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Secular variations of magma source compositions in the North Patagonian batholith from the Jurassic to Tertiary: Was mélange melting involved?

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ABSTRACT

This study of Sr-Nd initial isotopic ratios of plutons from the North Patagonian batholith (Argentina and Chile) revealed that a secular evolution spanning 180 m.y., from the Jurassic to Neogene, can be established in terms of magma sources, which in turn are correlated with changes in the tectonic regime. The provenance and composition of end-member components in the source of magmas are represented by the Sr-Nd initial isotopic ratios ($^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$) of the plutonic rocks. Our results support the interpretation that source composition was determined by incorporation of varied crustal materials and trench sediments via subduction erosion and sediment subduction into a subduction channel mélange. Subsequent melting of subducted mélanges at mantle depths and eventual reaction with the ultramafic mantle are proposed as the main causes of batholith magma generation, which was favored during periods of fast convergence and high obliquity between the involved plates. We propose that a parental diorite (= andesite) precursor arrived at the lower arc crust, where it underwent fractionation to yield the silicic melts (granodiorites and granites) that formed the batholiths. The diorite precursor could have been in turn fractionated from a more mafic melt of basaltic andesite composition, which was formed within the mantle by complete reaction of the bulk mélanges and the peridotite. Our proposal follows model predictions on the formation of mélange diapirs that carry fertile subducted materials into hot regions of the suprasubduction mantle wedge, where mafic parental magmas of batholiths originate. This model not only accounts for the secular geochemical variations of Andean batholiths, but it also avoids a fundamental paradox of the classical basalt model: the absence of ultramafic cumulates in the lower arc crust and in the continental crust in general.

INTRODUCTION

Andean (= Cordilleran)–type batholiths represent large volumes of silicic ($SiO_2 > 53$ wt%) magmas that are generated at active continental margins. The subduction of lithosphere is, directly or indirectly, the triggering process for magma generation. However, fundamental issues like the source of magmas and the locus of melting, mantle or crust, still remain debated. Competing processes have been proposed, such as (1) the melting of a metasomatized mantle wedge by action of fluids from a downgoing slab (Grove et al., 2002, 2005; Kushiro, 1974) (2) assimilation and melting of continental crustal rocks triggered by invasion of basalts at the lower crust (Hildreth and Moorbath, 1988), and, more recently, (3) melting of subducted mélanges within the mantle wedge (Castro et al., 2010; Codillo et al., 2018; Cruz-Uribe et al., 2018). In principle, the three mechanisms may result in the generation of silicic melts and/or their intermediate parental magmas, leading finally to the formation of batholiths. However, requirements imposed by geochemical and isotopic ratios are better accounted for by mechanisms involving mixing of sources that occurred previous to melting within the mantle (Nielsen and Marschall, 2017) rather than mixing of melts from different sources or assimilation of crustal contaminants by mantle-derived basaltic melts (Davidson et al., 1991; Hildreth and Moorbath, 1988). Consequently, determining whether isotopic features are inherited from the source or acquired by magmas during their ascent and emplacement is an essential step to decipher the role of isotopic ratios in supporting or rejecting the aforementioned mechanisms. We show here new U-Pb sensitive high-resolution ion microprobe (SHRIMP) zircon ages and Sr-Nd isotopic data from plutons of the North Patagonian batholith (Chile and Argentina), which can unravel the secular geochemical evolution of magma source compositions from the Jurassic onwards. In subduction zones, this evolution is expected to entail changes in the relative contributions of geochemically evolved continental reservoirs (e.g., sediments and ancient continental crust) and altered oceanic crust. Although there is agreement about the presence of these end members in the composition of Andean (= Cordilleran) batholiths (DePaolo, 1981b; Hervé et al., 2007; Lee et al., 2006; Pankhurst et al., 1999), the mechanisms by which they are incorporated into magmas remain poorly constrained. We discuss the determination of these mechanisms through study of geochemical secular variations in plutons of the North Patagonian batholith.