LATE PLEISTOCENE FIREBALLS OVER THE ATACAMA DESERT, CHILE. P. H. Schultz[1], R. S. Harris[2], S. Perroud[3], N. Blanco[4], A. J. Tomlinson[4] and M. Valenzuela[4], [1],Department of Earth, Environmental, and Planetary Science, Brown University, P.O. Box 1846, Providence, RI 02912 (peter_schultz@brown.edu). [2]Department of Space Sciences, Fernbank Science Center, 156 Heaton Park Drive, Atlanta, GA 30307. [3]AeroSpectre Ltda., Santiago, Chile. [4]Servicio Nacional de Geología y Minería, Avda Santa María 0104, Santiago, Chile.

Introduction: Large airbursts should be much more common than crater-forming impacts and could represent a significant threat. But the record of such crater-less blast effects is largely missing. Without witnesses of (and fallen trees) from of the Tunguska event in 1908, little evidence would remain after several centuries. Glasses strewn over a broad area in the Atacama Desert now reveal the effects of a much larger event during the Late Pleistocene and provides a new benchmark for understanding the processes associated with massive fireballs.

Background: Widespread glass fields in Australia [1.] and Western Egypt [2] have been attributed to ancient airbursts but the for a cosmic origin has been largely circumstantial (high temperatures and ambiguous PDF's). As a result, some have argued for an origin by lightning [e.g., 3] or grass fires. Recently, a new site in the Atacama Desert in Chile was identified and attributed to large fireballs [4,5], but subsequent contribution concluded that these glasses were also the result of grass fires [6]. New fieldwork and micro-analyses], however, firmly establish that the initial interpretations were correct [7,8]

Glass Distribution: Clusters of glass slabs are scattered in a north-south direction over 70 km on the Atacama Desert in northern Chile near the town of Pica (Fig. 1). At localities (Núñez and Chipana). The clusters (up to 10 m x 20 m) occur on a paleo-wetland and alluvial over-bank deposits of Pleistocene-Holocene age, occasionally on top of matted paleo grasses. In some cases, the underlying matt has been uplifted and distorted. When found in situ, the glasses occur on top of a 5 cm thick layer of silty sand, above the layer of paleo-grass. While some glasses contain entrained grass, the grasses had been diagenetically altered before being trapped in the glass. Isolated glass clusters also occur beyond the alluvial deposits, occasionally associated with pebbles (some broken), characteristic of the lag deposit on top of older colluvium. At the Núñez site, shallow, irregular depressions separate lobes of both glasses and the silty sand layer.

Glasses: Individual glass slabs exceed 30 cm across and 10 cm thick with un-melted pockets or seams of clay. The larger fragments, however, actually represent multiple folds of a single slab and form a single cooling unit (**Fig. 2a**). Smaller fragments (<5 cm) are occasionally oriented in a common direction. Some are simply fragments of larger pieces, whereas others are separately generated melts. Where found intact and in situ, underlying surfaces exhibit a rough surface with sediments attached. Upper surfaces, however, exhibit are smooth with quenched flow textures (Fig. 2b).

Composition: The glass composition (wt%) reflects the general composition of the overbank deposits as described in [4]: SiO_2 (59–64%); Al_2O_3 (10–15%); Na_2O (4–13%); CaO (4.7-6.5%); and Fe_2O_3 (3-4.5%) with variable amounts of H_2O (~0.2% to 2.6%). Most contain xeynocrysts from the silty soils but many contain zircons with variable degrees of thermal decomposition: some rimmed by baddeleyite; others, completely converted to ZrO_2 (Fig. 3). Detailed micro-analyses reveals that nearly every sample also contains small meteoritic fragments that indicate mixing with a regolith from a volatile-rich parent body [7]. In-situ examples indicate a profile of heating (and cooling), with the highest temperature melting at the top.

Formation Process: The twisting, shearing, rolling, and folding (in some cases more than twice) of the glasses before being fully quenched and the disruption and distortion of underlying sediments (including paleo-grass layers) require a dynamic mode of emplacement. The glassy texture and rapid quench features (e.g., multiple and overlapping flows and quenched "fingers" on one side) further indicate a rapid process of formation and rapid quenching. Nevertheless, some examples, appear to have been transported away from their site or origin and resulted in folding and twisting before quenching.

Interpretations: The field evidence, composition, extremely high temperatures, and entrainment of meteoritic fragments all implicate an origin by a cosmic collision. The absence of a parent crater(s), minimal shock effects, and similar occurrences over a broad area point to a series of low-altitude airburst, in agreement [4,5]. Based on the dispersed meteoritic fragments within the glasses and separate localities over broad areas, consistent with a weak rubble-pile object that was breaking up during entry. Trailing meteoritic fragments contained within the trailing wake were injected into melted soils. Based on the composition [7], we conclude that the body was likely a primitive, volatile-rich body that went through multiple stages of disaggregation during entry.

The proposed origin by intense grass fires was affected by the occasional association with paleo-grasses but did not recognize the dynamic process of emplacement or meteoritic components. Cited evidence against an airburst included: (a) absence of high-T effects; (b) range in ^{14}C ages; (c) different paleointensities in the glasses; and (d) different paleomagnetic inclinations. The first two pieces of evidence are counter to results from this study. The range in ages reflects the ages of different layers, on which the glasses rest (as noted in [6]. The last two concerns did not include the effects of the plasma developed during an airburst. Also in contrast with conclusions by [6], the Pica glasses are very different from the Argentine escoria, all of which contain materials from depth (excepting Rio Cuarto).

Implications: The Pica Glass fields represent the effects from a large, Late-Pleistocene fireball event that induced both intense radiation and high-speed winds. Based on computational models [9,10], both radiation and convection must have played a role in the heating and melting, which would account for the association with exposures of mobile fine-grained sediments without modifying colluvial pebbles. Micro-analysis of micro-particles [11] found in sediments of similar age 2700 km to the south [12] suggest a connection with the Pica glasses, indicating either widespread dispersal or additional events.

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Fig. 1: Overview of strewn field showing glass slabs in the middle of image range from 10 cm to 40 cm across.

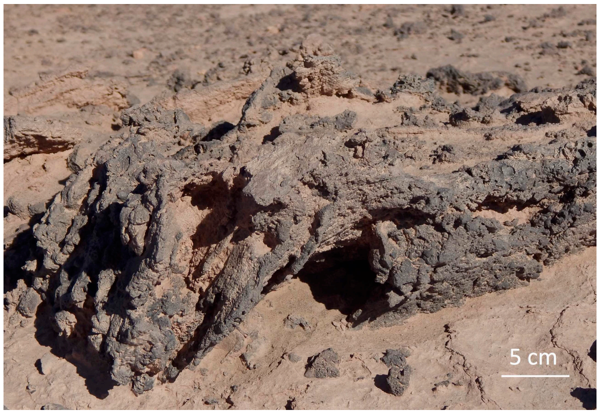

Fig. 2a: Large twisted and over-turned glass slab, indicative of a dynamic mode of emplacement and rapid quenching.

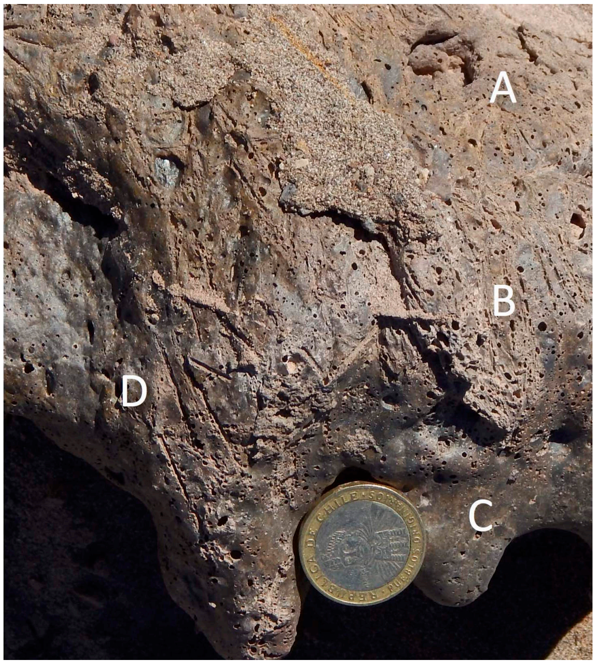

Fig. 2b: Close view of glass showing: (A) contact surface with attached sediments and grasses; (B) fused flow attached to surface and overlapping the quenched glassy surface (C); (D) casts of grass and twigs.

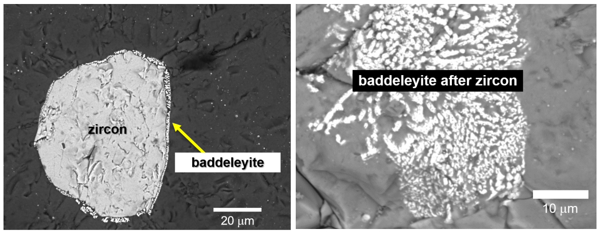

Fig. 4: Examples of zircons undergoing different degrees of thermal decomposition from rimmed baddeleyite (left) to complete decomposition (right), indicative of T > 1700°C.