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Timing and evolution of Late Oligocene to Miocene magmatism in the southern Sierra Madre Occidental silicic large igneous province: insights from zircon chronochemistry and Ar/Ar geochronology

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The Sierra Madre Occidental silicic large igneous province (SLIP) of western México (SMO) is one of the largest SLIPs known. Here we present new field, U-Pb zircon and ^{40}Ar/^{39}Ar geochronologic and chemical data from the central Bolaños graben (southern SMO); together with previous work (Bryan et al, 2008; J Petrol) on the SMO that sheds light on the temporal evolution of silicic magmatism. The exposed succession in the Bolaños graben spans at least 10 Myr, with a $\sim$1 km thick Oligocene volcanic pile dominated by ignimbrites interbedded with resedimented pyroclastic units (Zuloaga Series). The Zuloaga Series includes both crystal-poor ($<$15%) and crystal-rich ($>$30%) welded ignimbrites, with the crystal-poor types often being densely welded, high-grade ignimbrites. A distinctive ignimbrite (the Alacrán ignimbrite) and many rhyolitic domes were then emplaced at $\sim$24-23 Ma, which are also interbedded with basaltic lavas. These rhyolites are very crystal-poor ($\leq$5%) with the ignimbrites being distinctly poorly welded and they show distinctive zircon ages and chemistries in contrast with the preceding Oligocene Zuloaga Series and ignimbrites from the northern SMO. Capping the erupted succession is the non-welded Chimal Tuff (18.4 $\pm$ 0.4 Ma, ^{40}Ar/^{39}Ar) and basaltic lavas.

U-Pb age data from the northern SMO rhyolites show well-defined unimodal peaks in the age distribution, although there is some zircon inheritance in some units. In contrast, ignimbrites from the Bolaños area, particularly the $\sim$24-23 Ma suite of rhyolite ignimbrites and domes have more complex and polymodal zircon age distributions, and the U-Pb zircon population age can be up to 6 Myr older than the associated ^{40}Ar/^{39}Ar age. The combined zircon age and whole-rock chemical data reveal a trend toward polymodal and inherited zircon age distributions and zircon undersaturation of magmas through time. This is well-expressed in the $\sim$23 Ma (^{40}Ar/^{39}Ar) Alacrán ignimbrite with its low zircon abundance but high antecrystic zircon content (clustering at $\sim$29 Ma), and where $\sim$100% of the zircons are inherited. The inherited zircon ages suggest the Alacrán ignimbrite magma was sourced from igneous crustal rocks formed during previous stages of SMO magmatism. The $\sim$2 Myr age gap between the youngest zircon ages in this ignimbrite and the ^{40}Ar/^{39}Ar age argues against mush remobilisation and instead suggests re-melting has occurred. In addition, the Alacrán ignimbrite also has anomalous whole-rock chemistry such as enrichments in Rb, Cs, K and Al characteristic of clay compositions, suggesting that the crustal source for this ignimbrite may also have been hydrothermally altered.

The combination of zircon chemistry, U-Pb geochronology and whole-rock chemistry indicates the Early Miocene Bolaños graben rhyolites are the result of re-melting of highly differentiated granites generated during preceding phases of SMO activity, and which in part, may also have been hydrothermally altered. A long-term change in the locus and source of silicic magma generation from the Oligocene to Miocene is thus suggested by these data, whereby the source of melt generation appears to have moved upwards through the crustal profile. Crustal extension and shallow emplacement of significant volumes of basalt associated with Early Miocene graben formation in the southern SMO may have promoted crustal melting at shallower depths. The petrogenetic evolution appears to also

be reflected in the deposit characteristics of the ignimbrites, which change from moderate to high-grade and weakly lava-like welded ignimbrites erupted in the Oligocene (reflecting deeper, higher-temperature melt generation) to an Early Miocene suite of poorly to non-welded but sintered, crystal-poor, Zr undersaturated ignimbrites (reflecting mid- to upper-crustal and lower temperature melting) that notably will have a low preservation potential in the geologic record. This temporal trend in changing magma source depths may thus be poorly preserved in older silicic igneous provinces.