt with high viscosity and density lower than restite. The experimental data suggest that melt extraction could occur when melting degrees >10%. For a completely incompatible element enrichment by 10 times relative to protolith could is maximum achievable in anatectic process. Many elements are concentrated in residual phases and completely incompatible behaviour is rarely observed, hence reducing the efficiency of enrichment. The closes examples of incompatible behaviour during anatexis are restites produced by high-T anatexis, when accessory minerals experienced complete dissolution in melt, such as restites of the Kokchetav complex and septa from Ivrea Verbano Zone (Ewing et al., 2014). However, higher melting degree produce less enriched melt even for incompatible elements. For compatible element melt loss increase content in restite, but loss of 10% melt increase only by 11%, and 50% of melt loss (which could be considered as maximum) increase incompatible element by factor of 2. The mass balance constraints show limits of the possible effect of fluid/melt loss on rock composition and suggests that fluid loss could produce higher enrichment factors than melt loss.

References

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