HIGH-TEMPERATURE MELTING AT >2200°C PROVIDES EVIDENCE OF COSMIC IMPACT AT ABU HUREYRA, SYRIA AT THE YOUNGER DRYAS ONSET (~12.8 KA). A. Moore[1], J. P. Kennett[2], W. M. Napier[3], T. E. Bunch[4], J. C. Weaver[5], M. LeCompte[6], A. V. Adedeji[7], P. Hackley[8], G. Kletetschka[9], R. E. Hermes[10], J. Wittke[4], J. J. Razink[11], M. W. Gaultois[12], A. West[13], [1]College of Liberal Arts, Rochester Institute of Technology, Rochester, NY USA, [2]Department of Earth Science and Marine Science Institute, University of California Santa Barbara, Santa Barbara, CA 93106; [3]Buckingham Centre for Astrobiology, University of Buckingham, Buckingham, UK; [4]Geology Division, School of Earth and Sustainability, Northern Arizona University, Flagstaff, AZ 86011; [5]Wyss Institute for Biologically Inspired Engineering, Harvard University, Cambridge, MA 02138; [6]Elizabeth City State University, Center of Excellence in Remote Sensing Education and Research, Elizabeth City, NC 27909USGS, Menlo Park, California 94025, USA [7]Department of Natural Sciences, Elizabeth City State University, Elizabeth City, NC 27909 [8]U.S. Geological Survey (USGS), 12201 Sunrise Valley Drive, Reston, VA. [9]Institute of Geology, Czech Academy of Science of the Czech Republic; Charles University, Faculty of Science, Czech Republic; and University of Alaska Fairbanks, Alaska, 903 Koyukuk Drive, 99775 [10]Los Alamos National Laboratory (retired), White Rock, NM 87547. [11]Center for Advanced Materials Characterization at Oregon (CAMCOR), Univ. of Oregon, Eugene, OR 97403 USA [12]Leverhulme Research Centre for Functional Materials Design, The Materials Innovation Factory, Department of Chemistry, University of Liverpool, Liverpool, UK [13]Comet Research Group, Prescott, AZ.

Introduction: It was Firestone et al. [1], who first proposed that a cosmic impact event occurred ~12,800 years ago [2], by a way of possible multi-continental airbursts, perhaps due to the debris stream from a short-period comet [1,3]. Such event may have created the Younger Dryas boundary layer (YDB), with peak abundances of magnetic spherules [1,4], meltglass[5], carbon spherules [1], glasslike carbon [1], charcoal [6], platinum [7], iridium [8], nickel [9], cobalt [9], and/or nanodiamonds [10] at ~40 sites across North America and Europe. In this abstract we define the term "airburst/impact" as a collision of a cosmic body with the Earth's atmosphere. The collision follows with numerous smaller fragments that may strike the ground forming transient craters. Such an impact event would have triggered a cascade of secondary effects; a brief impact winter and severe Younger Dryas (YD) climate change (span: ~12,800-11,500 cal BP) [1]. Such collision may have possible contributions to the megafaunal extinctions and human population declines [11]. Moore and Kennett suggested that impact-triggered climate change caused the prehistoric villagers at Abu Hureyra to transition from hunting/gathering to cultivation. The cultivation is an activity indicative of the earliest agriculture, and this is one of the most significant cultural transformation in human history [12].

At Abu Hureyra, meltglass (AH glass) contained high-temperature minerals, such as corundum (Al_2O_3, melting point at ~2044°C), mullite ($3Al_2O_3 \cdot 2SiO_2$ at ~1840°C), and suessite (Fe_3Si at ~2300°C) [5]. The latter mineral is rare on Earth but common in meteorites. Such melted minerals suggested that the village was destroyed by a cosmic airburst [5]. Similar coeval meltglass in YDB strata was found at Melrose, Pennsylvania and Blackville, South Carolina, which are ~10,000 km away [5]. High-temperature melted evidence was found at Pilauco, Chile [13], 14,000 km away or ~35% of Earth's circumference. This is the most distant YDB site.

Thy et al.[14] examined meltglass from Abu Hureyra and several other sites in northern Syria, conducted heating experiments, and argued that AH glass resulted from thatched hut fires that melted AH sediment at no more than ~1200°C. This is in contrast with the report of melted high-temperature minerals in [5]. This is because report from [5] specifies melting on the outer surfaces and vesicles of Abu Hureyra meltglass, whereas Thy et al. [14] examined the interiors of meltglass, separated by the thermally insulating viscous, molten glass from the outside surfaces. As a result, the maximum temperatures inferred by Thy et al. [14] differ from those of Bunch et al. [5], and we re-examine here AH glass formation temperatures and explore multiple potential origins.

We addresses the following points: (i) maximum temperatures and potential origins of YDB meltglass and its mineral inclusions; (ii) nature of reflectance values for YDB charcoal and carbon spherules to infer accurate formation temperatures; (iii) remanent magnetization of the glass to infer potential formation processes of AH glass and spherules; and (iv) is Abu Hureyra meltglass similar or dissimilar to other high-temperature materials, including meltglass produced by known cosmic impact events, volcanism, anthropogenesis, lightning, and biomass burning.

While we report that specific high-temperature minerals are associated with AH spherules and with the outer surfaces of AH meltglass fragments they are also part of the inner surfaces of vesicles. We note that no high-temperature grains (e.g., quartz, zircon, chromite) were contained within the interior broken surfaces. This is a indication that internal glass temperatures (>1200°C) were, in fact, much lower than ambient outer surfaces. We applied heating experiments in the laboratory and infer the following. (1) Between ~1100° and 1550°C, specific original minerals (e.g., chlorapatite and pyrrhotite) became partially melted with minor vesiculation, along with AH glass matrix's elemental diffusion. (2) Between ~1500° and 1700°C, other specific minerals (e.g. (titano)magnetite) show signs of melting. (3) Between ~1700 and 2000°C, signs of melting include quartz and zircon, along with formation of titanium sulfide. (4) Between ~2000 and 2600°C, we observe melting of monazite, chromite, and chromium-rich magnetite with signs of boiling. (5) Minerals in all categories show crystallizations at varying temperatures under highly reducing conditions**.** Our observations indicated internal meltglass temperatures of ~1250°C, whereas ambient atmospheric temperatures exceeded 1750°C, in some cases reaching more than 2600°C, due to signs of the boiling points in case of chromite and magnetite [18].

Here the material's characteristics excavated at Abu Hureyra were compared to those from other sources. We exclude the following as potential formation mechanisms: building fires [14]; biomass or "haystack" fires [15] anthropogenic contamination; and lightning-induced melting. Our data infer that AH glass fragments resulted from the instantaneous melting and vaporization of regional biomass, soils, and floodplain deposits followed by rapid quenching. This is supported by the observation of meltglass containing flow marks and no apparent crystallization. In AH glass, high formation temperatures followed by rapid cooling created oxygen-deficient minerals, such as native iron, native silicon, and alloys of Fe Cr, Au, and Al. These materials are extremely rare under normal terrestrial conditions but common in impact events.

The observed range of characteristics for AH glass (e.g., low water, high-temperature minerals, low remanent magnetism, and minerals with low oxygen fugacity) allow us to exclude all potential origins for AH glass, except cosmic impact glass and tektites, with the latter offering the best match. Thus, the formation of AH glass appears to require the occurrence at Abu Hureyra of an intense and sudden high-temperature event similar to the ones that produced tektites. The collective evidence is best explained by the hypothesis that at least one high-energy, high-temperature, hypervelocity airburst occurred near Abu Hureyra ~12,800 years ago, possibly accompanied by ground impacts.

The YDB hypothesis posits multiple airbursts/impacts across at least four continents [3], [5]. These are posited to result from a series of short-period, active comets known to break up frequently and to shed dozens to thousands of fragments that are 10 to 1000 m in diameter, each capable of producing catastrophic airburst/impacts, as discussed in detail in Napier [6, 13, 16,17]. The largest cometary debris clusters are proposed to be able to cause thousands of airbursts within a span of minutes across one entire hemisphere of Earth, and an encounter with such a million-km-wide debris cluster would be thousands of times more probable than a collision with a 100-km-wide comet or a 10-km asteroid. The YDB hypothesis proposes this mechanism to account for the impact at Abu Hureyra and coeval impacts across >14,000 km of the Northern and Southern Hemispheres.

Part of this work was just published [18].

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