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Apatite U-Pb Thermochronology: A combined ID-TIMS and LA-ICP-MS study from southern Ecuador

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A combination of U-Pb LA-ICP-MS and ID-TIMS analyses of apatite has been used to investigate the high temperature (>450˚C) thermal history of the Ecuadorian Andean margin. The rocks of the Eastern Cordillera of Ecuador evolved via terrane collision and accretion events, and active margin magmatism since the Early Jurassic. Low temperature (<350˚C) thermochronological methods show that the Eastern Cordillera exhumed through ∼10-13 km since ∼75 Ma (e.g. Spikings et al., 2001; Spikings et al., 2010), and higher temperature methods are required to constrain Jurassic and Early Cretaceous thermal histories. Our approach is novel because i) previous U-Pb thermochronological studies (e.g. Schoene and Bowring, 2007; Blackburn et al., 2012) focused on the construction and stabilization of Precambrian cratons, whereas our study tests the applicability of U-Pb apatite thermochronology to relatively young rocks, and ii) we apply an inverse modeling technique to search for thermal history solutions to the data.

Apatite LA-ICP-MS and ID-TIMS U-Pb data have been acquired from a Triassic (247.2 ± 4.3 Ma; U-Pb zircon) granite from southern Ecuador, which formed during early rifting of western Pangaea. ID-TIMS data were obtained from fifteen, euhedral apatite size-fractions, of grain radii ranging between 45±5 um and 175±10 um, representing a theoretical Tc range of 450–510 ˚C for cooling rates of 10˚C/my. Concordant $^{238}U/^{206}Pb$ dates range between 81.9±2.6 Ma and 137.87±0.34, and positively correlate with grain size, supporting our hypothesis that Pb loss has occurred via thermally activated, fickian diffusion.

LA-ICP-MS ^{207}Pb corrected dates have been obtained from apatite size fractions that were fixed to a single epoxy mount. Primary and secondary standard apatites were: i) Emerald Lake (92.5 Ma; Chew et al., 2011), with a measured weighted mean age of 91.5 ± 1.3 Ma, 2σ (N = 12), and ii) McClure Mountain Syenite (∼523 Ma; Schoene et al., 2006), with a measured weighted mean age of 519.9 ± 4.4 Ma, 2σ (N = 47). The apatite ^{207}Pb corrected dates range from 196.9 ± 11.4 to 69.1 ± 12.1, 2σ (N = 43), with a majority of ages that cluster between 90 Ma and 100 Ma.

Time (t)-temperature (T) solutions for the data have been generated using a controlled random search procedure provided by the HeFTy software (version 1.7.0; Ketcham, 2011), using the diffusion parameters (Ea and Do) of Cherniak et al., (1991). Geological constraints for the t-T solutions provided considerable freedom, and are i) zircon crystallization at ∼247 Ma during crustal anatexis and ii) cooling during 75-65 Ma as a consequence of the collision of the Caribbean Large Igneous Province. The thermal history solutions simultaneous satisfy apatite ID-TIMS U-Pb ages obtained from six size aliquots. The The best fit t-T solutions (Kolmogorov-Smirnoff goodness of fit >0.5) reveal periods of: i) rapid cooling (∼240-220 Ma) through the Pb Partial Retention Zone (PRZ) shortly after crystallization, ii) residence at temperatures lower than the PRZ throughout the Jurassic, iii) reheating during 140-90 Ma, and iv) rapid cooling starting at 80-70 Ma. These findings corroborate conclusions based on geochronological and sedimentological data.

Additional in-situ age transects and age-depth profiling of apatite are scheduled to determine the concentration distribution of radiogenic lead in the apatites, which will be used to constrain further the mechanisms of lead loss.

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