**APPENDIX I:**

**SEPARATION AND ANALYTICAL TECHNIQUES FOR DETRITAL ZIRCON ANALYSIS AT THE UNIVERSITY OF ARIZONA LASERCHRON CENTER**

Mineral Separation (Stanford University)

 Rock samples were individually crushed and disaggregated using a jaw crusher and disk grinder. Disaggregated samples were individually processed on a Gemini table to remove muds and to separate heavy from light sand fractions. Heavy sand fractions were oven-dried and run through as lope Frantz to remove magnetic minerals. Settings for the slope Frantz were 100 volts at 0.4 angstroms (Å), 0.8 Å, and 1.2 Å. Final density separation of the nonmagnetic heavy fraction was run using methylene iodide (MEI; density of 3.3 g/cm3). Samples were individually packaged and sent to the University of Arizona LaserChron center for final preparation, where they were mounted in a 1-inch epoxy puck with fragments of Sri Lanka standard zircon, polished to half of mean grain thickness (~20 μm), and imaged with BSE to illuminate internal structures.

U-Pb Geochronology Analysis (University of Arizona LaserChron Center)

 U-Pb geochronology of zircons is conducted by laser ablation-multicollector-inductively coupled plasma mass spectrometry (LA-MC-ICPMS) at the Arizona LaserChron Center (Gehrels et al., 2006, 2008). The analyses involve ablation of zircon with a Photon Machines Analyte G2 excimer laser (or, prior to May 2011, a New Wave UP193HE excimer laser) using a spot diameter of 30 μm. The ablated material is carried in helium into the plasma source of a Nu HR ICPMS, which is equipped with a flight tube of sufficient width that U, Th, and Pb isotopes are measured simultaneously. All measurements are made in static mode, using Faraday detectors with 3x1011 ohm resistors for 238U, 232Th, 208Pb-206Pb, and discrete dynode ion counters for 204Pb and 202Hg. Ion yields are ~0.8 mv per ppm. Each analysis consists of one 15-second integration on peaks with the laser off (for backgrounds), 15 one-second integrations with the laser firing, and a 30 second delay to purge the previous sample and prepare for the next analysis. The ablation pit is ~15 μm in depth.

 For each analysis, the errors in determining 206Pb/238U and 206Pb/204Pb result in a measurement error of ~1-2% (at 2-sigma level) in the 206Pb/238U age. The errors in measurement of 206Pb/207Pb and 206Pb/204Pb also result in ~1-2% (at 2-sigma level) uncertainty in age for grains that are >1.0 Ga, but are substantially larger for younger grains due to low intensity of the 207Pb signal. For most analyses, the cross-over in precision of 206Pb/238U and 206Pb/207Pb ages occurs at ~1.0 Ga.

 204Hg interference with 204Pb is accounted for measurement of 202Hg during laser ablation and subtraction of 204Hg according to the natural 202Hg/204Hg of 4.35. This Hg correction is not significant for most analyses because LaserChron Hg backgrounds are low (generally ~150 cps at mass 204).

 Common Pb correction is accomplished by using the Hg-corrected 204Pb and assuming an initial Pb composition from Stacy and Kramers (1975). Uncertainties of 1.5 for 206Pb/204Pb and 0.3 for 207Pb/204Pb are applied to these compositional values based on the variation in Pb isotopic composition in modern crystal rocks.

 Inter-element fractionation of Pb/U is generally ~5%, whereas apparent fractionation of Pb isotopes is generally <0.2%. In-run analysis of fragments of a large zircon crystal (generally every fifth measurement) with known age of 563.5 ± 3.2 Ma (2-sigma error) is used to correct for this fractionation. The uncertainty resulting from the calibration correction is generally 1-2% (2-sigma) for both 206Pb/207Pb and 206Pb/238U ages.

 Concentrations of U and Th are calibrated relative to the Sri Lanka zircon standard, which contains ~518 ppm of U and 68 ppm of Th.

Gehrels, G.E., Valencia, V., and Pullen, A., 2006, Detrital zircon geochronology by laser ablation-multicollector ICPMS at the Arizona LaserChron Center, *in* Olszewski, T., ed., Geochronology: Emerging Opportunities: Paleontology Society Papers, v. 12, p. 67-76.

Gehrels, G.E., Valencia, V., and Ruiz, J., 2008, Enhanced precision, accuracy, efficiency, and spatial resolution of U-Pb ages by laser ablation-multicollector-inductively coupled plasma-mass spectrometry: Geochemistry, Geophysics, Geosystems, v. 9, Q03017, doi:10.1029/2007GC001805.

Stacey, J.S., and Kramers, J.D., 1975, Approximation of terrestrial lead isotope evolution by a two stage model: Earth and Planetary Science Letters, v. 26, p. 207-221.