DIFFERENTIATED IMPACT MELT SHEETS MAY BE A POTENTIAL SOURCE OF THE HADEAN DETRITAL ZIRCON POPULATION. Gavin G. Kenny*[1], Martin J. Whitehouse[2] and Balz S. Kamber[1], [1]Department of Geology, School of Natural Sciences, Trinity College Dublin, Dublin 2, Ireland, [2]Department of Geosciences, Swedish Museum of Natural History, 104 05 Stockholm, Sweden. (*kennyg2@tcd.ie)

Introduction: Constraining the origin and history of very ancient detrital zircons [1, 2] has unparalleled potential for reconstructing the nature of the Earth's very early crust and Hadean geodynamics. Previous applications of the Ti-in-zircon thermometer to > 4 Gyr-old zircons have identified a population with relatively low crystallization temperatures (T_{zir}^{xtln}) of *c.* 685 °C [3-6]. This was argued to be indicative of wet minimum-melting conditions producing granitic melts [3], unlike the basaltic compositions of primitive crusts on other rocky planets. However, > 4 Gyr ago was a time of much higher impact flux in the inner Solar System than today. Modeled production of impact-generated melt on the early Earth (constructed from the latest bombardment models for the Hadean Earth [7]) shows a striking match with the age distribution of detrital Hadean zircons. Here we aim to thoroughly test the hypothesis that differentiated impact melt sheets on the early Earth may have been a major source of the Hadean detrital zircon population. To do this, we employed the 2.5-3.0 km-thick differentiated melt sheet at the 1.85 Gyr-old subaqueous Sudbury impact basin as an analogue for long destroyed Hadean-Archean basins.

Methods: Zircons were separated from 12 samples (five norite, one quartz gabbro and six granophyre) from the southern limb of the impact melt sheet and one sample (norite) from the northern limb for comparison (fig. 1). Ti concentrations in zircon were determined by secondary ion mass spectrometry (SIMS) on the CAMECA IMS1280 ion microprobe at the Swedish Museum of Natural History. A selection of rare earth elements (REE) were then measured by laser ablation-inductively coupled plasma mass spectrometry (LA-ICPMS) at Trinity College Dublin. The grains were also U-Pb age dated by LA-ICPMS to confirm that they date to the established 1.85 Ga age of the impact melt sheet [8].

Results: Here we report the first comprehensive ion microprobe study of zircons from a transect through the differentiated Sudbury impact melt. The impact melt sheet at Sudbury displays Ti contents in unaltered zircon ranging from 1.2 ± 0.1 ppm to c. 20 ppm, corresponding to T_{zir}^{xtln} values of 578 ± 17 °C to c. 815 °C (fig. 2), compared to the Hadean detrital zircon population which has reported Ti contents varying from 1.3 ppm [4] to over 20 ppm [3, 6] with most Ti contents greater than *c*. 20 ppm associated with cracks or other crystal imperfections [5]. Ti contents and corresponding T_{zir}^{xtln} fully overlap with those of the Hadean zircon population (fig. 3). Previous studies, which measured Ti in impact melt sheet zircons did not find this wide range because they did not sample the stratigraphically highest, most felsic differentiation products [10, 11] and because they used laser ablation analyses [11] that can overestimate true Ti content and hence T_{zir}^{xtln} (as LA-ICPMS excavates a much larger sampling volume than SIMS, increasing the likelihood of encountering extraneous Ti in cracks and inclusions). It is important to note that internal differentiation of the impact melt is likely a prerequisite for the observed low T_{zir}^{xtln} in zircons from the most felsic rocks. At Sudbury, the explosive interaction of impact melt and seawater produced an anomalously thick (*c.* 1.5 km) complex series of breccias and tuffs overlying the impact melt sheet [12]. This overlying insulation likely played a major role in allowing the melt to crystallize slowly over 250,000-500,000 years [8, 13], resulting in differentiation and the low T_{zir}^{xtln} observed in the granophyre. This is consistent with an early hydrosphere promoting differentiation of impact melts and thus achieving the range of Ti contents and T_{zir}^{xtln} in Hadean zircons, as well as the lack of lunar hydrosphere result-

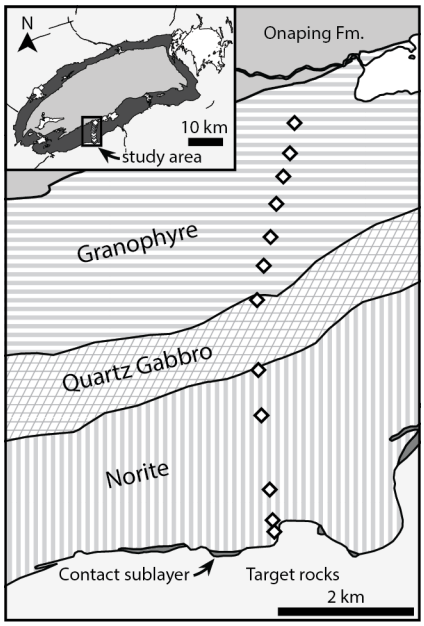

Fig. 1. Map of sampling locations (diamond symbols) in the Sudbury impact melt sheet. Lakes are shown in white. Maps modified from [9].

ing in little or no differentiation in large impact melt sheets (e.g. the Orientale basin [14]) and thus no low Ti contents, and T_{zir}^{xtln}, in lunar zircons [15].

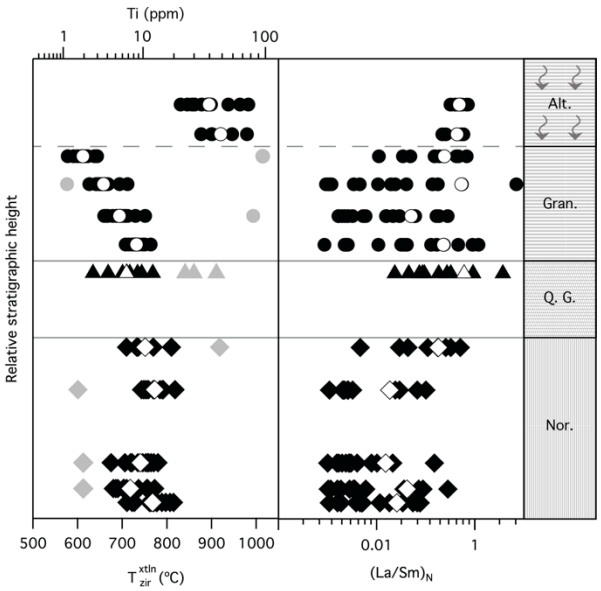

Fig. 2. Left: Ti-in-zircon crystallization temperature (T_{zir}^{xtln}) for Ti content measured by SIMS. T_{zir}^{xtln} calculation of [16]. Error bars have been removed for clarity; average error is 13 °C (1SD), which includes uncertainty introduced when calculating Ti-in-zircon crystallization temperature from Ti content. Outliers, shown in light gray, were excluded when calculating sample means, which are shown by open symbols. Elevated Ti contents of uppermost two samples are considered to be related to alteration and are not representative of the grains' original igneous composition. Nor. = norite; Q. G. = quartz gabbro; Gran. = granophyre; alt. = hydrothermally altered. Right: La/Sm_N for same zircons. Note that the uppermost two samples have consistently high La/Sm_N ratios which is indicative of pervasive alteration. Coupled with extreme alteration visible in cathodoluminescence imaging, this supports the interpretation that Ti contents in these two samples are not original igneous features.

Conclusion: The Ti contents of Hadean detrital zircon may not require wet, minimum-melting conditions and plate tectonic interactions on the early Earth but could also be explained by intense meteorite bombardment of a stagnant, predominantly mafic crust covered by an early hydrosphere.

We suggest that melt sheet differentiation is strongest in subaqueous impact basins due to insulating effects, potentially explaining the lack of differentiated impact melts on the Moon compared to Earth.

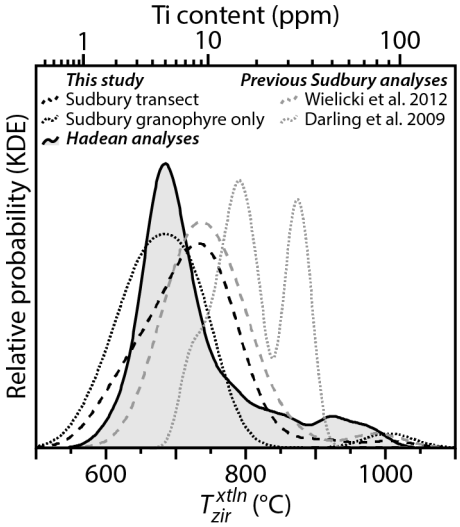

Fig. 3. Comparison of Ti (and Ti-in-zircon crystallization temperature – T_{zir}^{xtln}) distribution in the Hadean zircon population with that of melt sheet zircons at Sudbury. Curves represent all analyses and not grain averages. Analyses with Ti >100 ppm have been excluded. The following numbers refer to: number of analyses/number of grains analyzed/number of samples. Hadean data compiled from [3-6]: 286/134/34; Sudbury transect (this study) 124/124/10; Sudbury granophyre only (this study) 54/54/4; Sudbury samples [10] 26/26/2; Sudbury transect [11] 144/120/10. E.g. the Hadean compilation represents 286 analyses performed on a total of 134 zircons from 34 different samples. All data obtained by ion microprobe except [11] which is LA-ICPMS data. Kernel density estimates (KDE) were produced in MATLAB using the free software package of [17] which implements an automatic bandwidth selection method.

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