LETTER

Younger Dryas impact model confuses comet facts, defies airburst physics

In PNAS, Wittke et al. (1) present evidence that they indicate supports major airbursts and/or impacts at the beginning of the Younger Dryas, as proposed by Firestone et al. (2). One of the major criticisms of the hypothesis has been the lack of any physics-based model for the hypothesized event (3). Wittke et al. (1) attempt to remedy this flaw by including a section entitled "Preliminary Impact Model." Their model diverges significantly from the original but still provides no physics-based argument and demonstrates a misunderstanding of comets, as well as the physics of airbursts.

Wittke et al. (1) state "The impactor most likely broke apart in solar orbit before encountering Earth, as do most comets, including Comet Shoemaker–Levy 9." However, Shoemaker–Levy 9 broke up while in orbit about Jupiter, and the tidal fragmentation process leading to impact on Jupiter does not apply to comets in solar orbit or for approaches to terrestrial planets (4). A spontaneous breakup in heliocentric space, such as one recent example (5), would have to be exquisitely timed for an expanding cloud of fragments to strike the Earth. Near-Earth comets have average lifetimes of at least a century before breaking up. Within months after disintegration the comet fragments would be dispersed over an area much greater than that spanned by the Earth, precluding many nearly simultaneous impacts. Thus, dispersed impacts of multiple fragments would be at least 1,000 times less frequent (probable) than the impact of a single nucleus.

Wittke et al. (1) propose that, "When fragments of the YDB impactor entered Earth's atmosphere, they fragmented even further, yielding multiple atmospheric airbursts that each produced shock fronts." However, no model of cascading aerodynamic fragmentation provides any mechanism by which fragments can have a significant radial separation from the original entry track before exploding or striking the ground. Even grazing impacts such as the Chelyabinsk meteor generate a distributed "linear" explosion along the track. The putative Younger Dryas boundary (YDB) strewnfield spans about 70° in latitude and 180° in longitude. Separated fragments from a broken comet with a common radiant over such a large area would necessarily enter the atmosphere over a wide range of angles, including nongrazing trajectories that could not possibly transit a horizontal distance much greater than a few atmospheric scale heights.

The paper by Wittke et al. (1) also suggests that along the flight path, "... thermal radiation from the air shocks was intense enough to melt Fe-rich and Si-rich surficial sediments... at >2,200 °C." However, such temperatures are only exceeded in the air shock during a brief hypervelocity transit over a small area near the front of the bow shock before complete ablation or dark flight. Wittke et al. (1) provide no calculation of radiative flux at the surface from this transient source in support of their assertion or explain why no surface melting was observed at Tunguska. Even a 1-km object, if broken into about 10,000 equal Tunguska impactor-sized objects and uniformly distributed over 10% of the Earth's surface, would have an average separation of 100 km and, like Tunguska, melt no surface material.

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Mark Boslough[a,1], Alan W. Harris[b], Clark Chapman[c], and David Morrison[d]

[a]Sandia National Laboratories, Albuquerque, NM 87185; [b]MoreData!, La Cañada, CA 91011; [c]Southwest Research Institute, Boulder, CO 80302; and [d]SETI Institute, Mountain View, CA 94043

1 Wittke JH, et al. (2013) Evidence for deposition of 10 million tonnes of impact spherules across four continents 12,800 y ago. *Proc Natl Acad Sci USA* 110(23):E2088–E2097.

2 Firestone RB, et al. (2007) Evidence for an extraterrestrial impact 12,900 years ago that contributed to the megafaunal extinctions and the Younger Dryas cooling. *Proc Natl Acad Sci USA* 104(41):16016–16021.

3 Boslough M, et al. (2012) Arguments and evidence against a Younger Dryas impact event. *Climates, Past Landscapes, and Civilizations*, Geophysical Monograph Series, eds Giosan L, et al. (American Geophysical Union, Washington, DC), Vol 198, pp 13–26.

4 Bottke WF, et al. (1997) Can tidal disruption of asteroids make crater chains on the Earth and Moon? *Icarus* 126:470–474.

5 Sekanina Z (2007) Earth's 2006 encounter with comet 73P/Schwassmann-Wachmann: Products of nucleus fragmentation seen in closeup. *Near Earth Objects, Our Celestial Neighbors: Opportunity and Risk. Proceedings of IAU Symposium No. 236*, eds Milani A, Valsecchi GB, Vokrouhlický D (Cambridge Univ Press, Cambridge, UK), pp 211–220.

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[1]To whom correspondence should be addressed. E-mail: mbeb@unm.edu.