 TI-IN-ZIRCON THERMOMETRY AND TRACE ELEMENT GECHEMISTRY OF IMPACT PRODUCED ZIRCONS: IMPLICATIONS FOR HADEAN ZIRCONS. M. M. Wielički¹ and T. M. Harrison¹². ¹Department of Earth and Space Sciences, UCLA (595 Charles Young Drive East, Los Angeles, CA 90095-1567), ²Institute of Geophysics and Planetary Geophysics, UCLA (603 Charles Young Drive East, Los Angeles, CA 90095-1567).

Introduction: The longstanding view that the Hadean Earth was an uninhabitable, hellsish world [1,2] has been challenged by the discovery and geochemical characterization of ~4 Ga zircons from Mt. Narryer and Jack Hills, Western Australia [3]. Although there are no known terrestrial rocks older than ~4 Ga, Hadean zircons represent a mineral record capable of preserving information regarding the near-surface conditions of the Earth during their formation. Isotopic and petrologic analyses of these ancient grains have been interpreted to suggest that early Earth was much more like the present than previously envisioned, with water oceans, continental crust, and possibly even plate tectonics [4]. Alternatively, diamonds seemingly included in these ancient zircons have been suggested as evidence of their formation under ultra-high pressure (UHP >3.2 GPa) conditions [5], possibly due to a bolide impact. Understanding the crystallization environment of Hadean zircons provides important constraints on the near-surface conditions and habitability during the first 500 million years of Earth history. Here we present trace element and Ti-in-zircon thermometry of zircons isolated from preserved terrestrial impact melt sheets to better constrain the role of impacts in the formation of the Hadean zircons from Western Australia.

Ti-in-zircon thermometry: Applying the Ti-in-zircon thermometer [6] to impact-formed zircons from known terrestrial impact sites and comparing results to the remarkably low temperatures (~680°C; 7] associated with Hadean zircons could provide evidence in assessing a possible impact origin for these ancient grains. Crystallization temperatures from Ti-in-zircon thermometry of 111 zircons separated from Sudbury, Vredefort, Morokweng, and Manicouagan impact sheets indicate an average crystallization temperature of ~751±59°C. When impact temperatures are compared to that of the Hadean zircons, a Kolmogorov-Smirnov test shows that these are two distinct populations (p<0.002), and that impact formed zircons are not a dominant source of Hadean zircons. Ti-in-zircon crystallization temperatures are consistent with that calculated from Zr-saturation systematics [8], when target whole rock chemistry is available, but may underestimate crystallization temperature by 50-100°C [8]. Remarkably, the crystallization temperatures of melt sheet zircons from four individual terrestrial impacts are consistent with calculated Zr-saturation temperatures (i.e., ca. 780°C) from ~19,000 whole rock analyses of samples representing the spectrum of crustal rock types [6]. Modeling hypothetical Hadean crust and calculating Zr-saturation temperatures may provide reasonable target compositions to produce the Ti-in-zircon crystallization temperatures associated with Hadean zircons.

Trace Element Geochemistry: Trace element analyses of the impact-formed zircons yield results consistent with crustal formation in an igneous environment, similar to Hadean zircons [9]. They are characterized by a HREE enrichment and display positive Ce anomalies and negative Eu anomalies. The positive Ce anomaly could be explained by an oxidized magma source where more Ce⁴⁺ is present than Ce³⁺, thus less Ce will be compatible within the zircon crystal lattice. However this cannot explain the presence of a negative Eu-anomaly, unless we assume crystallization of plagioclase before zircon saturation as Eu can easily substitute for Ca within plagioclase and reduce the amount of Eu within the residual melt [9]. Plagioclase tends to be a dominant mineral within most of the impact rocks studied which supports the above assumption. REE patterns can be used to help determine whether or not the zircons are neo-crystalline or inherited by comparing the REE patterns of zircons within the impact melt sheet and those from the presumed target rocks. Due to the slow diffusion of REE within zircon [10] and the relatively short residence times of impact melts, different REE patterns would be a direct result of crystallization from variable sources and not due to resetting of the geochemical information.

Summary: Understanding the role of impacts during the Hadean provides constraints on the geophysical conditions and habitability of early Earth. Impacts have been invoked to explain the origin of the Moon (ca. 4.5 Ga) and hypothesized Late Heavy Bombardment (ca. 3.8-3.9 Ga), but their significance to Hadean petrogenesis is poorly understood. Although trace element analyses of impact melt sheet zircon are consistent with those of Hadean zircons, distinct Ti-in-zircon crystallization temperatures suggests that impact melt sheets were not a dominant source of the Hadean zircons. Calculations of Zr-saturation temperatures from modeled Hadean crustal compositions may provide the target rock type necessary for an impact event to provide the Ti-in-zircon crystallization temperatures observed within the Hadean population. Further under-
standing of impact melt sheet zircon formation has implications to the hypothesized Late Heavy Bombardment and future missions to other solar system bodies as impacts are one of the most common surficial features found within the solar system.