



## Experimental simulations of anatexis and assimilation involving metapelite and granitic melt

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### ABSTRACT

Assimilation of foreign material into a granitic magma body entails mixing between two end-member components: the initially solid assimilant, and the original magma, whose composition is mostly represented by a granitic liquid. In this study, we assess the interactions between a haplogranite liquid made to the composition of the minimum at 200 MPa H<sub>2</sub>O (Ab<sub>38.23</sub>Or<sub>28.72</sub>Qtz<sub>33.04</sub>Crn<sub>00.01</sub>) with a schist composed of muscovite and quartz with minor biotite and garnet and traces of ilmenite, plagioclase, apatite, and graphite, from 700° to 800°C at 200 MPa ± aqueous-carbonic fluid. The primary focus of this work is to assess the changes in compositions of granitic liquids that form in each reservoir as a result of the assimilation of schist by granitic magma. Before doing so, we evaluate the experimental database for the compositions of granitic liquids in equilibrium with peraluminous mineral assemblages. Most experiments that entail partial melting of peraluminous mineral assemblages begin with finely milled powders. This method yields melt pools (glass) too small for accurate analysis by electron beam methods. As a result, most published analyses of glasses from such experiments are more aluminous and less sodic than their actual compositions. The analytical errors are large, up to 50% relative to the mean value for some elements. In addition, the experimental melts are commonly more hydrous than reported, and vapor-saturated, even in experiments that are cited as “vapor” or “fluid-absent.” Experiments that combine sand-sized mineral grains and powdered granitic glass yield the best approach to chemical equilibrium and facilitate accurate analysis of the glass. Glasses from such experiments define the compositions of liquids that may be derived either from the anatexis of aluminous metasediments, or by the assimilation of aluminous rocks into a granitic magma whose composition is approximately represented by the minimum composition in the haplogranite system Ab–Or–Qtz–H<sub>2</sub>O. New experiments designed to simulate the assimilation of metapelites by granitic melt juxtaposed a solid core of anhydrous granitic glass with a solid core of mica schist, both as described above. At comparable conditions, melting within the mica schist alone is far less extensive than when coupled with the granitic liquid. This is because field diffusion, the long-range and highly organized migration of H, Na, and K throughout the entire volume of interconnected melt, quickly brings the composition of silicate liquid to chemical equilibrium across the metapelite–granite interface with respect to these components and in regard to the ASI, Aluminum Saturation Index and the H<sub>2</sub>O content of the melt. The most significant change entails the diffusion of Na from granitic liquid into the metapelite, which shifts the bulk composition of the metapelite toward the minimum in the granite system, and, in turn, promotes a greater proportion of melting within the metapelite. A weaker counter-flow of K back into the haplogranite raises its K\* (molar K/[Na + K]) and lessens the increase in ASI (molar Al/[Na + K]) due to Na loss. The solubility of H<sub>2</sub>O in granitic liquid is positively correlated with the ASI value. Hence, changes in the ASI of melt that follow from field diffusion of H, Na, and K ions also strongly affect the aH<sub>2</sub>O within the coupled metapelite–granite system.

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### 1. Introduction

Assimilation of foreign rock materials into a magma body is a mixing process. Like any other mixing process, assimilation can be recognized and assessed only to the extent that the compositions of

the end-members are known. Field exposures of magma-host contacts, or of unreacted xenoliths of rock in magma, may reveal the composition of the assimilant. The composition of the liquid, however, is more equivocal because magmas may (and do) contain crystals entrained from their sources, precipitated by cooling on the liquidus, or dispersed by disaggregation of assimilant. If the composition of a silicate liquid is known, then the proportion and mineralogy of entrained crystalline material (regardless of source) can be deduced by conventional chemographic methods: mass balance projections of

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liquid, bulk composition, and mineral phase assemblages onto appropriate phase diagrams (e.g., see [Morgan and London, in press](#)).

In this study, we use experiments to model the assimilation of metapelite by granitic liquid. These experiments juxtapose solid cores of an anhydrous granitic glass made to the composition of the minimum at 200 MPa H<sub>2</sub>O (Ab<sub>38.23</sub>Or<sub>28.72</sub>Qtz<sub>33.04</sub>Cr<sub>0.01</sub>) with a foliated and thinly laminated schist (JCT-COT) composed of muscovite and quartz with minor biotite and garnet and traces of ilmenite, plagioclase, apatite, and graphite. The experiments span the range from 700° to 800 °C at 200 MPa ± aqueous-carbonic fluid. In this case, the primary aim of the experimentation is to assess the changes in the composition of the granitic liquid as reaction proceeds between the “magma body” and the adjacent “host” muscovite schist. For this reason, we begin the paper with a brief review of experimental methods and results that pertain to the partial melting of aluminous minerals or rocks (metapelites). The aim of this review is an answer to this question: how well do we know (from experiments) the compositions of the granitic liquids that are equilibrated with peraluminous minerals or assemblages, whether derived from the partial melting of a metapelite or by assimilation of metapelite into granitic magma? This question is germane to an assessment of assimilation of metapelite into granitic magma, as granitic liquid represents one of the end-members of the potential mixing event.

## 2. Review of experimental materials and methods

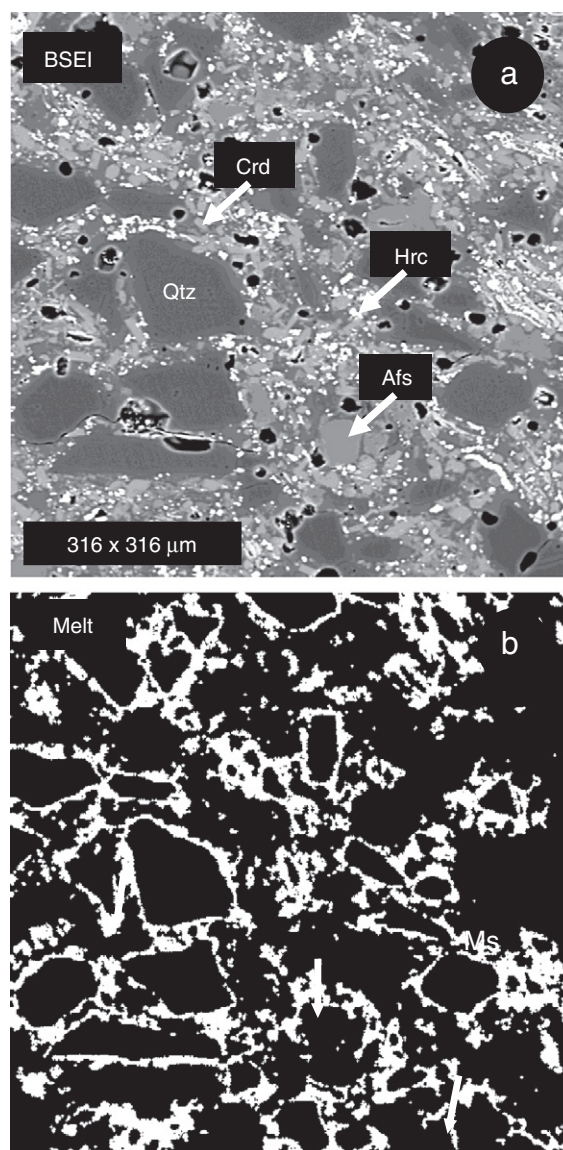
### 2.1. Experiments with powdered starting materials

In most experiments, the initial solid materials consist of finely-milled powders (~2–20 μm) of rock, mineral admixtures, oxide reagents, or glass. The comminution of rocks, minerals, or glasses to fine powders greatly increases the surface area of the reactants and homogenizes their distribution in the sample. This material, therefore, facilitates the progress of the melting reaction and achieves the quickest approach to equilibrium between minerals and melt in the timeframe of experiments. With the rapid approach to crystal-melt equilibrium, this method is best suited for the determination of the peritectic mineral assemblage in equilibrium with silicate melt, and for assessing the progress of melting reactions (phase identity and proportions) as functions of changing intensive or extensive variables.

#### 2.1.1. Vapor saturation

When they sinter, fine silicate powders trap a large fraction of air in the interstices between grains. Air, which is mostly N<sub>2</sub>, is highly compressible; however, N<sub>2</sub> possesses a very low solubility (~1 mol%) in highly polymerized and relatively oxidized silicate melts ([Mysen et al., 2008](#)). Consequently, when powders sinter, they trap air bubbles that persist at least up to a few hundred MPa of pressure ([Fig. 1](#)). Contrary to some authors' claims, such experiments are vapor-saturated, even when no water is added, and a fraction of H<sub>2</sub>O in the experiment partitions into the N<sub>2</sub>-rich vapor phase. This observation may be semantic, insofar as the experiments are represented as vapor-undersaturated. However, the effects of N<sub>2</sub> on the displacement of mineral-melt equilibria due to the loss of H<sub>2</sub>O from the melt to the N<sub>2</sub>-rich vapor may be non-negligible.

Micrometer-size powders of minerals, oxide reagents, and glasses also adsorb H<sub>2</sub>O to their surfaces. In temperate climates, such powders normally adsorb 1–4 wt.% of their weight in H<sub>2</sub>O through normal handling, and they retain adsorbed water when stored under desiccation. To our knowledge, no experimentalists have factored that adsorbed H<sub>2</sub>O into the total budget of H<sub>2</sub>O in their experiments. Consequently, many partially-melted experimental products that employ micronized powders at low (MPa) to moderate (GPa) pressures are at or near saturation in H<sub>2</sub>O, even those that are presented as no water added or H<sub>2</sub>O-undersaturated or fluid-absent. If hydrous minerals are part of the starting assemblage and they participate to a large extent in the melting



**Fig. 1.** Backscattered electron image (a) and threshold-sorted Si K $\alpha$  X-ray map (b) of a typical experimental product formed by heating a comminuted powder containing equal weight fractions of muscovite (Spruce Pine, NC), biotite (Rayleigh Peak, CO), and quartz (Minas Gerais, Brazil) without added H<sub>2</sub>O to conditions of 750 °C, 200 MPa, log  $f_{O_2}$  = NNO – 0.5, for 5 days. The BSE image shows the miniscule grain size of the peritectic phases produced by the melting reaction of all three reagents, and the largest glass pool is highlighted by a white line. The Si K $\alpha$  map depicts the small size of the glass pools that represent quenched silicate liquid.

reactions (e.g., muscovite), then melts will very likely be saturated in H<sub>2</sub>O at the low fractions of melting that are typical for these experiments.

#### 2.1.2. Electron microprobe analysis

When finely milled powders are employed, and the bulk compositions are far from that of the minimum melt composition for the system, then the resultant melt pools tend to be choked with tiny crystals of residual and peritectic minerals. Crystal-free melt domains rarely exceed 5–10 μm in maximum dimension ([Fig. 1](#)). Microprobe analyses of such small glass domains require a focused beam, and beam currents of 5–10 nA are commonly used to generate count rates that provide sufficient statistical accuracy. When a beam of 5–10 nA current is focused on a spot ≤ 20 μm in diameter, however, heating within the excitation volume causes Na to diffuse out of the irradiated area, producing a consequent drop in the Na K $\alpha$  X-ray

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