EVIDENCE OF MULTIPLE COMETARY AIRBURSTS DURING THE PLEISTOCENE FROM PICA (CHILE), DAKHLEH (EGYPT), AND EDEOWIE (AUSTRALIA) GLASSES. R. S. Harris[1] and P. H. Schultz[2], [1]Department of Space Sciences, Fernbank Science Center, 156 Heaton Park Drive, Atlanta, GA 30307, [2]Department of Earth, Environmental, and Planetary Sciences, Brown University, 324 Book Street, Box 1846, Providence, RI 02912; scott.harris@fernbank.edu.

Introduction: Blanco and Tomlinson [1] first suggested that thin slabs and twisted masses of vesicular glass cropping out near Pica, Chile were formed by fusing surficial sediments during an airburst of a large bolide over the Atacama near the end of the Pleistocene, approximately 12 ka. Although this interpretation was subsequently challenged, subsequent field work and sample analysis not only confirmed the original hypothesis but also detailed the conditions leading to their formation [2,3]. Specifically, samples contained not only evidence for ultra-high temperature mineral transformations, including the decomposition of zircon to baddeleyite + silica above 1700°C, but also abundant contamination of the melt by silt-size fragments of the impactor most often found on the walls of vesicles [4,5]. These studies implicated an origin by multiple near-surface explosions of a disintegrating comet or rubbly asteroid that generated intense heat and winds.

Osinski et al. [6,7] argued that glass discovered in the Dakhleh Oasis (southwestern Egypt) formed as the consequence of a similar event between 100 and 200 ka. And Haines et al. [8] suggested that the radiant pulse from a super-Tunguska airburst over South Australia approximately 700 ka could explain the slabby Edeowie glass. We have conducted additional microanalyses of samples from these locations following the same methods used to investigate Pica glass.

By "*following the vesicles*" we have identified meteoritical debris in each of these glasses with mineral assemblages that are consistent with both theoretical expectations for cometary materials and some Stardust observations of 81P/Wild. Our results demonstrate the reliability of a new technique and strategy for investigating the impact origin of glasses in the stratigraphic record and for diagnosing the impactors. Furthermore, the ability to confirm cometary airbursts, especially in recent epochs, is important for assessing the present risk of future collisions.

Methods: Polished, unpolished, carbon-coated, and non-contaminated samples in this study were analyzed using backscattered electron microscopy on a Hitachi SU-3500 VP-SEM at Fernbank Science Center employing accelerating voltages between 15 kV and 25 kV. Chemical compositions of selected phases were determined using an EDAX Element EDS detector, an accelerating voltage of 15kV, and a working distance of 10 mm. Selected samples were investigated using a field emission SEM (FEI Teneo) with a 150 mm Oxford XMax^N EDS detector.

Pica Glass: Pica glass contains abundant silt-sized and finer meteoritical particles that occur as individual phases and complex assemblages typically associated with vesicles [2,3]. They range from buchwaldite ($NaCaPO_4$), Ni-bearing troilite (FeS), and oldhamite (CaS) to rock fragments composed of Mg-Fe silicates, corundum-bearing perovskite ($CaTiO_3$), and serpentinite. CAIs occur with melilite corona surrounding cores of carbonate and Ca-rich silicates (wollastonite and monticellite). Most abundant are Fe-sulfide assemblages composed of hexagonal platelets of Ni-rich and Ni-poor troilite and pyrrhotite often with Ni-rich Cu-Fe sulfide rims (Fig. 1). The rim chemistry can be modeled as a stoichiometric Cu-bearing Fe-pentlandite. However, the chemistry also is compatible with cubanite ($CuFe_2S_3$) with nanoscale pentlandite inclusions. The latter possibility is consistent with the observation that the Cu-rich rims are similar to cubanite overgrowths reported from CI meteorites and Stardust samples [9-11].

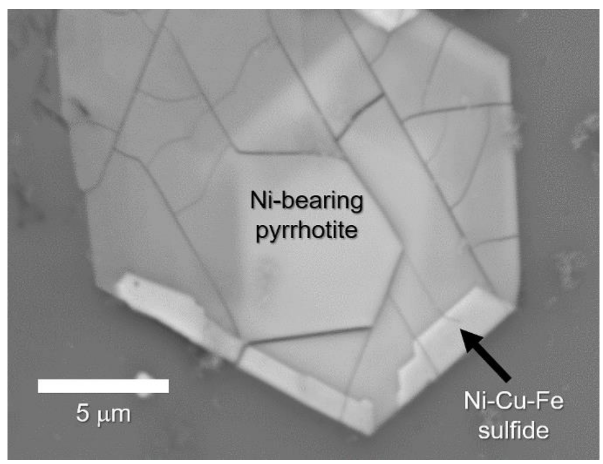

Figure 1. Electron backscattered (BSE) photomicrograph of an Fe-sulfide assemblage exposed on the wall of a vesicle in Pica glass. The rim appears similar to overgrowths of cubanite ($CuFe_2S_3$) observed on Fe-sulfides from CI meteorites, Stardust samples from Comet 81P/Wild, and experimentally produced sulfides prepared in environments intended to simulate aqueous alteration on comets [9-11].

Dakhleh Glass: The samples of Dakhleh glass examined contain lithic fragments of melilite similar in composition to CAI rims from Pica. Quenched mafic clasts are observed that contain tiny grains of kamacite and Ni-Cr spinel as well as altered mafic grains, possibly serpentinite containing elemental carbon. Many vesicles do contain familiar assemblages of hexagonal Fe-sulfide with Cu-Fe-sulfide overgrowths (Fig. 2), although significant concentrations of copper seem to have been lost either during incorporation into the impact melt or earlier alteration. The platelets are fractured, broken, and wedged into vesicle walls in a variety of orientations (Fig. 3), thereby confirming that they were dynamically emplaced and did not condense from vapor inside the vesicle. Nickle is not as common in the sulfides, but Fe-Ni metal occurs as discrete grains associated with them (Fig. 3).

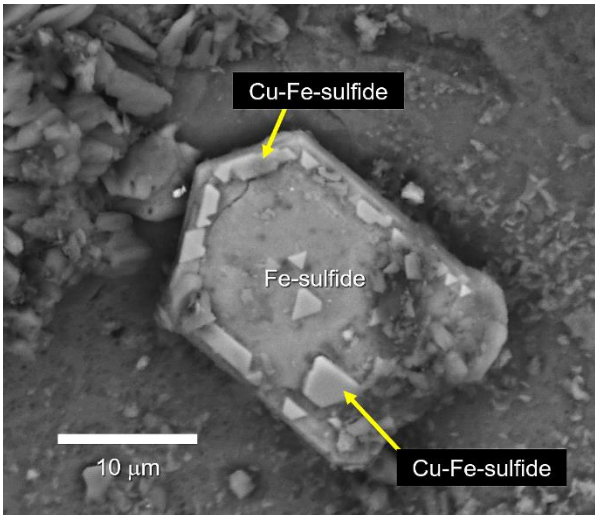

Figure 2. Electron backscattered (BSE) photomicrograph of an Fe-sulfide platelet exposed on the wall of a vesicle in Dakhleh glass. The rim exhibits similar overgrowths to those observed in Pica glass.

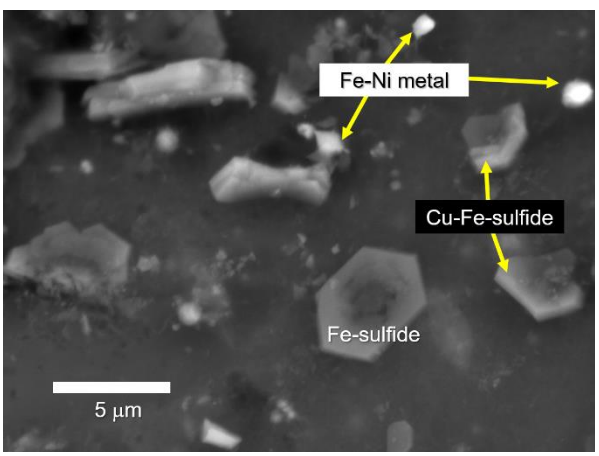

Figure 3. Electron backscattered (BSE) photomicrograph of multiple randomly oriented and broken Fe-sulfide platelets exposed on the floor of a vesicle in Dakhleh glass. Fe-Ni metal grains occur with the sulfides.

Edeowie Glass: The exogenic components in Pica and Dakhleh have marked similarities which do not appear to be repeated in the Edeowie glass. However, observations of vesicle walls yielded assemblages consistent with an extraterrestrial signature. We have identified niobium-bearing ulvöspinel, zinc-rich chromite, and Fe-Cr-sulfides (Fig. 4). Iron-titanium grains associated with vesicle walls also appear to contain significant chromium and vanadium. Similar chemistries are found in the oxide fraction of 81P/Wild [12].

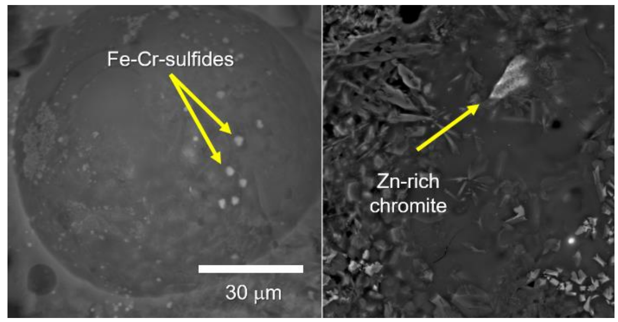

Figure 4. Electron backscattered (BSE) photomicrographs of an Fe-Cr-sulfide grains and a Zn-rich chromite grain exposed in vesicle walls in Edeowie glass.

Implications: Focusing microanalysis on the vesicles of vesicular impact glasses without obvious craters may prove useful for both demonstrating an impact provenance and for providing evidence that the bolides were most likely weak cometary bodies composed of primitive, volatile-rich materials, capable of releasing a large volume of dust when they exploded. If Earth was the target of numerous such airbursts during the Pleistocene perhaps $^{3}He/^{4}He$ ratios should be high over this time.

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