Han Kloosterman and the Catastrophic End of the Allerød Interstadial

Trevor Palmer

Abstract

This article records the involvement of the Dutch geologist and catastrophist, Han Kloosterman, in discussions from 1976 to the present day concerning a proposed catastrophist cause for the transition from the mild Allerød interstadial to the glacial Younger Dryas stadial near the end of the Pleistocene Epoch. This is now termed the Younger Dryas Boundary event. These discussions are placed within the context of more general debates about catastrophism and uniformitarianism.

Introduction

Figure 1. Han Kloosterman in Paris in 2009. Photo: Jessica Kloosterman.

In 1976, Johan (Han) Kloosterman (Figure 1), a Dutch geologist who was then working for a mining company in Brazil, founded the journal *Catastrophist Geology*, describing it as a magazine "dedicated to the study of discontinuities in Earth history". The first issue began with an article by Kloosterman himself, with the same title as the journal, which had been circulated a year earlier at a meeting in London to mark the centenary of the British geologist, Charles Lyell. That would have been a provocative action, since it was Lyell who had done most to establish the generally accepted theory of uniformity, which maintained that all change at the Earth's surface had taken place in a gradual, even-paced fashion, as a result of natural processes which were still operating [1].

Kloosterman pointed out that, even at the time of writing, a century after the death of Lyell, we had only a limited knowledge and understanding of the forces which could affect our environment, so there was no justification in maintaining that major catastrophic events could never occur, or in ridiculing those who wanted to give serious consideration to the possibility they had. In fact, processes which could give rise to major catastrophes had already come to light, without having any effect on the dominance of the Lyellian paradigm. Kloosterman wrote, "In spite of our proclaimed uniformitarianism, catastrophist hypotheses abound: the capture of the Moon, astroblemes, bursts of cosmic rays, natural nuclear reactors, the breaking up and the collision of continents. When proposed by geologists of non-catastrophist persuasion, such hypotheses are taken seriously, but when similar ideas are forwarded by less conditioned outsiders, they are regarded as evidence of lunacy simply because they violate uniformitarian dogma". He argued that geological evidence should be considered objectively, rather than be interpreted according to a paradigm which had become established on the basis of incomplete information [2].

Kloosterman concluded, "Catastrophes do occur. The dinosaurs did die out – whether it took a million years or a day – either through the cumulative effect of continuous causes…or through a unique, sudden, terrestrial or extraterrestrial event. Should such riddles ever be solved, the solution will come from an inspired search for clues and not through application of the methods of medieval scholastics or nineteenth-century rationalists" [3].

In his article, Kloosterman had written of the need for interactions between geologists and physicists. Four years later, the father and son team of Luis and Walter Alvarez, a physicist and a geologist, found increased levels of iridium at several sites in a thin layer at the very end of the Cretaceous Period, dated by geologists to about 65 million years before the present, when the dinosaurs and many other species became extinct. Since iridium has been found in abundance in extraterrestrial objects, they argued that this finding provided strong evidence that the extinctions at the Cretaceous-Tertiary (K-T) boundary (now called the Cretaceous-Palaeogene, or K-Pg, boundary) had resulted from the impact of a large asteroid or comet [4]. That was initially viewed with scepticism but, because of the iridium evidence, it could not

be ignored, as had happened to previous suggestions of a similar nature. Eventually, after more than two decades of acrimonious debates and further investigations, which included the finding of other impact indicators, such as tektites and nanodiamonds, and, above all, an impact crater of suitable size and age at Chicxulub, Mexico, it has now become widely accepted that a large extraterrestrial impact played a significant role in the extinction of the dinosaurs [5].

However, was this a unique event or have there been others, including ones in more recent times?

Evidence of an Allerød Conflagration?

In the second issue of *Catastrophist Geology,* Kloosterman quoted the following passage from *Nature of the Stratigraphic Record,* written by the British geologist, Derek Ager:

Along the chalk downs in southern England there are a number of short, steep-sided dry valleys traditionally blamed on the devil (for instance, Devil's Dyke near Brighton). These have been gouged out of the hills, probably under periglacial conditions, and their debris spread on the lowlands below. From careful work on the snail faunas of the chalk sludge from one of these (the Devil's Kneading Trough in Kent) Dr Michael Kerney showed that the erosion must have happened in a very short time indeed. Within the sludge there is a clear black horizon, only an inch or so thick, which has now been recognised all over southern England. The black colouration is due to charcoal fragments from burnt wood. In fact, at one stage in this study our thoughts ran on catastrophisms of a biblical kind and we pictured half-seriously a universal conflagration to account for the black band. It is more likely, however, that it represents a short period of dry climate when there were frequent bush fires. The snail fauna suggests the same thing and enabled the bed to be correlated with the Alleroed oscillation of Denmark and northern Europe generally. This was a brief episode of climate amelioration after the last glaciation. The charcoal made it possible to get a carbon-14 date on the deposit, giving an age of about 10,700 years before the present. This fits all over Europe and correlated remarkably well with the Two Creeks horizon of the same kind around the Great Lakes in North America. [6]

At the time this was written, there were uncertainties about the dating of the Allerød and its precise relationship to other stages around the end of the Pleistocene Epoch. It has since become established that, at the end of the Allerød, temperatures plummeted, heralding the start of the Younger Dryas stadial, now regarded as the final glacial period of the Pleistocene. Although uncalibrated radiocarbon dates for the transition from the Allerød to the Younger Dryas remained in line with the figure given by Ager, geologists came to accept it had taken place around 12,900 years before the present, on the basis of dates obtained by calibrating raw radiocarbon results with dendrochronological data, and also because of dates obtained from ice-core studies [7]. As dating procedures continued to be refined, that figure was recently adjusted to around 12,800 years.

Regardless of such details, Kloosterman pointed out that Ager had not explained why he "adopted a more conventional (uniformitarian) hypothesis in preference to a catastrophist one which assumes a very short episode of high temperature and a universal conflagration". He continued:

The fact that I stumble over such passages without looking for them makes me wonder whether many more possible indications of fiery conflagrations in the geological recent past are being explained away in the conventional literature? What if we started looking for them? [8]

In the next issue of *Catastrophist Geology*, published in 1977, Ager said that his reference to the possibility of global catastrophism had been intended as a joke:

The idea of a universal conflagration was just the sort of funny idea one casts off as a humorous aside, but it is so preposterous a notion as to not need taking seriously. That does not mean conservative narrow-mindedness, it is the fine old scientific principle of 'economy of hypothesis' or 'Occam's razor'. One goes for the simplest solution first rather than deliberately postulating something which requires a much more difficult mechanism. In this case a 'universal conflagration' (if possible) would certainly not last long enough to leave any sort of recognizable stratigraphical record, whereas a few centuries or millennia of occasional heath or forest fires, during a particularly dry spell, would probably do so without requiring any special mechanism. [9]

Kloosterman responded:

After a fire the forest usually recovers, and the ashes are incorporated in the humus layer. But you speak of '..a clear black horizon, only an inch or so thick', which is found interbedded with the debris from an erosion that 'must have happened in a very short time indeed'. That the layer is preserved would indicate that it was covered with sediments immediately after its formation. That leaves us with only one enormous forest fire, which is moreover correlatable from southern England to the Great Lakes of North America. Doesn't that sound somewhat like a universal conflagration? I wonder whether the sedimentary layers under the black horizon are disturbed by roots, in other words whether the material was carbonised in place or came from the surroundings by the action of wind and/or water? [10]

To this, Ager replied:

The dark band I referred to marks the Alleroed oscillation in southern England…Its dark colouration is due to very small fragments of charcoal and I see no reason why these should not have accumulated over a very long period of time. It proved quite difficult to accumulate enough pure charcoal to get the carbon date we did, and the date arrived at was certainly not an indication of accumulation in a single year, or anything like it. The correlation with the Two Creeks horizon in North America and elsewhere in Europe was on the basis of a short-lived climatic amelioration of the same age. I had no intention whatsoever of implying a 'conflagration', on any scale, throughout this vast area…I cannot remember any roots below the band, which is contained within a fairly pure white mud derived as hill-wash from the neighbouring chalk hills. The absence of any sizable fragments of wood or charcoal confirms the evidence from the snails that this was heath or scrub-land rather than forest…The sheer abundance of the snails at this level compared to those in equivalent thicknesses above and below suggests to me that deposition was extremely slow. [11]

Kloosterman, in his final contribution to the discussion, made it clear that he was not saying the black layer must have been formed by a catastrophist mechanism, because he had not even seen it, but he was strongly in favour of considering that possibility. Taking on the role of Devil's Advocate, he had gathered data on infestations of snails and concluded that, where sudden infestations had occurred, some kind of disequilibrium seemed to be involved, whether meteorological or ecological. He continued:

So, the abundance of snail shells in the debris of the Devil's Valleys might point to a disruption of the ecology due to a 'fiery catastrophe', accompanied by heavy rains causing gulley erosion. There is also another argument against a gradualistic explanation of the dark band (living in Brasil I should have thought of that before). In tropical countries pastures and savannahs are burnt every year. In parts of Brasil this practice has been going on for nearly 500 years now, not counting the presumably less intensive burning in pre-Columbian times. No charcoal-rich layer is formed anywhere, the ash is incorporated into the humus layer or washed away. [12]

Fifteen years after these exchanges, Ager, in the final year of his life, authored a book entitled *The New Catastrophism: The Importance of the Rare Event in Geological History* [13]. In the Preface, he noted how perceptions were changing, writing:

For a century and a half the geological world has been dominated, one might even say brain-washed, by the gradualistic uniformitarianism of Charles Lyell. Any suggestion of 'catastrophic' events has been rejected as old-fashioned, unscientific and even laughable…My thesis is that in all branches of geology there has been a return to ideas of rare violent happenings and episodicity. So the past, as now interpreted by many geologists, is not what it used to be. It has certainly changed a great deal from what I learned about it in those far-off days when I was a student.

Nevertheless, in the Introduction, he made it clear that the message of the book "is not the old-fashioned catastrophism of Noah's flood and huge conflagrations…*The New Catastrophism* is mainly a matter of periodic rare events causing local disasters". In the final chapter of the book, he discussed the asteroid theory for the extinction of the dinosaurs, and said he was prepared to be open-minded, yet his scepticism was very apparent. Like many academic geologists, Ager had become aware of the existence of forces which could cause catastrophes on a global scale, but seemed reluctant to accept that such an event might actually have happened.

Kloosterman, in contrast, perhaps because his career was as a geologist working for mining companies, had no such inhibitions, as he demonstrated in "The Usselo Horizon, A Worldwide Charcoal-Rich Layer of Alleröd Age", a paper presented at a symposium entitled "New Scenarios of Solar System Evolution and Consequences in the History of Earth and Man", held in Bergamo and Milan in June 1999 [14]. Kloosterman explained that a thin (5-10 cm) layer rich in charcoal, associated with the Allerød interstadial, had been found in a sandpit at Usselo, near Enschede in the Netherlands in 1940 by the Dutch archaeologist, Cornelis Hijszeler. According to Kloosterman, the Dutch geologists of the time were a fraternity of dogmatic uniformitarians and they tried to suppress the finding, but Hijszeler eventually published his results during the 1950s. Another early finding of the Usselo horizon came during the excavation of a tunnel at Velsen, west of Amsterdam. None of the series of papers describing the findings used the word "charcoal", the closest being a reference to "black speckles".

Since the first discovery in Holland, the horizon had also been found in Allerød deposits in Germany, Belgium, Great Britain, France, Poland and Belarus, and apparently also in Egypt, South Africa, India and Australia, the black layer in each case having "a radiocarbon age of about 11,000 years, and dendro-dated at about 13,000 years". German geologists showed that this charcoal-rich layer was synchronous with a huge explosion of the Laacher See volcano, which deposited ash from southern Sweden to northern Italy, and they postulated that this had produced widespread forest fires which gave rise to the black layer. The same causal relationship was accepted in Belgium and later in France. However, the geographical extent of the charcoal-rich layer in Allerød deposits was much greater than that of the ash-fall from the Laacher See eruption.

Kloosterman continued his presentation by pointing out that worldwide charcoal-rich horizons appeared to be "not very common". Wendy Wolbach, an American chemist, had found one at the K-T boundary [15], which was part of the evidence which led to the acceptance of the hypothesis that there had been a major impact event at this time. She then made a literature search for other worldwide charcoal-rich layers in the geological column, but was unable to find one. According to Kloosterman, that was "possibly because she had to rely on heavily biased literature, written by uniformitarians" [16].

Returning to the subject of the black layers in deposits from the Allerød interstadial at different sites, Kloosterman urged the adoption of the working hypothesis that they were all synchronous and had the same cause, and the examination of how this fitted together with other phenomena from the Late Pleistocene such as major climate changes and the mass extinction of mammoths and other large animals. He suggested that entering into discussions with uniformitarians was a waste of time, pointing out, "While we are born on a planet spinning and spiraling through a wildly dynamic universe, the uniformitarians try to impose upon us a static worldview". In Kloosterman's opinion:

We are in the middle of a major crisis in the biosphere, which started about 13,000 years ago, possibly by a cometary impact. Quite possibly it is the extinction of the Pleistocene megafauna – mostly herbivores but also their predators – which has opened an ecological niche for one predator that survived – humankind. The present population explosion and the continued faunal and floral extinctions occur in the wake of the universal conflagration of which the Usselo charcoal horizon bears witness. [17]

Firestone's Cosmic Firestorm

A related scenario was presented in 2006 by Richard Firestone, Allen West and Simon Warwick-Smith in *The Cycle of Cosmic Catastrophes*. At the time, Firestone, a nuclear physicist, worked at the Lawrence Berkeley National Laboratory in California, West ran a geosciences consulting company based in Arizona and Warwick-Smith, who had previously been a mining geologist in Australia, was a publishing consultant and publicist living in California [18].

The aim of the book was to propose a coherent theory to explain a number of apparently unconnected anomalies found as a result of geological and archaeological studies in the Great Lakes region of North America, as well as some anomalies of a more general nature. So, for example, the changing relationship over time between raw radiocarbon dates and "calendar dates" (the supposed actual dates, derived from dendrochronology and ice-core studies) indicated that substantial amounts of radioactive carbon (carbon-14) had been introduced into the Earth's atmosphere at around 41,000 BP (i.e. "before the present", defined as "years before 1950"). This occurred again at around 34,000 BP, and once more at around 13,000 years ago. How could that be explained, in a way which was consistent with other apparent anomalies? The authors' proposal was that there had been a supernova explosion close to the Earth, which caused widespread extinctions in the part of the world directly exposed to the destructive radiation emitted (Australia and Southeast Asia). There was a massive increase in global radiocarbon, and the Earth's magnetic field wavered and almost reversed. Around 34,000 BP, the first shock-wave of the supernova struck the Earth, again causing an increase in atmospheric radiocarbon and a near-reversal of the Earth's magnetic field. Ions and small particles bombarded the Earth, producing radioactive anomalies and also small holes resembling buckshot wounds in the bones of animals which had lived and died at this time. In addition, there was an increased incidence of impacts of asteroids or comets during this period, as a consequence of the perturbations caused by the supernova explosion. Global temperatures, particularly in the north, began to rise markedly around 16,000 BP but then, around 13,000 BP, one or more impacts by large comets whose orbits had been disturbed by the supernova explosion struck the Earth, causing a further supplementation of atmospheric carbon-14, another wavering of the Earth's magnetic field and further significant effects, including the fact that all traces of the megafauna of North America, including the Columbian mammoths, and of the Clovis culture of early humans, were buried under a black layer from this period known as the "Clovis layer" [19].

Only the final stage of this proposal has received much attention, and it should be apparent that the considerations would apply to any significant cometary impact at around 13,000 BP, regardless of what had happened earlier. The key was to produce objective evidence of a large impact at this time. The authors claimed evidence of enhanced iridium, magnetic microspherules, charcoal, soot, glass-like carbon containing nanodiamonds and fullerenes containing extraterrestrial helium in the Clovis layer. Citing Kloosterman, they also referred to evidence found by others of a significant impact at this time. After mentioning Wendy Wolbach's findings at the K-T boundary, they wrote, "Wolbach and Han Kloosterman (personal communication, 2006) together found the same 'grape-bunch' soot in the black mat at Murray Springs – a striking connection to the Ice Age extinction…Kloosterman told us that Wolbach believes the amounts are 'significant'. Kloosterman indicates that it is nearly identical to the KT soot, validating our theory that massive firestorms occurred at the same time the mammoths disappeared. We have agreed to collaborate with the researchers to confirm this at other Clovis-era locations in Europe" [20].

Later, under the heading, "Late-Breaking Discoveries", came the statement:

In addition, there is now a powerful connection between the [Clovis] Event and Europe. In our collaboration with Han Kloosterman, we tested sediment from the Usselo horizon near Lommel, Belgium, at a site occupied by the Magdalenian people. Contemporaries of Clovis, the Magdalenians also experienced a severe population decline during the Event 13,000 years ago. We found peaks of magnetic grains, metallic spherules, and charcoal, and there is a black mat just as Vance Haynes found at fifty sites in North America. In the magnetic fraction there, we found the largest Ir levels of all – an astounding 117 ppb [parts per billion]. [21]

Kloosterman has described elsewhere how he travelled to Murray Springs in Arizona in 2002 to collect samples from the Clovis layer, one of which was analysed by Wolbach, and in 2006 took a sample from the Usselo horizon near Lommel which was found to have an anomalous iridium content [22].

Firestone, West and Warwick-Smith then collaborated with Kloosterman and Wolbach, and also with a number of geologists holding university posts, including James Kennett and Luann Bekker of the University of California and Ted Bunch and James Wittke of Northern Arizona University, to write a scientific paper on the evidence for an extraterrestrial impact at the boundary between the Allerød and the Younger Dryas. This was published in *Proceedings of the National Academy of Sciences, USA*, in 2007 [23], the 26 authors (one of whom was Kloosterman) being regarded by some as the first manifestation of the "Clovis impact team", an informal group with a fluid membership. On the basis of detailed evidence from ten dated sites (nine in the USA and Lommel in Belgium), these authors concluded there had been an impact event around 12,900 years ago which contributed to the megafaunal extinctions, led to widescale conflagrations and caused the fall in temperatures which resulted in the glacial conditions of the Younger Dryas. Iridium levels, although high in some locations, were generally much lower than those found at the end of the Cretaceous Period, so it was thought that the impacting body must have had a low metal content and was probably a comet rather than an asteroid. No impact crater of appropriate age and size had been found, so it was suggested that the comet may have fragmented before striking the northern ice-sheet, resulting in a spread of explosive impacts rather than a single huge one, and so failing to leave an obvious mark on the ground beneath the ice. Alternatively, the fragments may have exploded in the atmosphere.

A few months before this paper was published, a summary of the findings was given by the same authors in a poster presentation at a meeting of the American Geophysical Union (AGU) in Acapulco in May 2007 [24]. That was one of ten presentations on the subject of *New Insights into Extraterrestrial Impacts, Younger Dryas Cooling, Mass Extinctions, and the Clovis People III* in a poster session in the Chichen-Itza Hall presided over by James Kennett [25]. One of these posters expressed scepticism about the impact hypothesis [26]. In another of the presentations, Wolbach and Kloosterman, together with Kennett, Becker, Firestone, West and Adrienne Stich, outlined the evidence for impact-triggered wildfires 12,900 years ago [27]. Kloosterman also made a solo contribution to the session, with a poster correlating the Usselo horizon in Europe with the Clovis layer in North America. He described the geographical range of the Usselo horizon, the first discovery of the horizon by Hijszeler and the uniformitarian interpretation of it by European geologists and archaeologists, before continuing:

The prehistoric Clovis culture of North America was found in the 1930s and dated to the Twocreekan, the last interstadial of the Wisconsin glaciation. The Clovis layer was especially investigated by C. Vance Haynes Jr. Visually, the layer is easily identifiable with the Usselo Horizon of Europe. Its stratigraphic position is coincident with the end of the Clovis culture and with the disappearance of the Pleistocene megafauna. In Europe, there is a clear correlation with the sudden demise of the Magdalenian culture, best known for the Franco-Cantabrian cave paintings, and with megafaunal extinctions such as those of the Irish elk, the cave bear, and cave lion. [28]

Kloosterman concluded by summarising evidence showing that the Usselo horizon and the Clovis layer had resulted from the same extraterrestrial impact event.

Kloosterman's Catastrophist Manifesto

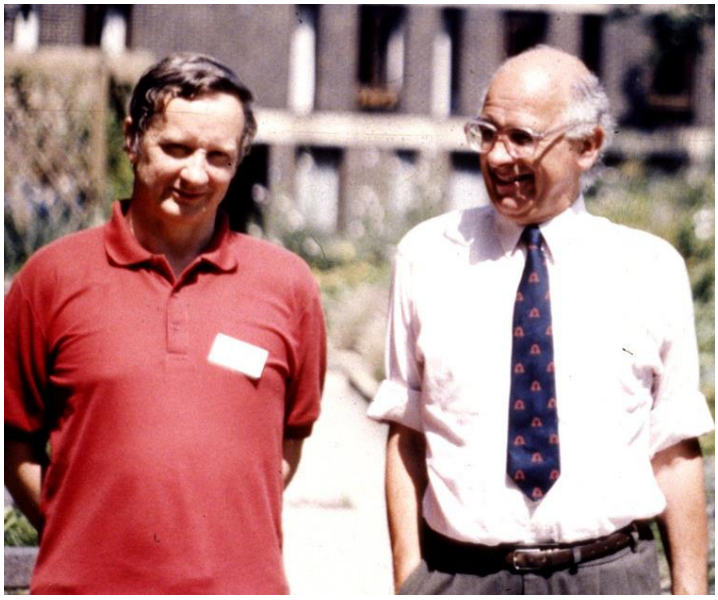
During the 2007 AGU meeting in Acapulco, Kloosterman circulated a document entitled *Catastrophist Manifesto* [29]. This began by presenting Kloosterman's ideas about how uniformitarianism came to be such a dominating and constraining force. His starting point was the use made of the adage, *natura non facit saltus* (nature does not make leaps), by the 17th century German philosopher, Gotfried Wilhelm von Leibniz. Like many of his contemporaries, Leibniz held a belief in natural theology, which maintained that the world had been created by a benign God and that there was no distinction between science and religion, the main purpose of studying nature being to find evidence of the existence of the Creator [30]. The adage associated with Leibniz came to dominate both geology and biology in Europe from the middle of the 19th century onwards. As Kloosterman wrote, "Linnaeus and Darwin quoted his slogan verbatim, and James Hutton and Charles Lyell were imbued with the spirit of it". This resulted in the development of strongly gradualistic scenarios, one aspect of which was the elimination of the notion of episodic worldwide catastrophes, popular during the first half of the 19th century [31].

Hutton's 1795 adage on the immensity of time, saying that the world showed "no vestige of a beginning, no prospect of an end" had, according to Kloosterman, been formulated 150 years earlier by Isaac de la Peyrère, a Calvinist nobleman, at a time when the short "biblical timescale" was generally accepted in Europe. This, Kloosterman said, had been introduced by "Catholic and Protestant fundamentalists…based upon their literal interpretation of the Hebrew Bible, whereas the Jewish tradition, with a much broader base, has no problem with [a longer] timescale. And neither have the Hindu, Maya or Maori traditions, and so on". He went on to write that the short timescale began to be abandoned in Europe during the 18th century by uniformitarians and catastrophists alike. He added, "Statements about the eternity of the world cannot be verified, so they belong to the realm of metaphysics rather to that of science" [32].

Kloosterman next pointed out that it is frequently said that the prominent French catastrophist, Georges Cuvier, who flourished early in the 19th century, wrote of repeated destructions followed by new creations, but Cuvier had never said anything of the kind. Indeed, it is perfectly true that, although Cuvier described the evidence for a series of widespread extinctions in Europe, he said nothing about total destructions or newly-created species [33]. It was Cuvier's contemporaries, Jean Deluc and Alcide d'Orbigny, who wrote of complete extinctions followed by new creations. However, as Kloosterman noted, even this extreme catastrophist view shows, despite obvious differences, some resemblances to the modern view of Earth history, which envisages partial extinctions followed by rapid evolution and diversification of surviving species, not the gradual, even-paced progression originally supposed by uniformitarians [34]. Turning to the possible cause of extinctions, Kloosterman wrote:

The 2005 Richard Firestone/Allen West breakthrough in impact geology is more far-reaching in its consequences than the 1980 K-T breakthrough, because the damage done to the biosphere in the Late Pleistocene also affected humanity. It brings together the North American school of catastrophism (repeated blows during Earth history) with the British school of Victor Clube and William Napier (repeated blows during human prehistory and history), researchers who situate themselves within the Halley-Whiston tradition that began, like uniformitarianism, around 1700. What was lacking in the Clube-Napier school, based on extrapolation of space-age data, is now provided by the Firestone-West findings, to wit, geological field- and laboratory data. [35]

Figure 2. Bill Napier (left) and Victor Clube at the Second SIS Cambridge Conference in 1997.



It may be noted that Napier (Figure 2) subsequently produced evidence to suggest that, in line with the Clube-Napier scenario [36], the event at the end of the Allerød 12,900 years ago which gave rise to the harsh conditions of the Younger Dryas, and was now being termed the Younger Dryas Boundary (YDB) event, was caused by debris from the disintegrating giant comet, proto-Encke [37].

Kloosterman went on to argue that the Firestone/West breakthrough could help bring about a rapprochement in a schism that has existed since the middle of the 19th century:

This schism pitted against each other, sometimes violently, academic geology (and biology, archaeology, history, mythology) and the so-called lunatic fringe, marginalised by the uniformitarian establishment – Atlantologists, pole-shifters, Velikovskians, Theosophists, etc. Perhaps the 2005 discoveries will induce the "lunatic fringe" to start thinking more critically. And perhaps they will induce the academic geologists to start thinking. If so, we can look forward to the next breakthrough in rather less than another quarter of a century. [38]

The controversy between catastrophism and uniformitarianism was often presented as a conflict within the geological sciences, but it was in fact "a conflict between two antagonistic, incompatible worldviews, vastly transcending the field of one particular discipline", and the fight had been raging for thousands of years. Plato was a catastrophist, whereas Aristotle tried to play down what Plato considered to be historical discontinuities. Two millennia later, Leibniz took the same stance as Aristotle. After a wave of catastrophist theories during the first part of the 19th century, the uniformitarians, without any justification, proclaimed their view to be the only scientific one, and triumphantly declared the battle won. When evidence arose which appeared to contradict their views, such as the K-T discoveries, the uniformitarians "stood their ground and tried to encapsulate the new findings into their system. They turned up with 'catastrophist uniformitarianism' – a *contradictio in terminis*, and worse, a metaphysical confidence trick: the appropriation of empirical findings by a magical formula". After the presentation of evidence for the YDB impact event in 2005, that would become

more difficult to do in future. Nevertheless, "as before, uniformitarianism will find its staunch defenders – not because they can produce arguments of any validity, but because they are well-conditioned: *Natura Non Facit Saltus*. Kloosterman feared the war of worldviews might go on unabated for a long time to come [39]. He then concluded:

This manifesto is not an attack but a counterblast. We, persons who have understood that we are born on a highly dynamic planet that tumbles and gyrates and spirals through a highly dynamic universe, have been calumniated, cold-shouldered, blacklisted, denied research funding, refused publication space, and chased out of jobs by sectarians who took power at the universities around 1860, sectarians as dogmatic and repressive as their Christian predecessors, and who tried – and continue trying – to describe the world as static as they can. And to enforce consensus, they continue using ad-hominem arguments, their "common sense", the anonymous peer-review censorship system, and the medieval Occam's razor, long since rusted and blunt. [40]

Arguments For and Against the Younger Dryas Boundary Impact Hypothesis

As Kloosterman had anticipated, the war of world-views continued, although initial criticisms of the comet hypothesis were relatively mild. A group of Canadian archaeologists headed by Briggs Buchanan reported that they could find no evidence of a population decline amongst the Palaeoindians at around 12,900 BP and they concluded, "Thus, minimally, the study suggests that the extraterrestrial impact hypothesis should be amended". Similarly, Jennifer Marlon of the University of Oregon, together with other Earth scientists, reported that the data they had collected did not support the hypothesis that a cometary impact at this time had initiated continental-scale wildfires. Again, geologist Nicholas Pinter of Southern Illinois University and others pointed out that none of the findings reported by the proponents of the hypothesis provided unequivocal evidence of an extraterrestrial impact [41].

That last-mentioned point was a valid one, but powerful evidence was about to be produced. In 2009, nine members of the Clovis impact team, all Earth scientists, headed by James Kennett and his son, Douglas (from the University of Oregon), announced in *Science* the finding of nanodiamonds in sediments dating to 12,900 BP at multiple locations across North America, some of these being in forms which clearly pointed to an impact origin. They wrote:

Selected area electron diffraction patterns reveal two diamond allotropes in this boundary later but not above or below that interval. Cubic diamonds form under high temperature-pressure regimes, and n-diamonds also require extraordinary conditions well outside the range of Earth's typical surficial processes but common to cosmic impacts. N-diamond concentrations range from ~10 to 3700 parts per billion by weight, comparable to amounts found in known impact layers. These diamonds provide strong evidence for Earth's collision with a rare swarm of carbonaceous chondrites or comets at the onset of the Younger Dryas cool interval, producing multiple airbursts and possible surface impacts, with severe repercussions for plants, animals, and humans in North America. [42]

This was soon followed by another paper from a group headed by the Kennetts, which reported the finding of a third impact-linked form, hexagonal nanodiamonds (also known as lonsdaleite), in the YDB layer at Arlington Canyon, California [43].

Shortly after the publication of the first of these papers, Kloosterman, who had given a talk at an SIS meeting in 2004 during which he had shown many slides of the Clovis layers and Usselo horizons at various sites, emailed to ask for help in contacting the Cardiff geologist, John Evans, who had taken him to see the black Allerød layer at Pitstone in Buckinghamshire some years previously (Figure 3). Kloosterman was keen to come and collect samples of the layer, so they could be examined for the presence of nanodiamonds. Unfortunately, Evans had died in 2005, but the location of the site could be determined from a map in his published report [44]. Phillip Clapham and I went to

Figure 3. The thin black Allerød layer at Pitstone, Buckinghamshire, at the time when Han Kloosterman visited the site with John Evans.

Pitstone to investigate, but the black layer was no longer present, apparently taken away, together with other superficial layers, during quarrying activities. Nevertheless, cubic nanodiamonds were soon discovered on the eastern side of the Atlantic in the corresponding black layer at Lommel in Belgium in 2010 [45].

This was timely because the existence of nanodiamonds in YDB layers had recently been brought into question. Physicist Tyrone Daulton of Washington University, St. Louis, together with palaeobotanist Andrew Scott of the University of London and Nicholas Pinter, claimed they had been unable to find nanodiamonds in the YDB layer at Arlington Canyon, suggesting that the Kennett team had mistakenly identified graphene as cubic diamond, graphene/graphane-oxide aggregates as hexagonal diamond and nanocrystalline copper or nanocrystalline cuprous oxide as n-diamond [46]. They went on to use this as a major argument in their claim that the Firestone/West proposal was no longer viable, presented in an article entitled, 'The Younger Dryas Impact Hypothesis – A Requiem' [47]. It was also a key aspect of articles by Richard Kerr in *Science* which similarly suggested that the hypothesis was facing major problems. In 'Mammoth-Killer Impact Rejected', Kerr wrote, "Counter-criticism aside, outsiders are now walking away from the mammoth killer impact in increasing numbers". He also quoted Philippe Claeys of the Free University of Brussels as saying, "The geochemical story is finished, it's over" [48].

Ironically, it was Claeys who found the cubic nanodiamonds at Lommel, showing that the geochemical story was far from finished [49]. Also, the Kennett team responded robustly to the claims of Daulton, Pinter and Scott, pointing out that, according to the information they presented, their samples were collected a considerable distance away from those of the Kennett team, and there were reasons to question whether the Daulton team's samples were actually taken from the YDB layer [50].

Nevertheless, despite the finding of the cubic nanodiamonds, Claeys remained sceptical about the impact hypothesis, he and his colleagues giving several reasons, including the absence of hexagonal nanodiamonds, for retaining their previous views [51]. Daulton similarly went on to argue that the presence of cubic nanodiamonds should not be taken as evidence of an impact unless hexagonal nanodiamonds were also present, and could be shown *not* to be graphene/graphane-oxide aggregates [52].

In 2012, Annelies van Hoesel and other geologists from Utrecht found cubic nanodiamonds but not hexagonal nanodiamonds, together with evidence of wildfires, at the Usselo horizon at Geldrop-Aalsterhut in the Netherlands, and concluded there was no evidence of an impact event. They suggested the cubic nanodiamonds had been formed by the wildfires (even though there is no known mechanism by which this could happen). They also stated that their radiocarbon dating studies showed that the wildfires had occurred 200 years after the start of the Younger Dryas [53]. However, there was a response from members of the Clovis impact team (including Kloosterman), saying that the statement about dating was "indefensible". The calibrated radiocarbon date of the Usselo layer at Aalsterhut was entirely consistent with that of the Clovis layer at Murray Springs, and with the date of the start of the Younger Dryas according to the GISP2 ice-core [54].

Before the discovery of the cubic nanodiamonds at Lommel, there had been an unfortunate development when highly-personal attacks were made on members of the Clovis impact team in an on-line article written in May 2011 by Rex Dalton, who had formerly been on the staff of *Nature*. The first target was the eminent James Kennett, described by Dalton as "a virtual father of marine geology", his crime being his refusal to accept the conclusions of the recently-published "Requiem" paper of Pinter and colleagues referred to above. Dalton wrote:

"We are under a lot of duress," said Kennett. "It has been quite painful." So much so that team members call their critics' work "biased," "nonsense" and "screwed up". Such intransigence has been seen before in other cases of grand scientific claims. Sometimes those theories were based on data irregularities. Other times the proponents succumbed to self-delusion. But typically, advocates become so invested in their ideas they can't possibly acknowledge error. A new look at the comet claim suggests all these phenomena may be in play, apparently creating a peculiar bond of desperation as the theory came under increasing attack. Indeed, the team's established scientists are so wedded to the theory they have opted to ignore the fact that their colleague "Allen West" isn't exactly who he says he is [55].

Dalton had begun by describing West as an "unknown academic from the mining industry". Now he went on to say, "West is Allen Whitt – who in 2002, was fined by California and convicted for masquerading as a state-licensed geologist when he charged small-town officials fat fees for water studies". Kennett was apparently unaware of West's history until Dalton "confronted" him with it in 2010, but he then continued to work and publish with West, which Dalton saw as evidence of Kennett's unreasonable obstinacy. Pinter, in contrast to Kennett, had said, "This is so far beyond the pale – outside our normal experiences in conducting science – you can't ignore it" and, when asked if he would work with West, replied, "I would run screaming away". Dalton suggested that Kennett's university should carry out an investigation, with a view to cutting off his research funding. As for the past, he wrote, "West's history – and new concerns about study results he was integrally involved in – raise intriguing questions about the veracity of the comet claim". He pointed out

that West had been "at the nexus of almost all of the evidence for the original comet claim", as described in the 2006 book [56].

Of course, evidence which seemed to point to much the same conclusion had since been found by other members of the Clovis impact team. In any case, an investigation by George Howard revealed a somewhat different picture about the history of Whitt/West to that given by Dalton. Howard reported:

Allen West was employed 13 years ago as a consultant for a company in California that contracted with several cities for water studies. Geophysicists can work without a license in California under some conditions. He thought they were following the law, but in this case, he needed a license. That inadvertent mistake led to a misdemeanor and a $4500 fine. The District Attorney acknowledged that there was no attempt to defraud and allowed the misdemeanor to be reduced to a simple infraction that was subsequently removed from his record. Allen West's record in the State of California is completely clean, and he has no "criminal record", contrary to the claim of Rex Dalton in his article. Dalton disparaged the quality of the work in question despite the fact that he is aware that West's California geophysical work continues to be referred to positively in 10 reports by four Federal and State governmental agencies, the US Geological Survey, the US Bureau of Reclamation, the California Department of Water Resources, and the California Energy Commission. In 2005, seven years after Allen completed that work, he retired and contracted to write *The Cycle of Cosmic Catastrophes.* Preferring privacy, he chose the pseudonym "West" instead of his given name of "Whitt", and filed that name with the State of Arizona as a legal tradename under the designation "author". He continued to use the new name in his scientific career and changed his name legally, meaning it is not an "alias" as erroneously reported by Dalton. People often change their name for various reasons, as for example Isaac Asimov, who changed his name from Ozimov – nobody accused Asimov of deception [57].

Moving away from *ad hominem* attacks back to considerations of scientific evidence, it must be acknowledged that some valid points were made in the "Requiem" paper, and in separate articles by the various authors of that paper, alone or with others such as Mark Boslough, Vance Holliday and Todd Surovell. Boslough, a physicist from the Sandia National Laboratories, with expertise in computer simulations, may have indicated his personal preferences when, if accurately quoted by Dalton, he said the Clovis impact hypothesis was "an impossible scenario", but he was undoubtedly correct in pointing out that nobody had yet provided a plausible, detailed model as to how the arrival of an extraterrestrial object of sufficient size to cause wildfires and extinctions over such a large area could have failed to produce a crater at the Earth's surface. Similarly, although Holliday, a geoscientist from the University of Arizona, had referred to the comet theory as "an outrageous hypothesis", his failure to agree a common interpretation of investigations of a Clovis site at Lubbock Lake with James Kennett could not necessarily be dismissed as being the result of prejudice, since Kennett had been pre-disposed to a different outcome, and the evidence was inconclusive. Holliday's investigations of Paleoindian cultures showed no indication of a population decline around 12,900 BP, and Surovell, an anthropologist from the University of Wyoming, was unable to confirm the presence of a claimed increase in magnetic spherules, an indicator of an extraterrestrial event, at seven Clovis sites. More generally, how did the Clovis impact theory explain the fact that megafaunal extinctions had occurred at different times in different places during the Late Pleistocene and why did the bison and brown bear survive the transition into the Younger Dryas in North America when many other species of megafauna became extinct? [58]

Clearly, there are many unanswered questions about details and mechanisms. However, let us concentrate on the key points relating to this article. Do the black Allerød layers east and west of the Atlantic indicate the occurrence of a common event, and is there convincing evidence to link this to a catastrophe of extraterrestrial origin?

In March 2012, members of the Clovis impact team headed by Isabel Israde-Alcántara reported the finding of various impact-related markers, including hexagonal nanodiamonds, in a black, carbon-rich layer dating to 12,900 BP in a core from Lake Cuitzeo in central Mexico, consistent with the YDB impact hypothesis. In response, a group led by Jacquelyn Gill of the Geography Department, University of Wisconsin, argued that the palaeoecological changes at the site were more likely to have resulted from regional climate changes than an extraterrestrial impact, but they said nothing to explain the presence of nanodiamonds [59].

Later in the same year, Bunch and other members of the Clovis impact team described the finding of very high-temperature impact melt products at 18 dated YDB sites in North America, Europe and Syria, spanning almost one-third of the planet. Similar findings had been reported in the northern regions of South America, but these had not been investigated by the Clovis impact team. The melt products at the 18 sites were found to be geochemically and morphologically comparable with ones from Meteor Crater, Arizona, and from the 1945 nuclear airburst in Socorro, New Mexico. The authors concluded, "These results are inconsistent with anthropogenic, volcanic, authigenic [i.e. generated *in situ*], and cosmic materials, yet consistent with cosmic ejecta, supporting the hypothesis of extraterrestrial airbursts/impacts 12,900 years ago". Results of further investigations on YDB material from the same sites were reported in the following year by Wittke and other team members, including Kloosterman. They acknowledged there had been

disputes about the identification of microspherules at the YDB and continued, “To further address this dispute and better identify YDB spherules, we present results from one of the largest spherule investigations ever undertaken regarding spherule geochemistry, morphologies, origins, and processes of formation. We investigated 18 sites across North America, Europe, and the Middle East, performing nearly 700 analyses on spherules using energy dispersive X-ray spectroscopy for geochemical analyses and scanning electron microscopy for surface microstructural characterization”. They concluded that, at 12,800 BP, “an estimated 10 million tonnes of spherules were distributed across ~50 million square kilometers, similar to well-known impact strewn fields and consistent with a major cosmic impact event” [60].

That paper was quickly followed by another from a separate group which produced evidence in support of a YDB impact event, but introduced complications. A team of planetary scientists from Harvard, headed by Michail Petaev found a large platinum anomaly at the YDB in the GISP2 ice-core which was not accompanied by a prominent iridium anomaly. The platinum/iridium ratio ruled out an Earth’s mantle or a chondritic source for the platinum. Ratios of platinum to other metals and groups indicated an extraterrestrial source for the platinum, and the authors concluded, “Such a source could have been a highly differentiated object like an Ir-poor iron meteorite that is unlikely to result in an airburst or trigger wide wildfires proposed by the YDB impact hypothesis” [61].

Meanwhile, Holliday continued to argue against catastrophist scenarios and, in May 2014, in partnership with David Meltzer and others, he mounted an attack on the Younger Dryas Impact Hypothesis (YDIH), concluding, “The YDIH fails the critical chronological test of an isochronous event at the YD onset, which, coupled with the many published concerns about the extraterrestrial origin of the purported impact markers, renders the YDIH unsupported. There is no reason or compelling evidence to accept the claim that a cosmic impact occurred around 12,800 years ago and caused the Younger Dryas” [62]. That was soon followed by a review article in the *Journal of Quaternary Science* in which Holliday, Surovell, Meltzer and colleagues wrote:

Geomorphic, stratigraphic and fire records show no evidence of any sort of catastrophic changes in the environment at or immediately following the YDB. Late Pleistocene extinctions varied in time and across space. Archaeological data provide no indication of population decline, demographic collapse or major adaptive shifts at or just after around 12,900 BP. The data and the hypotheses generated by YDIH proponents are contradictory, inconsistent and incoherent. [63]

The members of the Clovis impact group continued to take a very different view and published the results of a large-scale study in the *Journal of Geology* in September 2014. Their paper was 31 pages in length, with a further 33 pages of technical appendices. The 26 authors, headed by Charles Kinzie of DePaul University, Chicago, investigated 22 dated stratigraphic sections at sites in the northern hemisphere where nanodiamonds (NDs) had been found at the YDB. One of these was in Greenland (Kangerlussuaq), one in the Isle of Wight (Watcombe Bottom), two in Belgium (Lommel and Ommen), one in Germany (Lingen), one in Spain (Santa Maira), one in Syria (Abu Hureyra) and the remainder in Mexico, USA and Canada. They noted that independent researchers had similarly found NDs at four of these sites and at two others, including Aalsterhut in Holland. Concentrating on the key issues - the synchronicity of the black layers and the geochemical evidence for an extraterrestrial impact at this time - they concluded:

Analysis of YDB dates indicates that 18 of 24 sites, including the Aalsterhut and Arlington Canyon sites, are statistically part of the same population, with ages falling within the proposed YDB age range of 12,800 ± 150 (12,950-12,650) cal BP. These ages also correspond to the onset of YD climate change in the GISP2 ice core within an age range of 12,892 ± 260 (13,152-12,632) b2k, consistent with the hypothesis that the cosmic impact triggered the cooling event.

Some researchers have proposed that YDB NDs originated from wildfires, volcanism, the mantle, and/or by unknown processes that are coincidentally coeval, but those hypotheses can be rejected because each fails to account for the entire assemblage of proxies. Numerous accepted impact events display the same evidence as found at the YDB, and the YDB and the K-Pg impact layers contain the only known multicontinental, coeval abundance peaks in the entire assemblage of proxies within the past 65 m.yr. Of all the proposed hypotheses, a cosmic-impact event at the onset of the YD cooling episode is the only hypothesis capable of explaining the simultaneous deposition of peak abundances in NDs, magnetic and glassy spherules, melt-glass, platinum, and/or other proxies across at least four continents (≈50 million km^2). The evidence strongly supports a major cosmic-impact event at 12,800 ± 150 cal BP [64].

The arguments will undoubtedly continue and, as happened during the K-T (K-Pg) boundary debates, many will be reluctant to accept the possibility of an extraterrestrial scenario unless the crater produced by the proposed impact can be identified, regardless of other findings. Nevertheless, on the basis of the evidence presented in the *Journal of Geology* paper, the YDB impact hypothesis clearly remains a viable one. One of the authors of this major paper was Kloosterman, then aged 83, 38 years after he had first raised the question of a possible global conflagration during the Allerød interstadial.

References

1. S. J. Gould, *Time's Arrow, Time's Cycle,* Penguin, London, 1988, pp. 99-179; T. Palmer, 'Uniformitarianism, Catastrophism and Evolution', *C&C Review* 1996:1, pp. 4-13; T. Palmer, *Perilous Planet Earth*, Cambridge University Press, 2003, pp. 42-59.
2. J. B. Kloosterman, 'Catastrophist Geology', *Catastrophist Geology* 1:1, July 1976.
3. *Ibid.*
4. L. W. Alvarez, W. Alvarez *et al,* 'Extraterrestrial Cause for the Cretaceous-Tertiary Extinctions', *Science* 208, 1980, pp. 1095-1108; T. Palmer, 'Catastrophism and Evolution', *SIS Review* VII, 1985, pp. 9-20.
5. P. Schulte, L. Alegret *et al*, 'The Chicxulub Asteroid Impact and Mass Extinctions at the Cretaceous-Paleogene Boundary', *Science* 327, 2010, pp. 1214-1218; P. Vellekoop, A. Sluijs *et al,* 'Rapid Short-Term Cooling Following the Chicxulub Impact at the Cretaceous-Paleogene Boundary', *Proceedings of the National Academy of Sciences, USA, (PNAS)* 111, 2014, pp. 7537-7541; T. Palmer, *Perilous Planet Earth, op. cit.* [1], pp. 215-243.
6. D. V. Ager, *The Nature of the Stratigraphical Record,* Halsted Press, New York, 1973, p. 40.
7. S. Mithen, *After the Ice,* Phoenix, London, 2004, pp. 12-15.
8. J. B. Kloosterman, 'Apophoreta-2', *Catastrophist Geology* 1:2, December 1976.
9. 'An Allerød Conflagration? (Discussion)', *Catastrophist Geology* 2.1, June 1977.
10. *Ibid.*
11. *Ibid.*
12. *Ibid.*
13. D. Ager, *The New Catastrophism,* Cambridge University Press, 1993.
14. J. B. Kloosterman, 'The Usselo Horizon, a Worldwide Charcoal-Rich Layer of Alleröd Age', *Catastrophist Manifesto,* www.catastrophist.org/home/usselo-2002/.
15. W. S. Wolbach, R. S. Lewis *et al,* 'Cretaceous Extinction – Evidence for Wildfires and Search for Meteoritic Material', *Science* 230, 1985, pp. 167-170; W. S. Wolbach, I. Gilmore *et al,* 'Global Fire at the Cretaceous-Tertiary Boundary', *Nature* 334, 1988, pp. 665-669; T. Palmer, 'Tektites, Wildfires and the Extinction of the Dinosaurs', *C&C Workshop* 1987:1, pp. 3-4.
16. J. B. Kloosterman, 'The Usselo Horizon, a Worldwide Charcoal-Rich Layer of Alleröd Age', *op. cit.* [14].
17. *Ibid.*
18. R. Firestone, A. West and S. Warwick-Smith, *The Cycle of Cosmic Catastrophes,* Bear, Rochester, Vermont, 2006.
19. R. Firestone, A. West and S. Warwick-Smith, *op. cit.* [18], pp. 6-148.
20. R. Firestone. A. West and S. Warwick-Smith, *op. cit.* [18], pp. 339-351 (quotation on p. 341).
21. R. Firestone, A. West and S. Warwick-Smith, *op. cit.* 18], p. 352.
22. J. B. Kloosterman, 'The Usselo Horizon, a Worldwide Charcoal-Rich Layer of Alleröd Age', *op. cit.* [14], postscript 2007.
23. R. Firestone, A. West *et al,* 'Evidence for an Extraterrestrial Impact 12,900 Years Ago that Contributed to the Megafaunal Extinctions and the Younger Dryas Cooling', *PNAS* 104, 2007, pp. 16016-16021.
24. R. Firestone, A. West *et al,* 'Evidence for an Extraterrestrial Impact 12,900 Years Ago that Contributed to the Megafaunal Extinctions and the Younger Dryas Cooling', *Transactions of the 2007 AGU Joint Assembly*, Abstract PP43A-01.
25. American Geophysical Union, www.agu.org/meeting/sm07-sessions/sm07_PP43A.html.
26. S. J. Fiedel, 'Did a Bolide Impact Trigger the Younger Dryas and Wipe Out American Megafauna? A Skeptic's Reaction to an Intriguing Hypothesis', *Transactions of the 2007 AGU Joint Assembly,* Abstract PP43A-04.
27. W. S. Wolbach, A. Stich *et al*, 'Is There Evidence for Impact-Triggered Fires at the End Pleistocene?', *Transactions of the 2007 AGU Joint Assembly,* Abstract PP43A-02.
28. J. B. Kloosterman, 'Correlation of the Late Pleistocene Usselo Horizon (Europe) and the Clovis Layer (North America)', *Transactions of the 2007 AGU Joint Assembly,* Abstract PP43A-02.
29. J. B. Kloosterman, 'Catastrophist Manifesto', *Cosmic Tusk,* cosmictusk.com/catastrophistjohan-bert-kloosterman/; *Catastrophist Manifesto,* www.catastrophist.org/home/catastrophist-manifesto-2007/.
30. E. Mayr, *The Growth of Biological Thought,* Harvard University Press, 1982, pp. 103-105; P. Bowler, *Evolution – The History of an Idea,* University of California Press, revised edition, 1989, pp. 52-57; T. Palmer, *Perilous Planet Earth, op. cit.* [1], pp. 36-37.
31. J. B. Kloosterman, 'Catastrophist Manifesto', *op. cit.* [29].
32. *Ibid.*
33. P. Bowler, *op. cit.*, pp. 116-117; T. Palmer, *Perilous Planet Earth, op. cit.* [1], pp. 29-32; A. Hallam, *Great Geological Controversies,* Oxford University Press, 2nd edition, 1989, pp. 37-39.
34. T. Palmer, 'Catastrophism and the History of Life on Earth', *C&C Review* 2005, pp. 7-18; T. Palmer, *Perilous Planet Earth, op. cit.* [1], pp. 244-251; S. J. Gould, *The Structure of Evolutionary Theory,* Harvard University Press, 2002, pp. 1296-1320.
35. J. B. Kloosterman, 'Catastrophist Manifesto', *op. cit.* [29].
36. V. Clube and B. Napier, *The Cosmic Winter,* Basil Blackwell, Oxford, 1990; T. Palmer, 'Catastrophism and the History of Life on Earth', *op. cit.* [34], pp. 10, 13.

37. W. M. Napier, 'Palaeolithic Extinctions and the Taurid Complex, *Monthly Notices of the Royal Astronomical Society,* 405:3, 2010, pp. 1901-1906.
38. J. B. Kloosterman, 'Catastrophist Manifesto', *op. cit.* [29].
39. *Ibid.*
40. *Ibid.*
41. B. Buchanan, M. Collard *et al,* 'Paleoindian demography and the extraterrestrial impact hypothesis', *PNAS* 105, 2008, pp. 11651-11654; J. R. Marlon, P. J. Bartlein *et al*, 'Wildfire Responses to Abrupt Climate Change in North America', *PNAS* 106, 2009, pp. 2519-2524; N. Pinter and S. E. Ishman, 'Impacts, Mega-Tsunamis, and Other Extraordinary Claims', *GSA Today* 18:1, 2008, pp. 37-38; F. S. Paquay, S. Goderis *et al,* 'Absence of Geochemical Evidence for an Impact Event at the Bølling-Allerød/Younger Dryas Transition', *PNAS* 106, 2009, pp. 21505-21510.
42. D. J. Kennett, J. P. Kennett *et al,* 'Nanodiamonds in the Younger Dryas Boundary Sediment Layer', *Science* 323, 2009, p. 94.
43. D. J. Kennett, J. P. Kennett *et al,* 'Shock-Synthesized Hexagonal Diamonds in Younger Dryas Boundary Sediments', *PNAS* 106, 2009, pp. 12623-12628.
44. J. G. Evans, 'Late-Glacial and Post-Glacial Subaerial Deposits at Pitstone, Buckinghamshire', *Proceedings of the Geological Association* 77:3, 1966, pp. 347-365.
45. H. Tian, D. Schryvers and P. Claeys, 'Nanodiamonds Do Not Provide Unique Evidence for a Younger Dryas Impact', *PNAS* 108, 2011, pp. 40-44.
46. T. L. Daulton, N. Pinter and A. C. Scott, 'No Evidence of Nanodiamonds in Younger-Dryas Sediments to Support an Impact Event', *PNAS* 107, 2010, pp. 16043-16047.
47. N. Pinter, A. C. Scott, T. Daulton *et al,* 'The Younger Dryas Impact Hypothesis: A Requiem', *Earth-Science Reviews* 106, 2011, pp. 247-264.
48. R. A. Kerr, 'Mammoth-Killer Impact Rejected', *Science: News,* news.sciencemag.org/2010/08/mammoth-killer-impact-rejected; R. A. Kerr, 'Mammoth-Killer Impact Flunks Out', *Science* 329, 2010, pp. 1140-1141.
49. H. Tian, D. Schryvers and P. Claeys, *op. cit.* [45].
50. J. H. Wittke, J. C. Weaver *et al,* 'Evidence for Deposition of 10 Million Tonnes of Impact Spherules Across Four Continents 12,800 Years Ago', *PNAS* 110, 2013, E2088-E2097.
51. H. Tian, D. Schryvers and P. Claeys, *op. cit.* [45].
52. T. L. Daulton, 'Suspect Cubic Diamond 'Impact' Proxy and a Suspect Lonsdaleite Indentification', *PNAS* 109, 2012, E2242.
53. A. van Hoesel, W. Z. Hoek *et al*, 'Nanodiamonds and Wildfire Evidence in the Usselo Horizon Postdate the Allerød-Younger Dryas Boundary, *PNAS* 109, 2012, pp. 7648-7653.
54. J. H. Wittke, T. E. Bunch, J. P. Kennett *et al,* 'Reply to van Hoesel *et al*: Impact-Related Younger Dryas Boundary Nanodiamonds from the Netherlands', *PNAS* 110, 2013, E3897-E3898.
55. R. Dalton, 'Comet Theory Comes Crashing to Earth', www.miller-mccune.com/science/comet-claim-comes-crashing-to-earth-31180/.
56. *Ibid.*
57. G. Howard, 'Allen West Smeared by Dalton, Former *Nature* Writer', *Cosmic Tusk,* cosmictusk.com/allen-west-defense/.
58. N. Pinter, A. C. Scott, T. Daulton *et al, op. cit.*; R. Dalton, *op. cit.;* M. Hardiman, A. C. Scott *et al,* 'Inconsistent Redefining of the Carbon Spherule "impact" proxy', *PNAS* 109, 2012, E2244; M. Boslough, 'Inconsistent Impact Hypothesis for the Younger Dryas', *PNAS* 109, 2012, E2241; M. Boslough, K. Nichol *et al,* 'Arguments and Evidence Against a Younger Dryas Impact Event', *Geophysical Monograph Series* 198, 2012, pp. 13-26; J. S. Pigati, C. Latorre *et al,* 'Accumulation of Impact Markers in Desert Wetlands and Implications for the Younger Dryas Impact Hypothesis', *PNAS* 109, 2012, pp. 7208-7212; V. T. Holliday and D. J. Meltzer, 'The 12.9-ka ET Impact Hypothesis and North American Paleoindians', *Current Anthropology* 51, 2010, pp. 575-606; M. Blaauw, V. T. Holliday *et al*, 'Age Models and the Younger Dryas Impact Hypothesis', *PNAS* 109, 2012, E2240; T. A. Surovell, V. T. Holliday *et al,* 'An Independent Evaluation of the Younger Dryas Extraterrestrial Impact Hypothesis', *PNAS* 106, 2009, pp. 18155-18158; V. T. Holliday, 'A Cosmic Catastrophe: The Great Clovis Comet Debate: A Personal Perspective on an Outrageous Hypothesis', *Argonaut Research Fund, Arizona,* www.argonaut.arizona.edu/Clovis_Comet_Debate.html; G. Haynes, 'The Catastrophic Extinction of North American Mammoths and Mastodonts', *World Archaeology* 33, 2010, pp. 391-416; E. Scott, 'Extinctions, Scenarios and Assumptions', *Quaternary International* 217, 2010, , p. 225; M. A. Carrasco, A. D. Barnovsky *et al,* 'Quantifying the Extent of North American Mammal Extinction Relative to the Pre-Anthropogenetic Baseline', *PLoS ONE* 4:12, 2009, e8331.
59. I. Israde-Alcántara, J. L. Bischoff *et al,* 'Evidence from Central Mexico Supporting the Younger Dryas Extraterrestrial Impact Hypothesis', *PNAS* 109, 2012, E738-E747; J. L. Gill, J. L. Blois *et al*, 'Paleoecological Changes at Lake Cuitzeo Were Not Consistent With an Extraterrestrial Impact', *PNAS* 109, 2012, E2243.
60. T. E. Bunch, R. E. Hermes *et al,* 'Very High-Temperature Impact Melt Products as Evidence for Cosmic Airbursts and Impacts 12,900 Years Ago' *PNAS* 109, 2012, E1903-E1912; J. H. Wittke, J. C. Weaver *et al, op. cit.* [50].
61. M. I. Petaev, Shichun Huang *et al,* 'Large Pt anomaly in the Greenland Ice Core Points to a Cataclysm at the Onset of Younger Dryas', *PNAS* 110, 2013, pp. 12917-12920; S. Redfern, 'Ice Core Data Supports Ancient Space Impact Idea', *BBC News,* www.bbc.co.uk/news/science-environment-23536567.

62. D. J. Meltzer, V. T. Holliday *et al,* 'Chronological Evidence Fails to Support Claim of an Isochronous Widespread Layer of Cosmic Impact Indicators Dated to 12,800 Years Ago', *PNAS* 111, 2014, E2162-E2171.
63. V. T. Holliday, T. Surovell *et al,* 'The Younger Dryas Impact Hypothesis: A Cosmic Catastrophe', *Journal of Quaternary Science* 29, 2014, pp. 515-530.
64. C. R. Kinzie, S. S. Que Hee *et al,* 'Nanodiamond-Rich Layer Across Three Continents Consistent with Major Cosmic Impact at 12,800 Cal BP', *Journal of Geology* 122:5, 2014, pp. 475-506.