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The Younger Dryas impact hypothesis: a critical review

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ABSTRACT

The Younger Dryas impact hypothesis suggests that multiple extraterrestrial airbursts or impacts resulted in the Younger Dryas cooling, extensive wildfires, megafaunal extinctions and changes in human population. After the hypothesis was first published in 2007, it gained much criticism, as the evidence presented was either not indicative of an extraterrestrial impact or not reproducible by other groups. Only three years after the hypothesis had been presented, a requiem paper was published. Despite this, the controversy continues. New evidence, both in favour and against the hypothesis, continues to be published.

In this review we briefly summarize the earlier debate and critically analyse the most recent reported evidence, including magnetic microspherules, nanodiamonds, and iridium, shocked quartz, scoria-like objects and lechatelierite. The subsequent events proposed to be triggered by the impact event, as well as the nature of the event itself, are also briefly discussed. In addition we address the timing of the Younger Dryas impact, a topic which, despite its importance, has not gained much attention thus far. We show that there are three challenges related to the timing of the event: accurate age control for some of the sites that are reported to provide evidence for the impact, linking these sites to the onset of the Younger Dryas and, most importantly, an apparent age discrepancy of up to two centuries between different sites associated with the proposed impact event. We would like to stress that if the markers at different locations have been deposited at different points in time, they cannot be related to the same event. Although convincing evidence for the hypothesis that multiple synchronous impacts resulted in massive environmental changes at ~12,900 yrs ago remains debatable, we conclude that some evidence used to support the Younger Dryas impact hypothesis cannot fully be explained at this point in time.

1. Introduction

In 2007, a group of researchers led by Firestone et al. (2007) proposed a unique mechanism for the onset of the Younger Dryas (YD) cold period that followed the Allerød interstadial near the end of the Last Glaciation (Hoek, 2008). According to the YD impact hypothesis (YDIH), one or more extraterrestrial objects hit, or exploded over, the Laurentide Ice Sheet – possibly at a location near the current Great Lakes area – at the onset of the YD, ~12,900 yrs ago (Firestone et al., 2007). Besides initiating several short term cooling mechanisms, the force and extreme heat generated by this impact, according to this hypothesis, would have destabilized the ice sheet, yielding enough meltwater to disrupt ocean circulation and hence initiate the observed long term climate cooling. This hypothesis (Firestone et al., 2007) thus provides a unique trigger for the generally accepted meltwater re-routing mechanism which was probably responsible for the YD cooling. This meltwater re-routing mechanism includes re-routing of meltwater to the northern Atlantic or Arctic Ocean, disabling the thermohaline circulation and initiating climate cooling (Broecker et al., 1989; Tarasov and Peltier, 2005; Broecker et al., 2010; Murton et al., 2010; Fiedel, 2011). In addition to the rapid climate change, Firestone et al. (2007) also claim that the YD impact accounts for extensive wildfires, Pleistocene megafaunal extinctions and decline of the prehistoric Clovis culture in North America. Evidence presented for the YD impact hypothesis (YDIH) consists of peak concentrations of various markers found in profiles taken across the Allerød-YD boundaryat several sites in North America and one in Europe. These markers included magnetic grains and microspherules, charcoal, carbon spherules and glass-like carbon, iridium concentrations, and fullerenes with extraterrestrial helium (Firestone et al., 2007).

Although the YDIH gained further support from a study in 2009 reporting nanodiamonds at the Allerød-YD boundary (Kennett

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et al., 2009a, 2009b), the hypothesis was received with scepticism and is still considered as controversial (Dalton, 2007; Kerr, 2007; Pinter and Ishman, 2008; Dalton, 2009; French and Koeberl, 2010; Kerr, 2010; Jones, 2013). Most reported YD impact markers are not considered diagnostic evidence for impacts (French and Koeberl, 2010). These non-diagnostic markers include different forms of carbon, magnetic grains and spherules and fullerenes. Furthermore, researchers trying to reproduce the work often failed to find nanodiamonds or peaks in magnetic spherule concentration (Surovell et al., 2009; Daulton et al., 2010). Four years after publication of the hypothesis, a review paper titled “The Younger Dryas impact hypothesis: A requiem” argued against all of the evidence presented for the YDIH (Pinter et al., 2011). However, this “requiem” review paper left several questions unanswered: for example, the recent work on a South American site (Mahaney et al., 2010a, 2010b, 2011), although mentioned, is not discussed in any detail and the conclusion that the reported nanodiamonds were probably misinterpreted seems to ignore earlier reports by other independent researchers (Tian et al., 2011). In addition, convincing alternative explanations for the occurrence of these nanodiamonds in the Allerød-YD boundaryare lacking.

In this review we address these outstanding questions in the light of the most recent research on the topic (e.g. Andronikov et al., 2011; Marshal et al., 2011; Bunch et al., 2012; Fayek et al., 2012; Israde-Alcántara et al., 2012; Pigati et al., 2012; van Hoesel et al., 2012; Wittke et al., 2013b) and discuss the arguments both in favour of and against the different lines of evidence in detail. The subsequent events supposedly triggered by the impact event and the nature of the event itself are also briefly discussed. Further, we address the timing of the YD impact, a topic which, despite its importance, has not gained much attention thus far. Three main challenges related to the timing of the event are considered: accurate age control for some of the sites that provide evidence for the impact, linking these sites to the onset of the YD and, most importantly, an apparent age discrepancy of up to two centuries between different sites associated with the YDIH. Lastly, we conclude with some recommendations for future studies, with respect to sampling strategies and age control.

2. Summary of data for and against the Younger Dryas impact hypothesis

To substantiate their claim of an extraterrestrial impact at the Allerød-YD boundary, Firestone et al. (2007) report evidence from a wide range of sites, predominantly in North America. Most of their sites contain the so-called Black Mat: a dark grey to black layer with high organic content formed during the early YD (Haynes, 2008). Other samples were taken from the rims of several of the Carolina Bays, elliptical depressions that Firestone et al. (2007) relate to the impact. An impact origin for the bays, however, is unlikely as the bays were not formed instantly, furthermore, there is evidence that the bays were formed before the YD (Brooks et al., 2010; Pinter et al., 2011). Only one of the sites analysed by Firestone et al. (2007) is located outside of North America, namely Lommel (Belgium), where the Usselo horizon was sampled. The Usselo horizon is a buried soil horizon formed during the late Allerød to early YD and is widespread in the European coversand area (Kaiser et al., 2009). Like the Black Mat, the Usselo horizon thus approximately marks the onset of the YD in the sedimentary record. In later studies, sites located in South America and the Middle East were also investigated (Mahaney et al., 2010a; Bunch et al., 2012). Fig. 1 gives an overview of all the sites at which YDIH markers have been reported.

Firestone et al. (2007) report peak concentrations of a wide range of markers across the Allerød-YD boundary. The main markers they report include “magnetic grains with iridium, magnetic microspherules, charcoal, soot, carbon spherules, glass-like carbon containing nanodiamonds, and fullerenes with ET [extraterrestrial] helium”. Of the markers put forward by Firestone et al. (2007), only elevated iridium (Ir) concentrations are commonly used as an impact indicator (Tagle and Hecht, 2006; French and Koeberl, 2010; Koeberl et al., 2012). Fullerenes with extraterrestrial helium on the other hand, are considered controversial and have not been confirmed independently at any known impact site (French and Koeberl, 2010). Charcoal, soot, carbon spherules and glass-like carbon are only indicative of biomass burning, regardless of what initiated the fires. As fullerenes, charcoal or soot cannot be

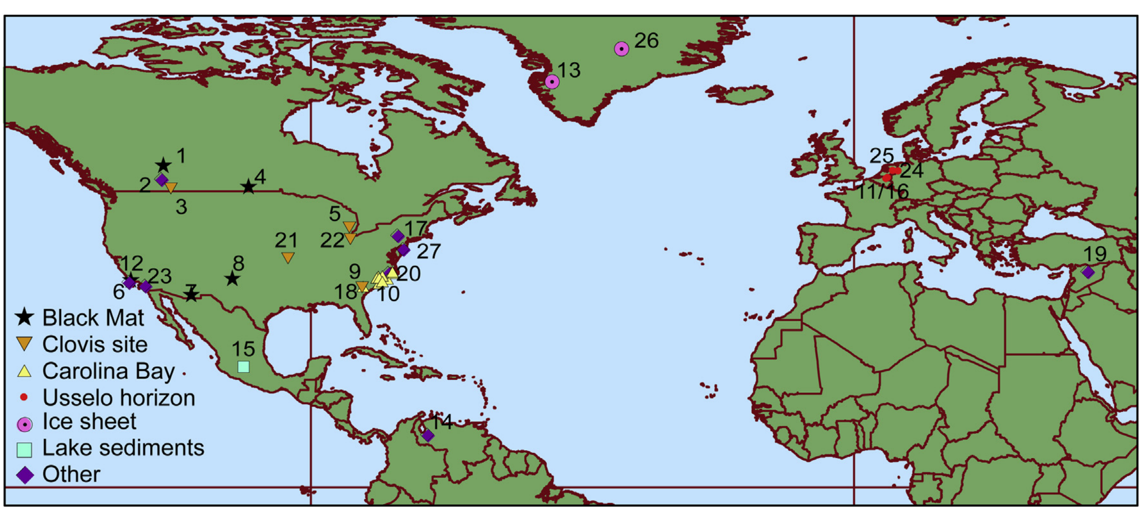

Fig. 1. Overview of all the sites where different YDI markers have been reported. 1. Chobot[a,b,r] 2. Morley[a] 3. Wally's beach[a] 4. Lake Hind[a,b] 5. Gainey[a,r] 6. Daisy Cave[a] 7. Murray Springs[a,b,c,d,e,f,r,t] 8. Blackwater Draw[a,g,h,i,r,t] 9. Topper[a,b,g,h,l,r] 10. Carolina bays[a,g] 11. Lommel[a,g,j,r,t] 12. Arlington Canyon[d,k,l,r] 13. Kangerlussuaq[m] 14. Mucubaji[n] 15. Lake Cuitzeo[o,r] 16. Geldrop Aalsterhut[p] 17. Melrose[q,r,t] 18. Blackville[a,q,r] 19. Abu Hureyra[q,r] 20. Barber Creek 21[r]. Big Eddy[r] 22. Sheridan Cave[r,t] 23. Talega[r] 24. Lingen[r] 25. Ommen[r]. 26. GISP2[s] 27. Newtonville[t] Different type of sites or sedimentary archives are indicated by different symbols. [a]Firestone et al. (2007); [b]Kennett et al. (2009a); [c]Haynes et al. (2010); [d]Daulton et al. (2010); [e]Fayek et al. (2012); [f]Pigati et al. (2012); [g]Paquay et al. (2009); [h]Surovell et al. (2009); [i]LeCompte et al. (2012); [j]Tian et al. (2011); [k]Kennett et al. (2008, 2009b); [l]Scott et al. (2010); [m]Kurbatov et al. (2010); [n]Mahaney et al. (2010b; 2010; 2011); [o]Israde-Alcántara et al. (2012);[p]van Hoesel et al. (2012); [q]Bunch et al. (2012); [r]Wittke et al. (2013b); [s]Petaev et al. (2013); [t]Wu et al. (2013).