On silica-rich granitoids and their eruptive equivalents

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ABSTRACT
Silica-rich granites and rhyolites are components of igneous rock suites found in many tectonic environments, both continental and oceanic. Silica-rich magmas may arise by a range of processes including partial melting, magma mixing, melt extraction from a crystal mush, and fractional crystallization. These processes may result in rocks dominated by quartz and feldspars. Even though their mineralogies are similar, silica-rich rocks retain in their major and trace element geochemical compositions evidence of their petrogenesis. In this paper we examine silica-rich rocks from various tectonic settings, and from their geochemical compositions we identify six groups with distinct origins. Three groups form by differentiation: ferroan alkali-calcic magmas arise by differentiation of tholeiite, magnesian calc-alkalic or calcic magmas form by differentiation of high-Al basalt and andesite, and ferroan peralkaline magmas derive from transitional or alkali basalt. Peraluminous leucogranites form by partial melting of pelitic rocks, and ferroan calc-alkalic rocks by partial melting of tonalite or granodiorite. The final group, the trondhjemites, is derived from basaltic rocks. Trondhjemites include Archean trondhjemites, peraluminous trondhjemites, and oceanic plagiogranites, each with distinct geochemical signatures reflecting their different origins. Volcanic and plutonic silica-rich rocks rarely are exposed together in a single magmatic center. Therefore, in relating extrusive complements to intrusive silica-rich rocks and determining whether they are geochemically identical, comparing rocks formed from the same source rocks by the same process is important; this classification aids in that undertaking.

Keywords: Granite, rhyolite, geochemistry, trondhjemite, leucogranite, petrogenesis, Invited Centennial article, Review article

INTRODUCTION
Silica-rich granites and rhyolites are components of igneous rock suites found in many tectonic environments, including convergent margins, divergent margins, and intraplate hotspot and extensional regimes. They are most voluminous in continental settings but also occur in oceanic environments. Silica-rich magmas may arise from various processes including partial melting, fractional crystallization, magma mixing, and extraction of melt from a crystal mush. Although all are dominated by quartz and feldspars, silica-rich rocks form by different petrogenetic processes and from various parental materials, and they retain evidence of their petrogenesis in their major and trace element geochemical compositions. In this paper, we identify six geochemically distinct groups of high-silica granitic rocks and rhyolites that appear to have formed by nearly end-member processes of partial melting or differentiation (either fractional crystallization or melt extraction). We suggest that recognition of these groups is a necessary preliminary to resolving questions about high-silica rocks, including for example, the relationship of volcanic rocks to their plutonic complements.

Using a similar geochemical approach, Frost et al. (2001) recognized peraluminous leucogranites as a special family of granitoids. These rocks are characterized by high silica (>70%) and range from ferroan to magnesian and from calcic to alkalic. Their only common geochemical features are their high silica content and peraluminous nature. Because all of the leucogranite suites tabulated in their study contained rocks with more than 70% SiO2 (see Fig. 3 in Frost et al. 2001) they put the cut-off for peraluminous leucogranites at 70% SiO2. In addition to peraluminous leucogranites there are several other groups of silica-rich granitoids, many of which are true leucogranites, and all of which are summarized in this paper.

Our approach relies first on major element analyses utilizing four geochemical indices: Fe-index, modified alkali-lime index (MALI), alumina saturation index (ASI), and alkali-lime index (AI) (Frost et al. 2001; Frost and Frost 2008; Table 1). As silica content increases in granitoids, the proportions of other elements necessarily decrease, and as a result, the oxides used in these geochemical indices (e.g. Al2O3, CaO, Na2O, K2O, FeOtot, and MgO) make up an increasingly small proportion of the total. Nevertheless, different occurrences of silica-rich rocks define distinct characteristics, ferroan and magnesian, alkalic to calcic, and metaluminous, peraluminous, and peralkaline. Because