In this study, we quantitatively investigate crystal-melt segregation processes in two upper-crustal, intermediate-to-silicic plutons from the Tertiary Adamello Batholith, Italian Alps, by combining (1) an estimation of the amount of crystallized interstitial liquid using cathodoluminescence images, phase maps, and mass-balance calculations with (2) quantification of crystal preferred orientation using electron backscatter diffraction. Cathodoluminescence images, phase maps, and plagioclase profiles are used together to distinguish early grown primocrysts from overgrowths formed after the rheological “lock-up” of the magma bodies. Mass-balance calculations, taking into account mineral compositions and bulk-rock chemistry, are used as an additional means to quantify the amount of trapped melt. The following features are indicative of crystal accumulation (or melt loss) in some parts of the batholith: (1) The amount of crystallized interstitial liquid can be low and negatively correlated with crystal (and shape) preferred orientations. Locally, up to ca. 27% melt may have been lost. (2) Significant intracrystalline deformation in plagioclase (up to ca. 13° of lattice distortion) is present in strongly foliated samples, resulting from compaction in a highly crystalline mush. These mineralogical and textural features indicative of variability in the degree of crystal accumulation in some areas of the Adamello batholith may explain the highly scattered bulk-rock geochemical patterns (particularly in trace elements). However, the precise quantification of the amount of melt loss remains challenging in felsic plutons, because of the compositional deviation from liquid lines of descent due to multi-scale variations in the degree of crystal-melt segregation and the fact that magmatic textures indicative of crystal accumulation can be subtle.

Keywords: Adamello, crystal cumulate, crystallized interstitial liquid, intermediate-to-silicic batholith, phase maps, cathodoluminescence

Research interest

Melt extraction from intermediate-to-silicic crystal mush has been the topic of numerous studies to explain the origin of crystal-poor rhyolites (e.g., Bacon and Druitt 1988; Hildreth and Fierstein 2000; Hildreth 2004; Bachmann and Bergantz 2008; Deering and Bachmann 2010; Huber et al. 2012). Most of these studies concentrated on the volcanic products, without clearly linking them to the plutonic record. Yet, the latter retains a more complete (time- and composition-wise) record of the magma reservoir dynamics (see recent publications by Miller and Miller 2002; Turnbull et al. 2010; Paterson et al. 2011; Tappa et al. 2011; Beane and Wiebe 2012; Coint et al. 2013; Gutiérrez et al. 2013; Putirka et al. 2014; Graeter et al. 2015; Lee and Morton 2015; Barnes et al. 2016) and can provide important information on the physical mechanisms involved, if any melt segregation has occurred.

Melt segregation can be traced by investigating the crystal cumulates left over after melt separation (e.g., Weinberg 2006; Deering and Bachmann 2010). However, the existence of cumulates in intermediate-to-silicic igneous rocks in the mid- to upper crust is still strongly debated (Bartley et al. 2006; Streck and Grunder 2007; Reubi and Blundy 2009; Deering and Bachmann 2010; Tappa et al. 2011; Davis et al. 2012; Mills and Coleman 2013; Gelman et al. 2014; Streck 2014; Glazner et al. 2015; Lee and Morton 2015; April 2016 issue of Elements). If felsic cumulates do not exist, the generation of eruptible melt pockets from shallow, evolved crystal mush, or at least the mechanisms behind it, would be in question. Alternatively, the presence of a significant trapped melt component would render the cumulate signature very subtle (e.g., Gelman et al. 2014).

The presence of cumulates in plutonic lithologies may be recorded by the bulk geochemical signature. For example, as concentrations of incompatible trace elements must increase along the liquid line of descent, the greater the melt loss, the stronger the depletion in incompatible trace elements in the final bulk-rock composition. Strong variability in trace element concentrations within a single differentiation series has been reported from individual plutons all over the world (e.g., Lee and Morton 2015; Walker et al. 2015; Eddy et al. 2016), and part of this variability may be related to crystal-melt segregation. However, identification of cumulates utilizing such bulk-rock techniques suffers from the fact that multiple liquid lines of descent can occur in a single magmatic series, in particular for incompatible elements or...