RARE INCLUSIONS IN DARWIN GLASS: PARTIAL MELTS. Layton Neil[1] & K. T. Howard[123]. [1]Kingsborough Community College of the City University of New York. [2]American Museum of Natural History. [3]The Natural History Museum, London. Email: Layton.Neil27@students.kbcc.cuny.edu

Introduction: Darwin glass is a siliceous impact glass that was formed at approximately 800ka [1]. Darwin crater (diameter =1.2km), in Western Tasmania, Australia, was discovered in 1972 and suggested to be the source of Darwin glass, which forms a 400km^2 strewn field around the suspected crater [2,3]. The composition of Darwin glass can be explained as a mixture of the target rocks at Darwin crater [4,5], which is consistent with the crater being the source of the glass. Physical distribution trends in the glass relative to crater also suggest a genetic relationship between Darwin glass and Darwin crater [6]. However, despite the abundance of glass in the strewn field, glass in the crater-fill stratigraphy is incredibly rare and no evidence for diagnostic impact shock metamorphism has ever been reported [7]. This means that the impact origin of Darwin crater has never been confirmed: it is not officially recognized as an impact crater and does not appear on the Earth Impact Database [8].

Here we report the discovery of partially molten target rock fragments inside of an unusual sample of Darwin glass. Partially molten target rock materials have not previously been reported from Darwin crater [6,7]. Our aim is to characterize these inclusions and the glass. Linking the mineralogy and chemistry of the rock fragments in the host glass to the target rocks at Darwin crater, may provide more evidence to support the impact origin of the structure.

Discovery: The host glass fragment (Fig. 1) was discovered during investigations at Darwin crater between the years 2000-2003. The sample was recovered around 1-2km from the crater site. Relative to typical bulk Darwin glass, this fragment has a much less vitreous appearance. Perhaps because of its dull appearance, the sample was largely overlooked until now.

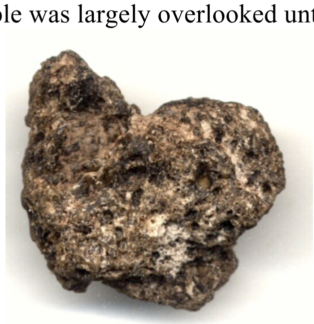

Fig. 1 Darwin glass, 'dirty' fragment. Actual width ~4 centimeters. The inclusions described here were discovered in thin sections of this sample. It appears much less vitreous than is typical of Darwin glass.

Methods: The sample was cleaned in an ultrasonic bath prior to cutting and preparation of thin sections.

Optical Microscopy: Thin sections of the glass were examined in an attempt to identify any crystalline components that may have been formed during impact or that were contained in included clasts. Areas of apparent dark staining in the glass alerted us to heterogeneity. In close examination of these regions, a hint of flash extinction was observed from quartz crystals; imaging by Scanning electron Microscope (SEM) revealed that these quartz grains were contained in the inclusions described here.

SEM: After carbon coating, the section was analyzed on a JEOL JSM-6390 SEM operated in high-vacuum using both back-scattered electron (BSEI) and secondary electron imaging (SEI) modes. Energy dispersive spectrometry (EDS) was used to analyze points of interest and map the composition of the inclusions. A Zeiss EVO 60 Variable Pressure SEM was used for additional imaging (BSEI and SEI).

Electron Microprobe: Quantitative elemental determinations (wavelength dispersive spectrometry [WDS]) for the inclusions and host glass were performed on a Cameca SX-100. A 10µm beam size was used with the aim being to estimate bulk compositions in order to allow for comparisons with previous analyses of Darwin glass and target rocks [4,5]. Quantitative line scans across the boundary between the host glass and included rock fragments were also recorded to examine evidence for elemental diffusion.

Results: Below we describe the petrography and chemistry of the inclusions and the host glass in order to provide a framework for comparisons with known target rocks at Darwin crater.

Petrography: Viewing the glass in BSEI revealed that regions appearing at first as empty vesicles (by optical microscopy) were in fact filled with angular mineral fragments ranging from >200µm to <1µm in size, along with <10µm sized lath shaped crystals (Fig. 2). Some regions of the inclusion show what appears to be a melt texture, and in other places the mineral fragments appear to be set in a matrix of melt (Fig. 3). Along the boundaries between the inclusions and the host melt, we often observe macro porosity. The host glass itself contains abundant vesicles and shows complicated flow textures.

Composition of Host Glass: Microprobe (WDS) analyses of the host Darwin glass (n=50) reveal the following ranges in elemental abundances: SiO_2 (70-

98%); Al_2O_3 (0.1-13%); TiO_2 (0.05-1.55%); FeO (0.03-5%); MgO (0.01-0.9%); K_2O (0.01-2.5%); CaO (<0.01-0.05%) and Na_2O (<0.01-0.13%). These major oxide abundances are all within the previously reported compositonal ranges for Darwin glass [4,5]. As is typical of Darwin glass, the sample shows gross compositional heterogeneity evident in contrasting gray scales in BSEI images (Fig. 2).

Composition of inclusions: EDS and WDS analysis reveal angular fragments in the inclusion to be quartz (SiO_2). EDS indicates that the laths shaped crystals are rutile (TiO_2) and K-feldspar. EDS shows that areas of the inclusions that exhibit apparent melt textures are dominated by SiO_2, like the host glass outside the inclusion, but significantly enriched in K_2O, Al_2O_3 and FeO relative to the surrounding glass. EDS Element maps and WDS line scans show clear evidence for a gradient in K_2O abundances that are richest in the included fragment and appear to have diffused outwards into the host glass (Fig. 4).

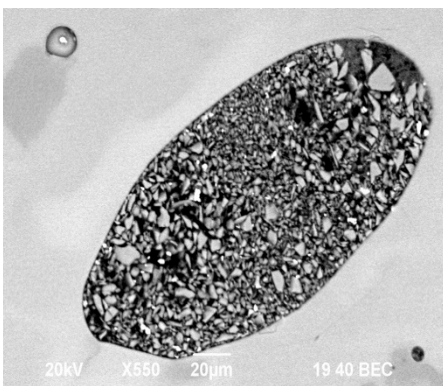

Fig. 2. SEM image (BSEI) of Darwin glass showing the presence of included rock fragments. Note the angularity of the grains that are mostly quartz (SiO_2).

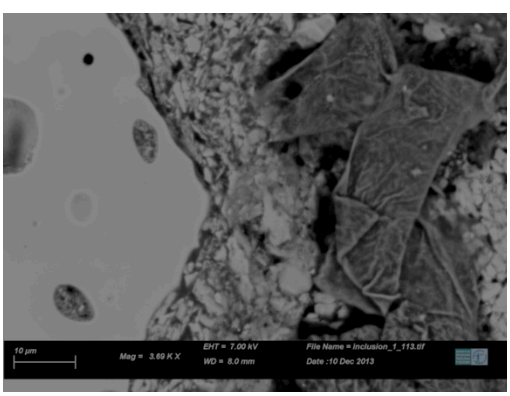

Fig. 3. SEM image (BSEI) of Darwin glass showing the presence of included rock fragments exhibiting textures indicative of melting.

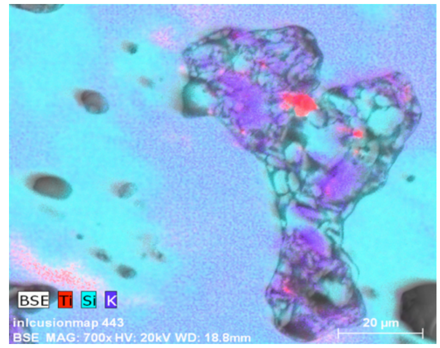

Fig. 4. SEM (EDS) 3-element map showing: Ti (red), Si (blue), and K (purple).

Discussion: The inclusions discovered in the Darwin glass sample appear to be fragments of rock. The extreme angularity of clasts indicates that brecciation has occurred. Flow textures and compositional data also suggest that the rock fragment has undergone partial melting. We suggest that these are fragments of target rocks that were brecciated during impact and entrained in the host glass, were melting commenced but ceased before completion.

The observed mineral phases in the included rock fragments and the compositional data are consistent with the geology of the target rocks at Darwin crater, which are quartzites and pelitic shales; often closely related on a thin-section scale [7]. Work is ongoing to further characterize the chemistry of the inclusions, e.g., determining trace element abundances in order to make more robust comparisons with the target rocks at Darwin crater.

Conclusions: Being that there have never been any target rock inclusions discovered in Darwin glass, or reports of partially molten target materials at Darwin crater, this is an important sample to further study. By linking the chemistry and petrography of the included rock fragments to the target rocks at Darwin crater, this may provide a novel line of evidence in support of the impact origin of Darwin crater.

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