Geophysical Research Abstracts,
Vol. 10, EGU2008-A-10753, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-10753
EGU General Assembly 2008

Growth of a large magma chamber: An example from the Tuolumne batholith, Sierra Nevada, California

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Field, geochronology and geochemistry results from the magmatic lobes of the 1100 km^2, 95-85 Ma, normally zoned Tuolumne batholith, Sierra Nevada, California, increasingly support the idea that the incremental growth of this magma body resulted in a large region of interconnected melt in a centralized magma chamber, which was large and long-lived enough for processes like fractionation crystallization, widespread mixing and recycling of older pulses into younger to operate.

Four magmatic lobes – tongues of magma that emplaced at the distal parts of the central Tuolumne body and did not interact with other, younger intruding Tuolumne pulses – represent each of the three major Tuolumne batholith units: (1) the marginal and most mafic, 95-93 Ma Kuna Crest granodiorite, (2) the 92-88 Ma equigranular and Kfs-porphyritic Half Dome granodiorites, and (3) the central, 88-86 Ma Kfs-megacrystic Cathedral Peak granodiorite. All lobes are characterized by a pattern of more mafic marginal granodiorites that grade successively into more felsic, leucogranitic units towards the center. Internal contacts are mostly steep and gradational with local crosscutting intrusive relationships indicating inward younging, which is verified by CA-TIMS U/Pb zircon geochronology. Element and isotope geochemistry of the lobes suggest that the compositional pattern is due to fractionation crystallization and additional minor mixing processes in the larger lobes, whereas mixing and recycling are the dominant processes in the main chamber. The high precision U/Pb geochronology results also show that the lobes are older parts of the magma system, and short-lived magmatic bodies that froze in snap-shots of earlier magma chamber processes.

We suggest that the 10-30 km^2 magmatic lobes are probably single pulses emplaced too far away from the eventual focus of magmatism and thus failed to amalgamate with other pulses to form part of the large, central magma chamber. Due to their distance to the main zone of amalgamation they cooled earlier and were able to freeze in their initial magma composition and isotopic signature. Closer to the main chamber, gradational mixed units formed indicating the areal extent of amalgamation. Contacts, magmatic foliation and lineation, and local flow channels dip or plunge steeply in lobes and in the main chamber implying that the pulses dominantly grew vertically.

Although it is difficult to identify the number and size of magma pulses that built up the Tuolumne batholith, pulses must have been large enough or arrived fast enough to amalgamate and form a large, centralized area of interconnected melt. This must particularly be true during growth of the 92-88 Ma old Half Dome granodiorite and the 88-86 Ma Cathedral Peak emplacement as is evidenced by gradational contacts, recycled antecrystic zircons and cognate inclusions into younger units, and geochemical results.