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Relationships between rates of silicic magma generation, eruption and extensional tectonics: Insights from the Bolanos Graben, Southern Sierra Madre Occidental, Mexico

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Recent studies have realised potential differences in the rates of eruption of large-volume ($>10^2$ km^3) silicic magmas that bear on connections and relationships between silicic plutonic systems and their volcanic counterparts. Large-volume rhyolite eruptions may represent either: 1) the end product of prolonged steady-state or episodic growth of a melt-rich magma bodies or large-volume, crystal-rich, melt-poor mushes, or 2) rapid accumulations of melt bodies formed shortly prior to each eruption, either through crustal melting, or extraction from crystal-rich mushes. In addition, active rifting processes and tectonic disruption of mush piles are increasingly being invoked as an important trigger mechanism for eruptions. Two important consequences of eruption timing linked to active rifting processes are that: 1) gaps between the eruption age and peak model crystallisation ages can develop (Charlier & Wilson, 2009; J Petrol.); and 2) batholithic volumes of crystal-rich ($\sim$50% vol.) and apparently uneruptable magma or mush piles can be evacuated (Gottsman et al., 2009; EPSL). The 140 km long, N-S trending Bolaños graben, in the southeastern part of the Sierra Madre Occidental silicic large igneous province, was cited as an example by Gottsman et al. (2009) where large-volume silicic eruptions tapping semi-molten batholiths were triggered by concurrent extensional faulting, and produced crystal-rich, fissure-fed ignimbrites and 'graben calderas'. Here we present new field, U-Pb zircon geochronologic and chemical data from the central Bolaños graben that are at odds with this 'graben caldera' model and provide important insights into source regions and mechanisms for crystal-poor rhyolite generation. An $\sim$1km thick Oligocene succession of moderate- to high-grade rhyolitic ignimbrites interbedded with resedimented pyroclastic units form the walls to the central Bolaños graben but in detail, both crystal-poor ($<$15%) and crystal-rich ($>$30%) ignimbrites are present. Capping the graben wall succession and partly infilling the graben is a $\sim$24-23 Ma suite of very crystal-poor ($\leq$5%) rhyolite to high-silica rhyolite ignimbrites and domes that are interbedded with, and overlain by, basaltic lavas. The Chimal Tuff (18.4 $\pm$ 0.4 Ma, ^{40}Ar/^{39}Ar) is the youngest ignimbrite deposited within the graben. Rhyolite dome emplacement was focussed around a major NE-trending transfer fault zone to the graben, as well as along bounding N-S faults during graben initiation. The $\sim$23 Ma (^{40}Ar/^{39}Ar) Alacrán ignimbrite is the best candidate for a graben-caldera-related ignimbrite, however, several aspects contradict eruption(s) from a pre-existing molten or semi-molten batholith. The Alacrán ignimbrite is very crystal poor ($<$5%), much less extensive and lower in erupted volume ($\leq$100 km^3) than previously assumed, and the low zircon yields, high antecrystic zircon content (clustering at $\sim$29 Ma) and Zr dissolution modelling indicate rapid magma generation and eruption with magma residence times $<$30,000 yrs. Furthermore, rhyolite domes emplaced in the graben and associated in space and time with the Alacrán ignimbrite have subtly different age systematics and zircon compositions, precluding a common batholithic chamber existing beneath the graben. The repeated and widespread eruption of basalts (forming lava packages $\sim$200 m thickness) via extensional faults is also hard to reconcile with a semi-molten chamber, which should have acted as a density barrier to ascending mafic magmas. We favour a model in which early Miocene extension allowed basalts to intrude at shallow depths and erupt, as well as causing the partial (re-)melting of Oligocene plutons. Typically Zr undersat-

urated rhyolite melts were generated and rapidly erupted rather than being extracted from any large-volume crystal mush piles or batholiths.