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SPECIAL COLLECTION: PERSPECTIVES ON ORIGINS AND EVOLUTION OF CRUSTAL MAGMAS

Crystal accumulation in a tilted arc batholith

Calvin G. Barnes[1,*], Nolwenn Coint[2], and Aaron Yoshinobu[1]

[1]Department of Geosciences, Texas Tech University, Lubbock, Texas 07409-1053, U.S.A.
[2]Geological Survey of Norway, PO Box 6315, Sluppen, 7491 Trondheim, Norway

Abstract

The Wooley Creek batholith is a Late Jurassic, arc-related, calc-alkaline plutonic complex in the Klamath Mountain province of California. Post-emplacement tilting and erosion have exposed ~12 km of structural relief. The complex consists of an older (~159.1 Ma) lower zone (pyroxenite to tonalite) assembled by piecemeal emplacement of many magma batches, a younger (~158.2 Ma) upper zone (quartz diorite to granite), and a transitional central zone. In the lower zone, pyroxenes are too Fe rich to be in equilibrium with a melt whose composition was that of the host rock. Mass-balance calculations and simulations using rhyolite-MELTS indicate that these rocks are cumulates of pyroxenes and plagioclase ± olivine and accessory apatite and oxides. Percentages of interstitial melt varied from ~7.5–83%. The plagioclase/pyroxene ratios of cumulates vary considerably among the most mafic rocks, but are relatively uniform among quartz diorite to tonalite. This near-constant ratio results in compositional trends that mimic a liquid line of descent. In the upper zone, bulk-rock compositional trends are consistent with differentiation of andesitic parental magmas. Upward gradation from quartz dioritic to granitic compositions, modeled via mass-balance calculations and rhyolite-MELTS simulations, indicate that structurally lower parts of the upper zone are cumulates of hornblende and plagioclase ± biotite and accessory minerals, with 37–80% trapped melt. In contrast, the structurally higher part of the upper zone represents differentiated magma that escaped the subjacent cumulates, representing differentiated melt fractions remaining from 92–54%. The ratio of cumulate plagioclase/(plagioclase + mafic minerals) is ~0.48 among upper-zone cumulates, mimicking a liquid line of descent.

The results suggest that compositional variation in many calc-alkaline plutons may be at least as representative of crystal accumulation as of fractional crystallization. If so, then the assumption that arc plutons geochemically resemble frozen liquids is dubious and should be tested on a case-by-case basis. Moreover, comparisons of plutonic rock compositions with those of potentially comagmatic volcanic rocks will commonly yield spurious results unless accumulation in the plutons is accounted for.

Keywords: Calc-alkaline plutons, crystal accumulation, fractional crystallization, mass balance, Invited Centennial article