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The Younger Dryas impact hypothesis: A requiem

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ABSTRACT

The Younger Dryas (YD) impact hypothesis is a recent theory that suggests that a cometary or meteoritic body or bodies hit and/or exploded over North America 12,900 years ago, causing the YD climate episode, extinction of Pleistocene megafauna, demise of the Clovis archeological culture, and a range of other effects. Since gaining widespread attention in 2007, substantial research has focused on testing the 12 main signatures presented as evidence of a catastrophic extraterrestrial event 12,900 years ago. Here we present a review of the impact hypothesis, including its evolution and current variants, and of efforts to test and corroborate the hypothesis.

The physical evidence interpreted as signatures of an impact event can be separated into two groups. The first group consists of evidence that has been largely rejected by the scientific community and is no longer in widespread discussion, including: particle tracks in archeological chert; magnetic nodules in Pleistocene bones; impact origin of the Carolina Bays; and elevated concentrations of radioactivity, iridium, and fullerenes enriched in ^{3}He. The second group consists of evidence that has been active in recent research and discussions: carbon spheres and elongates, magnetic grains and magnetic spherules, byproducts of catastrophic wildfire, and nanodiamonds. Over time, however, these signatures have also seen contrary evidence rather than support. Recent studies have shown that carbon spheres and elongates do not represent extraterrestrial carbon nor impact-induced megafires, but are indistinguishable from fungal sclerotia and arthropod fecal material that are a small but common component of many terrestrial deposits. Magnetic grains and spherules are heterogeneously distributed in sediments, but reported measurements of unique peaks in concentrations at the YD onset have yet to be reproduced. The magnetic grains are certainly just iron-rich detrital grains, whereas reported YD magnetic spherules are consistent with the diffuse, non-catastrophic input of micrometeorite ablation fallout, probably augmented by anthropogenic and other terrestrial spherular grains. Results here also show considerable subjectivity in the reported sampling methods that may explain the purported YD spherule concentration peaks. Fire is a pervasive earth-surface process, and reanalyses of the original YD sites and of coeval records show episodic fire on the landscape through the latest Pleistocene, with no unique fire event at the onset of the YD. Lastly, with YD impact proponents increasingly retreating to nanodiamonds (cubic, hexagonal [lonsdaleite], and the proposed n-diamond) as evidence of impact, those data have been called into question. The presence of lonsdaleite was reported as proof of impact-related shock processes, but the evidence presented was inconsistent with lonsdaleite and consistent instead with polycrystalline aggregates of graphene and graphane mixtures that are ubiquitous in carbon forms isolated from sediments ranging from modern to pre-YD age. Important questions remain regarding the origins and distribution of other diamond forms (e.g., cubic nanodiamonds).

In summary, none of the original YD impact signatures have been subsequently corroborated by independent tests. Of the 12 original lines of evidence, seven have so far proven to be non-reproducible. The remaining signatures instead seem to represent either (1) non-catastrophic mechanisms, and/or (2) terrestrial rather than extraterrestrial or impact-related sources. In all of these cases, sparse but ubiquitous materials seem to have been misreported and misinterpreted as singular peaks at the onset of the YD. Throughout the arc of this hypothesis, recognized and expected impact markers were not found, leading to proposed YD impactors and impact processes that were novel, self-contradictory, rapidly changing, and sometimes defying the laws of

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physics. The YD impact hypothesis provides a cautionary tale for researchers, the scientific community, the press, and the broader public.

Contents

1. Introduction

A recent and controversial theory attributes the onset of the Younger Dryas (YD) climate interval, extinction of large mammalian fauna across North America, demise of the North American Clovis culture, and a range of other effects ~12,900 years ago to an extraterrestrial impact event (Firestone et al., 2007a; Kennett et al., 2009a,b). This hypothesis entered widespread scientific discussions at the May, 2007 meeting of the American Geophysical Union in Acapulco, Mexico. Since then, the YD impact hypothesis (YDIH) has been the subject of on-going research across a broad range of disciplines, several publications (supportive as well as skeptical), and remarkable attention in the popular media. In technical circles, some disciplines have remained critical of the hypothesis (e.g., meteoritics and impact science), whereas others have seen broader acceptance of a catastrophic impact 12,900 years ago (e.g., archeology). Media coverage has included numerous print articles worldwide, at least three television documentaries (for *National Geographic*, *Nova*, and *History Channel*), and a variety of on-going Web-based commentary. Now, after three years, sufficient time has elapsed and sufficient independent research has taken place to thoroughly review the YD hypothesis, evaluate the range of evidence presented both in support and against the proposed impact, and assess some broader questions posed by the YD impact debate.

1.1. The hypothesis

The end of the Pleistocene, following the Last Glacial Maximum (LGM), was a period of rapid and dramatic global change. Post-glacial warming during the Bølling–Allerød period reversed starting about 12,900 cal BP (calibrated years before present), with colder conditions prevailing during the ~1300-year Younger Dryas (YD) interval (Broecker et al., 2010; Meltzer and Holliday, 2010). In North America, an estimated 33 genera of mammalian megafauna (fauna > 100 kg; e.g., mammoths, mastodons, giant short-faced bear, saber-tooth tigers; Barnosky et al., 2004) went extinct at about this time, followed shortly thereafter by extinction of ~50 mammalian genera in South America (Barnosky et al., 2004; Fiedel, 2009). The interval between the LGM and the YD also coincided with the arrival and dispersal of Paleoindians through North and South America. The beginning of the YD coincides approximately with the end of the Paleoindian Clovis-type lithic technology (Haynes, 2010; Meltzer and Holliday, 2010). At some archeological sites, Clovis artifacts occur immediately below the YD basal horizon but are absent above (Haynes, 2008). Other paleo-environmental changes during the terminal Pleistocene include regional shifts in vegetation, fire frequency, and landscape-scale geomorphic response (e.g., Peros et al., 2008; Marlon et al., 2009; Pinter et al., 2011). Intense scientific interest, research, and discussion have long focused on these changes. In particular, the timing of post-LGM climatic changes, human arrival in North America, and megafaunal extinctions – and the question of which event(s) caused the other(s) – have engendered particularly vigorous debate (e.g., Grayson and Meltzer, 2003 + comments and reply). Against this background, the YDIH introduced a grand, potentially unifying solution promising to tie together some or all of these post-LGM changes.

Although the YDIH was formally debuted in 2007, a version of the hypothesis first appeared in Firestone and Topping (2001), with substantial elaboration in the Firestone, West, and Warwick-Smith (2006) book. These early sources contain a number of suggestions – impact origin of glacial drumlins, supernova eruptions leading to “deadly nerve toxins” in Pleistocene algal mats, etc. – that are highly unlikely. Morrison (2010) suggested that “If more scientists and science journalists had been aware of [Firestone et al. (2006)] when the YD hypothesis was first published in PNAS, it might never have gained