Extraction of high-silica granites from an upper crustal magma reservoir: Insights from the Narusongduo magmatic system, Gangdese arc

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Abstract

The genesis of high-silica igneous rocks is important for understanding the behavior of shallow magmatic systems. However, although many such studies have focused on the eruption of crystal-poor high-SiO2 rhyolites, the origin of high-silica granites (HSGs) has received comparatively little attention. Here, we present a detailed study of HSGs from the Narusongduo volcanic complex, Gangdese arc. Combining zircon U-Pb geochronology with stratigraphic investigations, we show that the Narusongduo magmatic system was constructed over a period of ≥3.7 Myr with or without lulls. On the basis of zircon textures and ages, diverse zircon populations, including antecrysts and autocrysts, are recognized within the HSGs and volcanic rocks. All of the igneous rocks within the Narusongduo volcanic complex have highly radiogenic Sr–Nd isotopic compositions. Our results indicate the presence of an andesitic magma reservoir in the upper crust at a paleodepth of ~8 km. Ubiquitous zircon antecrysts in the HSGs, combined with compositional similarities between the HSGs and evolved melts of the andesitic magma reservoir, indicate that the Narusongduo HSGs represent melts extracted from the shallow magma reservoir. In addition, our results suggest that magma recharge promoted the escape of high-silica melts to form the Narusongduo HSGs. This work presents an excellent case that kilometer-scale high-silica granites are the differentiated products from an upper crustal magma reservoir. It would make a contribution to contemporary debates concerning the efficiency of crystal–melt separation in upper crustal magmatic systems.

Keywords: High-silica granite, magma reservoir, crystal–melt separation, upper crust, rhyolite

Introduction

High-silica granites (HSGs) and rhyolites, although comprising a small proportion of the upper continental crust, are important for understanding the behavior of shallow magmatic systems. Their study can test the efficiency of crystal–melt separation within upper-crustal magma reservoirs (Bachmann and Huber 2019). In crustal magmatic systems, heat is one of the main controlling factors and determines rheological properties and dynamic behavior of magmas (e.g., Caricchi and Blundy 2015; Blundy and Annen 2016). Thus melt segregation in hot, deep crust is efficient, where chemical differentiation is achieved through crystal fractionation of primitive magmas and/or partial melting of crustal rocks (Hildreth and Moorbath 1988; Annen et al. 2006).

In contrast, large-scale extraction of residual melts from upper-crustal magma bodies is currently debated. The obvious thermal problems might be reconciled by the existence of a long-lived (several million years) transcrustal magmatic system that would facilitate the formation of a magma reservoir with prolonged survivability in the upper crust (e.g., de Silva and Gregg 2014; Karakas et al. 2017). In such a case of a thermally mature system, the time needed for phase separation to occur might be enough (Bachmann and Huber 2019). Compaction is widely invoked as an efficient mechanism for driving separation of melt in silicic magma reservoirs (e.g., Miller et al. 1988; Bachmann and Bergantz 2004). However, there is little microstructural evidence in support of widespread compaction in the solidification of silicic magma chambers (Holness 2018), although this argument against compaction is not widely accepted (e.g., Sparks et al. 2019).

Field examples can help in understanding the dynamic behavior of shallow magmatic systems. Studies of large-scale evolved melts that were segregated from upper-crustal magma bodies have focused on crystal-poor high-SiO2 rhyolites (e.g., Hildreth 1979; Lipman 1988; Bachmann and Bergantz 2004; Deering et al. 2011). In contrast, convincing examples of their intrusive counterparts, representing the separation of highly evolved melts at shallow crustal levels to form pluton-scale...