The Cause of the Megafaunal Extinction: Supernova or Galactic Core Outburst?

(Twenty-Two Problems with the Firestone-West Supernova Comet Theory)

Paul A. LaViolette, Ph.D.
The Starburst Foundation

starburstfound@aol.com

October 12, 2007

Many of the ideas presented below are novel. Those wishing to use any such ideas in future publications are kindly requested to cite the author as the source, mentioning either this website posting (starburstfound.org/YDextinct/p1.html) or his respective publication whichever is most appropriate.

---

1. Geochemical Evidence Indicating an ET Cause to the Megafaunal Extinction.

The Cosmochemical Evidence of the YDB Group. At the May 2007 American Geophysical Union meeting in Acapulco, a group of researchers, the so-called "Younger Dryas Boundary (YDB) group," reported interesting findings pointing *overwhelmingly* to an extraterrestrial cause for the extinction of the Pleistocene megafauna. Particularly significant was the report of high concentrations of iridium (Ir) and other extraterrestrial material indicators at the Allerod/Younger Dryas boundary marking the terminal horizon in the extinction of the Pleistocene megafauna which dates around 12,950 calendar years before year 2000 (b2k) on the basis of the Cariaco Basin gray scale climate profile chronology. Since iridium is over 10,000 times more abundant in cosmic dust and chondritic meteorites than it is in terrestrial crustal material, it serves as an excellent ET material indicator. Other ET markers included magnetic grains, microspherules, and fullerenes saturated with the rare isotope helium-3. Their findings, many of which are reported in the group's *PNAS* paper (Firestone, et al., 2007), include the following:

- Firestone, et al. (2007a, 2007b) report detecting 3.75 ppb of Ir in sediment samples taken from the Allerod/Younger Dryas (AL/YD) boundary at nine Clovis-age sites, with no Ir being detectable above or below this horizon. Magnetic grain microspherules extracted from this boundary were found to contain up to 51 ppb of Ir at North American sites as well as considerable amounts of the cosmic indicators nickel and cobalt. Grains from a site in Belgium were found to contain 117 ppb Ir, equivalent to 25% of the value typical of chondrites.
- Wolbach, et al. (2007) report that sediments at the base of a 12,900 calendar years B.P. carbon-rich dark layer coincident with the AL/YD boundary and containing significant amounts of soot contained high concentrations of Ir, magnetic grains, microspherules, and fullerenes abundant in ^{3}He.
- Kobres, et al. (2007) report analysis of seven cores penetrated along the long axis of Howard Bay in North Carolina, which is one of the many elliptical depressions known as the "Carolina Bays." They find elevated Ir concentrations, abundant magnetic grains, microspherules, and carbon spherules similar to assemblages found in the YD boundary layer and conclude that these were deposited either immediately before or soon after the bay was formed.

- West, et al. (2007) report detecting some of the highest AL/YD boundary ET markers in sediments from the Gainey Clovis site in Michigan, which included iridium, magnetic grains, microspherules, carbon spherules, soot, and fullerenes with ET helium. At the Topper Clovis site in South Carolina, they also report finding AL/YD boundary ET markers in a 5 cm thick layer lying immediately above the Clovis artifacts. Also they report finding iridium at 51 ppb (10% chondritic concentrations) inside an extinct horse skull at the Wally's Beach Clovis kill site suggestive of rapid burial following the YD event. They also examined several other sites that date to 12.9 kyrs b2k: glacial Lake Hind in Manitoba, Canada, an ice-aged drumlin at Morley in Alberta, Canada, Daisy Cave on the Channel Islands of California, and Lommel in Belgium. They report that the AL/YD boundary layer, which was evident at all of these sites, contained abundant ET markers.
- Darrah, et al. (2007) report that the Blackwater Draw Clovis site in New Mexico contains metallic iron grains while the Topper site in South Carolina also contains iron spherules, Fe-Ni metallic grains, and Fe-Ni oxides. They also analyzed fullerines taken from the AL/YD boundary and found that they contained helium with an extraterrestrial isotopic signature. Carbonaceous residues extracted from AL/YD boundary bulk sediments taken from two of the sites contained elevated concentrations of helium-3 (0.3 to 3.5 ncc/g ^{3}He) with an ET isotopic ^{3}He/^{4}He ratio of 30 to 220, suggesting substantial exposure to galactic cosmic rays. In particular they report that the residue from Daisy Cave, California contains helium with an isotopic ^{3}He/^{4}He ratio of 374 to 800, indicative of a significant galactic cosmic ray input. They conclude that the increase in ^{3}He concentrations (5 to 8 ncc/g) with ET ^{3}He/^{4}He isotopic ratios ranging from 10 to 25 near the AL/YD boundary likely reflects an increase in the flux of interstellar dust particles.

Preliminary evidence of ET indicators in Paleo-Indian artifacts dating to the time of the AL/YD boundary event were also reported in 1998 and 1999 internet postings. For example, in February 1999 William Topping called attention to the presence of 1) spherules/chondrules present on some of the particles embedded in Paleo-Indian artifacts, 2) a "spike" of magnetite/ilmenite particles and spherules in the sediments directly "on" the Paleo-Indian horizon at the Gainey site in Michigan, and 3) elevated chromium and nickel in sediments from the Gainey Paleo-Indian horizon as evidenced through XRF analysis. Also in a June 1998 internet posting Baker, Taylor, and Topping reported the existence of surface pits in cherts on Paleo-Indian artifacts some containing embedded particles, some as large as 100 microns, having spherule-like protrusions suggesting in-flight particle heating. They conclude that the embedded particles are of extraterrestrial origin and had been heated during hypervelocity flight through the atmosphere. Based on shotgun experiments he conducted, Topping estimates that the particles entered these cherts at speeds as high as 0.4 km/s.

The evidence unveiled by the YDB group clearly establishes beyond a doubt that the megafaunal extinction had an extraterrestrial cause. But whether it was entirely due to a comet explosion or impact is questionable. Firestone, West, and Smith (2006) also have done an admirable job in their book of making the case that the Earth was subject to intense bombardment by cometary masses of various sizes at the beginning of the Allerod/Younger Dryas transition. Their discussion of comet explosions taking place over eastern Canada and Michigan, and craters in the Carolinas and elsewhere appears convincing.

However, as the reader may discover below, their suggestion that the megafaunal demise was due exclusively to a comet impact or aerial comet explosion appears to be highly unlikely as does their contention that these comets were debris shot out from a recent supernova explosion. Their theory has captured the imaginations of many scientists and has served as the organizing nucleus for an impressive series of discoveries. But like all theories we must subject them to critical assessment and if necessary abandon them should they prove to be inadequate.

2. Confirmation of a Key Early Prediction of the Superwave Theory

Before beginning this critique of the supernova/comet theory of the mass extinction, I would like to briefly discuss the Galactic superwave theory and its explanation of the mass extinction, a theory that was first advanced in 1983 and which since that time has had at least 14 of its predictions subsequently confirmed by observation; for a summary of these please see http://starburstfound.org/LaViolette/Predict.html. Here we focus specifically on the theory's prediction that high concentrations of extraterrestrial material would be found in geologic strata spanning the megafaunal extinction and its subsequent overwhelming confirmation by the findings of the YDB Group, for which I am particularly thankful.

My 1983 Ph.D. dissertation and subsequent publications had proposed that the megafaunal extinction and abrupt climatic change at the end of the ice age were both precipitated by the arrival of what I term a "Galactic superwave," an intense Galactic cosmic ray electron volley arriving from our Galaxy's core which propelled large amounts of cosmic dust and cometary debris into the solar system and triggered a period of elevated solar flare activity (LaViolette, 1983a, 1983b, 1983c). In the first chapter I made the following predictions:

a) About 11,000–14,000 years ago the Earth should have been exposed to elevated levels of cosmic ray radiation,

b) There should have been an increased rate of deposition of cosmic dust around 11,000–14,000 years BP, and

c) There should have been a greater chance of extinction of animal life at this time.

See posting at http://starburstfound.org/downloads/superwave/Ch-1.pdf

Also in chapter 10 of my dissertation where I discussed the terminal Pleistocene megafaunal extinction and its superwave related cause, I had specifically predicted that this extinction event would coincide with increased concentrations of cosmic dust evidenced by indicators such as iridium and nickel. I stated:

> "Future determinations of C-14, Be-10, and *cosmic dust concentrations* in ice cores spanning this period should confirm this hypothesis."

See posting at http://starburstfound.org/downloads/superwave/Ch-10.pdf

All three of these predictions have since been verified. Subsequent studies by various researchers verified that there was a C-14 anomaly at the AL/YD boundary; for example, see figure 1 from Hughen, et al.(2000). Also polar ice core data that was subsequently published indicates that Be-10 concentration was elevated during the Allerod and Bolling periods when the extinction was taking place. Beryllium-10 deposition rate, charted in figures 2 and 3 below (LaViolette, 1997, 2005c) is a good indicator of the cosmic ray intensity that was falling on the Earth. The third indicator mentioned above, that high cosmic dust concentrations would exist in association with this extinction event, has now also been found. This was announced by the YDB group in May 2007 although they overlooked mentioning that their findings strongly confirm a key prediction of the superwave theory.

In addition, I also made an apriori prediction about Earth being exposed to elevated concentrations of cosmic dust in 1990 in a paper published in the journal *Anthropos*. The paper focused specifically on the subject of superwave induced extinction events and included a discussion of the terminal Pleistocene megafaunal extinction event as well as earlier ice age extinction events. I proposed a cosmic origin for the extinctions and attributed the lethality to a combination of factors: increased UV radiation, cosmic ray radiation from the impact of an intense solar coronal mass ejection (i.e., solar proton event), climatic change (i.e., unusual climatic warmth), and intense glacial meltwater flooding (LaViolette, 1990, p. 241). I then mentioned my 1983 polar ice core analysis study in which I had detected high concentrations of the cosmic dust markers Ir

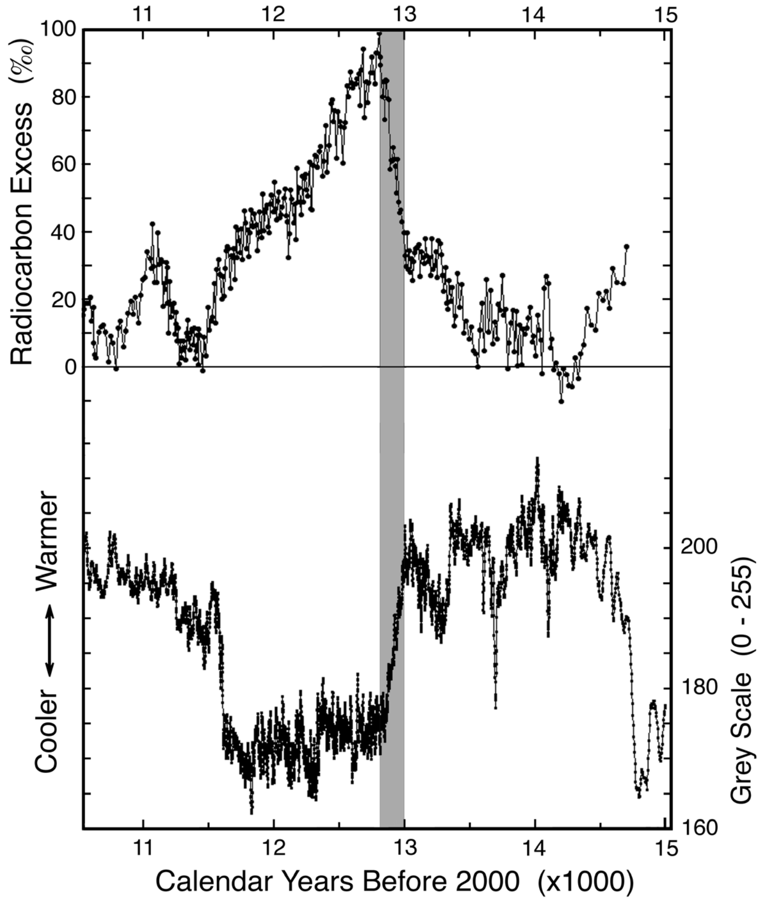


Figure 1. Upper profile: radiocarbon abundance excess relative to trend line as seen in a Carioca Basin sediment core. Lower profile: Corresponding gray scale climatic profile for the Carioca Basin. Higher values indicate warmer temperatures (after Hughen, et al. 2000).

and Ni at several depths in the Camp Century, Greenland ice (having calendar ages of 38.7, 45, 49.5, 50, 50.5, 58.7, and 78.5 thousand years b2k).* Following this I stated the need to look for ET markers in strata associated with the megafaunal extinction:

> "At present (circa 1990) no data is available on solar system cosmic dust concentrations prevailing during the terminal Pleistocene extinction episode. A study to obtain such data is urgently needed to help determine the connection between this extinction and the coincident cosmic ray event." (P. LaViolette, 1990)

Now, 17 years after that date, the iridium, nickel, and cosmic spherule findings announced by the YDB group validate the superwave theory's apriori prediction. Although much of the dust at the AL/YD boundary is likely to have been deposited from cometary body explosions or impacts occurring at that time, a large proportion of this dust is also likely to have entered the Earth's atmosphere as micron and submicron sized dust particles which I proposed were present in space in high concentrations.

---

* These values give the corrected sample ages. Sample ages given in the *Anthropos* paper and in my 1983 dissertation are overly young compared to the dates ascribed to them by more recent ice core chronologies. Greenland and Antarctic ice cores became more accurately dated later as more accurate dating techniques were applied to ice cores that were subsequently drilled.

3. The Galactic Superwave Explanation of the Megafaunal Extinction and Related Effects

The superwave theory does not propose a cometary impact or an aerial explosion of one or more cometary bodies as the sole cause of the conflagration/flood demise of the megafauna. It suggests a scenario that is a bit more complex. It proposes that lethality was due to a number of factors which arose through the following chain of events:

1) First, there was the arrival of an intense volley of Galactic cosmic rays termed a "Galactic superwave" which lasted several thousand years. These cosmic rays became magnetically trapped and concentrated in the heliopause sheath and in the bow shock that formed around the heliopause.

2) This solar system "radiation belt" then vaporized comets and frozen cometary debris present within and immediately around the solar system creating a nebula. Cometary heating in this radiation belt also induced cometary fragmentation and increased the influx of comets into the solar system and hence increasing the chance of terrestrial impacts.

3) Propagating cosmic-ray-driven shock fronts pushed nebular material into the inner solar system substantially increasing the opacity of the zodiacal cloud.

4) This increased solar system nebular congestion, in turn, increased the influx of debris falling onto the Sun and the amount of radiation back-scattered onto the Sun's surface thereby creating an aggravated solar state similar to that seen in T Tauri stars.

5) Solar flare activity jumped by several orders of magnitude destroying the Earth's ozone layer and increasing the influx of harmful UV rays.

6) The entry of cometary and interstellar dust into the solar system and falling onto the Sun would have caused a climatic warming effect on the Earth by increasing the Sun's bolometric luminosity, shifting the solar spectrum toward the infrared which reduced the Earth's albedo, allowing UV radiation to pass through the atmosphere, and by back-scattering outgoing solar radiation back toward the Earth.

7) Giant solar proton events (SPE) produced by the arrival of coronal mass ejections expelled by these super-sized solar flares would have continually impacted the Earth. One that was hundreds of times more energetic than the most intense SPE experienced in modern times would have been sufficiently strong to overpower the geomagnetic field sheath and make contact with the Earth's surface, thereby creating a ground-level firestorm (LaViolette, 1983a, ch. 4; LaViolette, 1997); see posting at http://starburstfound.org/downloads/superwave/Ch-4.pdf . This would explain the occurrence of the black layer found at the Allerod/Younger Dryas boundary.

8) The increased insolation that prevailed during the deglacial period, globally warming the climate to interglacial temperatures, would have at times rapidly melted the upper surface of the ice sheets. This would have caused high altitude water ponding and dam failures that would have released immense meltwater deluges. These "glacier waves" would have magnified in intensity as they swept toward the ice sheet margin, continuing on at high speed across the continental land mass to bury unsuspecting megafauna. These would have been particularly severe at the time of a ground contacting SPE such as is proposed to have struck the Earth close to the time of the Younger Dryas megafaunal termination boundary.

9) The elevated flux of solar cosmic rays striking the Earth's atmosphere would have generated condensation nuclei which would have formed high altitude clouds. These, in turn, would have increased the atmospheric albedo and lowered ground temperature. Also, large amounts of dust trapped in the Earth's meteoric veil would have reduced the insolation intensity to the

Earth. Either of these effects, or a combination of them, would have caused global temperature to gradually drop, producing the Younger Dryas cold period. In the event of a global conflagration, the soot-filled air would also have had a cooling effect by temporarily reducing the amount of solar radiation reaching the ground. [Evidence that the 200 year cooling trend at the onset of the YD occurred in step with the rise of atmospheric radiocarbon suggests that of these various effects the solar cosmic ray cooling effect was the lead cause.] The influx of cold glacial meltwater and formation of North Atlantic sea ice during this period would have shut down deep water production and helped to maintain cold temperatures during the remainder of the Younger Dryas.

10. Eventual expulsion of the invading cosmic dust from the solar system would have returned the solar system to its present condition allowing the ice sheets to melt and recede.

So the demise of the megafauna would have been due to a number of factors:

- Death or illness due to an excessive dose of ionizing radiation, both UV and cosmic ray, due to elevated solar flare activity and a ground-contacting solar proton event.
- Death due to famine since vegetation would have withered during the cool arid Younger Dryas climate and preceding Intra Alleröd Cold Peak.
- Death due to heat stroke and smoke inhalation from exposure to the firestorm that produced the black mat layer evident today in North America and Europe.
- Death due to drowning in the glacial meltwater deluges that swept across the continent.
- Death due to poisoning by noxious fumes released from the meteoric ice vaporized in the atmosphere.

While the superwave scenario may seem complex to some people, it nonetheless involves a sequentially connected chain of events, one necessarily leading to the next in inevitable fashion. The scenario proposed by Firestone and West is conceptually simpler, but avoids/neglects considering the bigger picture of what was happening in the solar system with interplanetary medium and the Sun, and it ignores events taking place in the much larger Galactic neighborhood including evidence of recurrent cosmic ray outbursts originating from the Galactic center. Also their theory does not take into account events recurring over a much longer time period, as evidenced by cosmic dust peaks or beryllium-10 spikes that recur frequently throughout the last ice age cycle and, more generally speaking, throughout the geologic record. Although Firestone and West to some degree delve into events occurring in the immediate Galactic environment with their proposal of a single nearby supernova occurring around 41,000 year BP which they propose as the source of their proposed comet onslaught, there are substantial problems with that proposal which are discussed below.

4. <u>The Supernova/Comet Theory vs. the Superwave Theory: Similarities, Differences, and Inherent Problems with the Former</u>

The Firestone-West theory and the superwave theory are similar in that both involve the influx of cometary material into the solar system. The principal difference between them is that the superwave theory proposes that this cometary material enters mostly as nebular material (cometary dust and gas) accompanied by larger chunks of frozen cometary debris ranging on up to comet-sized bodies, whereas the Firestone-West theory focuses mainly on the entry of comet bodies of relatively large size (1 - 500 kilometer diameter range).

<u>Chameleon aspect</u>. In their initial 2005 Lawrence Berkeley Laboratory press release they proposed that a 10 kilometer diameter comet either exploded in the atmosphere or struck the North

American ice sheet 12,900 years ago. In their book published in 2006, the size of the incoming comet was increased to 480 kilometers, and it was proposed to have been accompanied by four other comets ranging in size from 105 to 290 kilometers all being proposed to have ground impacts. The following year, however, the team was quoting far smaller comet sizes ranging from 2 to 3 km diameter (Mckie, 2007) to 5 km in diameter (Burns, 2007). Although previous publications by Firestone et al. (2001, 2006) associated the YD comet impact event with a supernova, their paper in the National Academy of Sciences proceedings (Firestone, et al., 2007c) makes no mention of a supernova connection. So there has been a kind of "chameleon" aspect to the progression of their theory.

Extended versus discrete duration. The energetics triggering the YD boundary firestorm in the superwave theory come primarily from the scorching effects of a ground contacting solar proton event, the Sun becoming overly active due to the high concentrations of nebular material invading the solar system. In the Firestone-West theory, on the other hand, the energy would come mainly from the kinetic energy of the impacting comet fragments. The preexisting superwave theory predicts a temporally extended effect transpiring over several thousand years with a climax at the AL/YD boundary, whereas the Firestone-West scenario involves discrete impact events with debris presumably settling to the ground within a few years. To explain meltwater peaks and radiocarbon peaks occurring at earlier climatic boundaries, e.g., around 17,000 and 18,000 years BP, they propose an earlier wave of cometary onslaughts. Thus although comet impacts are inherently a temporally discrete phenomenon, to make their theory account for these earlier geologic events, they propose earlier bombardments associated with the passage of a more leading part of the supernova shell and presumably traveling at a higher speed, around 2500 -3200 km/s. Thus for effects to be spread out over this length of time, their proposed supernova remnant shell is inferred to be about 50 light years thick.

Age differences. Another similarity between the two theories is that in both cases the cometary material is derived from a local supernova explosion. However there are substantial differences. In the superwave theory, cometary bodies in orbit about the Sun are vaporized by the superwave cosmic rays and this vaporized debris subsequently enters the solar system to initiate a long sequence of hazardous events. Most of this cometary material is proposed to have originated from the North Polar Spur (NPS) remnant. This is a very old local supernova remnant whose shell currently immerses our solar system and whose geometrical center lies about 400 ± 200 light years from us in the constellation of Lupus. Estimates place its age at roughly 2 million years. It is expanding very slowly, moving at roughly 3 km/s, and this remnant's material has been gravitationally captured by the Sun due to the Sun's proper motion through its debris field.

In the Firestone-West theory, on the other hand, the cometary material is proposed to come from a supernova that allegedly exploded at a distance of about 200 to 250 light years from us in the direction of the Gemini constellation, the Geminga neutron star being identified as the progenitor star's remnant core (F-W-S, 2006). They, however, propose a much younger age for their supernova, claiming that it occurred just 41,000 years ago, or 28,000 years prior to the YDB extinction event.

Differences in entry speed. A related difference between the theories concerns the speed that each proposes for the entry of the cometary material. The superwave theory proposes that the nebular material (cometary dust and gas) enter at a relatively low velocity, at several kilometers per second for material vaporized from comets already captured in orbits about the Sun and at about 20 km/s for material vaporized from long-period comets newly entering the solar system. The former would enter from the direction of the Galactic center while the latter would approach from a direction close to the solar apex, i.e., a direction opposite to direction of the Sun's motion through the local interstellar environment.

The Firestone-West theory, on the other hand, proposes that the cometary bodies responsible for the YD boundary catastrophe had entered at a very high velocity, thousands of kilometers per second, due to the remnant's outward expansion. For the iron rich grains which they say entered the solar system and impacted the Earth around 34 kyrs b2k, they estimate a speed of about 10,000 km/s; 200 to 250 light years divided by 7,000 years (Lawrence Berkeley press release, 2005). For the comet bearing remnant shell passing around 13 kyrs b2k, they imply a speed of around 2100 to 2700 km/s; 200 to 250 light years divided by 28,000 years.

Problem 1: Supernova direction does not align with the radiant for long-period comets. As we shall see below, there are several reasons why such high speeds are problematic for the Firestone-West theory. But the direction of entry also poses a problem. They propose that this material was entering the solar system from the direction of Geminga, a neutron star that currently lies in the constellation Gemini and which they claim to be the core remnant of their proposed 41 kyr b2k supernova. However, if a barrage of comets had passed through the solar system from that direction, one would expect that some of these would have been gravitationally captured into highly eccentric orbits aligned in that direction. Instead, long-period comets, which comprise most of the comets entering the solar system, have a radiant that deviates by about 50° from the Geminga direction. The Geminid meteor shower does not stand as very good evidence of a past disturbance from this direction since this shower, which originates from the Kuiper belt, makes up a tiny fraction of the cometary debris that presently enters the solar system. Moreover its proximity to this direction may be regarded as mainly a chance association.

Problem 2: Insufficient material to form a cometary barrage. Another problem with the Firestone-West model is that the supernova shell would provide an insufficient amount of material to form a cometary barrage. Let us say that the supernova progenitor was a 10 solar mass star and that given enough time that 70% of its mass would be able to condense into cometary masses. This amounts to a dispersal of about 10^{34} grams of comet forming material. Spread this out over a 250 light-year diameter shell, and you come up with only 20 nanograms per square centimeter! Figuring how much material would intersect an area the size of the Earth's orbit around the Sun and you calculate an amount sufficient to condense into a two kilometer diameter comet.

But, Firestone, West, and Warwick-Smith (2006) imply that this shell of supernova cometary debris was passing through our solar system for approximately 6000 years since, as mentioned above, they attempt to explain geologic anomalies as recent as 12,950 years b2k and as early as 18,000 to 19,000 years b2k. So to get some reasonable coverage for these earlier events we should spread this mass out over this period of time. As a result, we find that there is a chance that a one kilometer diameter comet might have intersected the Earth's orbit every 500 years. Factor into that the probability that the Earth might have a single direct hit and you are down to one chance in a hundred million per millennium. Certainly, these probabilities are far too low to explain a single event, let alone a whole series of events. They certainly would not appreciably raise the probability of Earth being hit by a comet over probabilities that already exists from comets currently entering our solar system. So it seems that their theory that Earth was struck by a barrage of comets originating from a passing supernova shell does not have much merit.

They might try to modify their theory by saying that the solar system must have been struck by a clump of supernova debris, e.g., a 100 million-to-1 enhancement over the amounts estimated above on the basis of the uniform distribution assumption. However, this would drastically reduce the likelihood that a supernova explosion this close to the solar system would have affected us. Supernovae within 300 light years of the Sun are estimated to occur about once every million years.

The chance that such a supernova would occur and have a clump cross our solar system now drops to once every hundred billion years, or essentially not likely in the Earth's 4.5 billion year history.

Claiming that the supernova remnant swept up dust and gas present in the interstellar medium and thereby added to its total mass would not help much either since there isn't much gas to sweep up. The Sun resides within a very low density 300 light year radius cavity called the "Local Bubble" which contains a gas density of only 10^{-3} particles per cm^3, or about 10^{-27} g/cm^3. Over a 250 light year distance this would present a column density of about 200 nanograms per square centimeter. So if the supernova shell were to sweep up 100% of this material and accelerate it to its speed of 10^3 - 10^4 km/s, it would only increase the remnant's total column density by 10 fold. The downside is that a ten fold increase in remnant mass would decelerate the remnant to a speed ten fold lower. As a result, it would take some 200,000 years to reach the solar system and hence should still be somewhere out in space coming towards us. The idea of killing off the Pleistocene megafauna would certainly be out of the question.

Comparing cometary injection mechanisms. Comparing the supernova-comet theory to the superwave theory, we see that each propose differing modes of comet injection into the solar system. According to the Firestone-West scenario, the condensed cometary bodies and nebular material making up the remnant purported to enter the solar system received their energetic forward thrust 41,000 years ago from a supernova explosion and are in a coasting mode when they arrive. In their book, they propose a different comet injection mechanism 41,000 year ago when the gamma ray flash arrived. This one turns out to be very similar to the superwave comet injection mechanism that I had originated in 1983 and which was summarized in section 3 above (point number 2).

In the superwave version, the superwave galactic cosmic rays would become trapped in the heliopause magnetic sheath as well as in its surrounding shock front region and would have built up to a sufficiently high energy density to have vaporized material from the surfaces of comets already in orbit about the Sun and those continually entering the solar system from the 2 million year old North Polar Spur supernova remnant. This vaporization process was theorized to fragment cometary bodies and nudge some of them into orbits that would cause them to pass into the inner solar system (LaViolette, 1983a, ch. 3); See posting at: http://starburstfound.org/downloads/superwave/Ch-3-a.pdf. The influx of smaller-sized Tunguska-like cometary bodies would be far more common than comets several kilometers in diameter.

Firestone, West, and Warwick-Smith (2006) propose a similar mechanism, except they replace the superwave cosmic rays with gamma radiation from their supernova explosion. They suggest that the arriving gamma radiation pulse vaporized material from comets orbiting the Sun and that the resulting gas jets would have nudged some of these comets into the inner solar system, increasing the risk of Earth impacts for a few thousand years. Since such comets would have entered at relatively low speeds, their 41 kyr b2k scenario avoids the problems inherent with the hypervelocity comet scenario discussed below. In my opinion they would be closer to the truth if they dispensed with the idea of hypervelocity supernova fragments and orbiting comets being vaporized by a supernova gamma ray flash and instead substituted superwave cosmic rays as the vaporizing agent.

Problem 3: Unreasonably high comet kinetic energy. The contention that cometary material made a high-speed entry into the solar system 34,000 and 13,000 years ago creates serious problems for the supernova theory. A velocity of 2100 to 2700 km/s is about 100 times higher than the velocity estimated for the asteroid that caused the extinction of the dinosaurs. Since kinetic energy scales as v^2, this implies that each gram of matter in the Firestone-West comet carried 10,000 times as much kinetic energy as a gram of matter in the asteroid that impacted at the C/T boundary. As noted above, it would have been extremely unlikely that a comet even one kilometer in diameter would have collided with the Earth. But suppose that their comet had a diameter of 4 kilometers as Firestone and West have recently proposed. At this high speed the comet would have had 8 times the impact energy of the C/T boundary asteroid (given that the C/T asteroid had a diameter of 20 to 40 km and a density of 3 g/cc). This would have been the equivalent of 400,000 megatons of TNT.

But, in their book they propose even larger comet impacts, several bodies being in the giant comet range with diameters ranging from 105 to 480 kilometers. Again disregarding the fact that such sizes would have been even less likely to have been supplied by an expanding supernova remnant, the impact energies now become outrageously large, each impact carrying between 10^5 and 10^7 the impact energy of the asteroid that caused the dinosaur extinction, or 10^{10} to 10^{12} megatons of TNT. At these levels we are more in the realm of complete sterilization of the Earth's surface. If the energy of just one of the larger of these proposed impacts were spread evenly over the Earth's surface, it would dump about 5×10^{27} joules into the Earth's atmosphere, or 100 calories into each cubic centimeter, raising the temperature of the Earth's atmosphere over 300,000 degrees Celsius and instantly turning it into a plasma. It would be a wonder that we would have any atmosphere at all left after that kind of impact. It is understandable then why Firestone and West have been quoting more modest comet sizes in their more recent press interviews.

<u>Problem 4: Not enough time for a comet to explode</u>. The notion that the comet exploded in the atmosphere before it struck the Earth also encounters difficulty. If we assume that the comet entered at an angle of 25 degrees relative to the Earth's surface, its path length through the troposphere should have measured about 26 kilometers. If its entry speed was a few thousand km/s, this implies that it would have passed through the Earth's atmosphere to impact the ground in about 10 milliseconds! Surely this time is far too short for a comet to explode and aerially disperse its contents prior to reaching the Earth's surface. Also the shock wave created in the atmosphere by a comet impacting at almost one percent of the speed of light would have had to be enormous, again raising serious doubts.

<u>Problem 5: The hypervelocity vaporization problem</u>. There is also the question as to how volatile metals and carbonaceous materials containing helium could have survived such a high impact energy without being entirely vaporized. It is likely for this reason that Darrah, et al. (2007) attribute the increased He-3 in the carbonaceous residues found in the boundary layer bulk sediment to an increase in the influx of interplanetary dust particles, i.e., material already existing in particle form in space and settling through the atmosphere at a more leisurely rate. As such, their interpretation more strongly supports the superwave cosmic dust theory than the Firestone-West comet explosion theory.

The relativistic entry velocity issue becomes even more problematic in the case of the 34,000 year old mammoth tusk event. In 2005, Firestone and West proposed that iron rich grains had passed through the Earth's atmosphere at 10,000 km/s (3 percent of the speed of light) to create pits in the surface of 34,000 year old mammoth tusks. It is highly improbable that grains traveling at such a high velocity would have survived entry and reached ground level without totally vaporizing. Dust particles and meteoritic grains currently observed to travel at tens of kilometers per second usually burn up before reaching the ground leaving a trail of meteoric smoke. Only particles with low entrance velocities are able to make the journey to the ground intact. Indeed, this unusual claim of 10,000 km/s speeds has sparked serious criticism in internet astronomy discussion groups. Although blog comments do not carry the same weight as refereed publications, nevertheless, the correspondents bring up points very worthy of consideration. Regarding hypervelocity micrometeorites, one correspondent writes:

> "If a particle enters the atmosphere at a [given] speed, pressure will build up at the front of this particle. The higher the speed, the higher the pressure. The higher the pressure, the

> higher is the temperature caused by the pressure, and the greater is the force working against that moving particle, and thus it is braking down the particle. If the pressure is too high, the resulting force can be too much for the structure of the particle to stand it, and then the particle breaks up... No particle which travels at a speed of 10000 km/s into the atmosphere will be able to reach the ground intact, and still be at this speed!

Günther: http://www.bautforum.com/archive/index.php/t-1180.html%3C/t-33032.html

Another blog correspondent wonders whether the claim for 10,000 km/s arose because a reporter writing this story had misinterpreted the scientists' statements. He then exclaims: "Grains" of iron simply cannot strike the surface of the Earth at high speed. It cannot happen."

http://www.unexplained-mysteries.com/forum/index.php?showtopic=52036

Sadly, news reporters faithfully quoted this 10,000 km/s speed from the Lawrence Berkeley Laboratory press release issued on September 23, 2005 (http://www.lbl.gov/Science-Articles/Archive/NSD-mammoth-extinction.html). It is a pity that science news reporters do not more critically evaluate the veracity of ideas issued in press releases. Just because the press release comes from a "reputable" government institution does not necessarily mean that it is error free.

So why would Firestone and West propose such a high speed for the supernova ejecta? Well, they need the speed to be this high so that their supernova blast wave theory is able to account for radiocarbon peaks dated at 41,000 and 34,000 years BP, as observed in Icelandic marine sediments. They proposed that the supernova occurred about 41,000 years ago and that its gamma ray flash arrived within a few hundred years to create the first C-14 peak at 41,000 years b2k peak. They then suggest that the supernova's condensed ejecta arrived 7000 years later to impact the mammoth tusks around 34 kyrs b2k and that this was accompanied by trapped cosmic rays which produced a second radiocarbon peak. Divide 250 light years (which is what they proposed for the distance to the supernova explosion center) by 7000 years of flight time and you get 10,700 km/s. Thus their contention of a relativistic iron grain volley arriving at 3% c was intended primarily as a "fit" to this Icelandic data, the 41,000 years b2k peak being attributed to gamma rays and cosmic rays from the initial supernova explosion and the 34,000 years b2k peak being attributed to the arrival of the supernova's relativistic ejecta. They then proposed the occurrence of an additional cometary impact event in order to offer an explanation for the 12,900 years y2k megafaunal extinction event. However, not only does this supernova model seem to be a forced fit to the geological record, it also appears to be quite implausible.

This third radiocarbon increase at 13 kyrs b2k, they speculate, may have been produced by hypervelocity comets and debris from the supernova striking the Earth and injecting radiocarbon into the Earth's atmosphere. Their explanation here is a bit suspect since meteoric or cometary material would not contain radiocarbon in sufficient quantities to have an appreciable effect on the atmospheric radiocarbon levels. Furthermore as we shall see, there are more than just three radiocarbon increases that need explaining as well as numerous beryllium-10 peaks.

<u>Problem 6: Hot supernova gases can't condense into iron particles in just 7000 years</u>. I also agree with the blog correspondent named Günther who questions whether supernovae can produce iron-rich particles within the 7000 years time that it would take for these particles to reach the solar system after crossing a distance of 250 light years at 10,000 km/s. He notes:

> "Investigations performed by radioastronomic and astrophysical research over decades has revealed that if a supernovae explodes, it does this at extremely high temperatures (many millions of kelvin), and that it casts ejectae into space at speeds of up to 40000 km/s. At such a temperature, these ejectae are not solid matter, but are a hot plasma which is at a high pressure. Driven by this pressure the cloud of plasma travels out into space, where it expands and reduces its pressure. As it expands, it collides with the cooler interstellar matter that surrounds location of the supernova.

This collision creates a hot shock front that moves through the interstellar matter, collecting that matter and filling up its former location with the matter from the supernova. According to these scientists, it takes hundreds of thousands of years until the ongoing collision with the interstellar matter has reduced the speed of expansion to a rate equal to that of the average speed of interstellar matter. Then the shock front dies away and cools down, and the matter of the ejectae is able to cool down to some thousand kelvin.

Only that cool, the matter is able to do the transition from its plasma state to form atoms. At that state, the matter ejected from the supernova may fill a sphere with a radius of many light years. That is a huge volume, and the density of the matter within this volume is extremely low.

It takes another hundred of thousands of years until micron-sized dust particles may start to grow in this thin matter, and it takes further millions of years for these particles to create larger particles, which break up again, as they collide with each other in the long course of time. It takes extremely long time to form bodies from an environment which contains only a few atoms per cubic inch. Thus, the estimation of 7000 years for this process, as proposed by the researchers, is far too low. The matter ejected from a supernova explosion requires much more time to cool down and form particles, if it will form any particles at all. I never read a report on or heard of a comet that may have grown in a short time. It very much looks like physics simply do not allow this."

Günther: http://www.bautforum.com/archive/index.php/t-1180.html%3C/t-33032.html

Problem 7: Insufficient supernova buckshot. From the pictures that Firestone, West, and Warwick-Smith show in their book, we learn that these iron grains ranged from half to two millimeters in size and were spaced on the average roughly 5 centimeters from one another. This implies a particle mass flux of approximately 1 to 5 milligrams per square centimeter. They found this pitting in one tusk out of 70. So let us reduce our mass flux estimate by two orders of magnitude. This gives a flux of about 10 micrograms per square centimeter. Clearly, this is far greater than could be supplied from the 41 kyrs b2k supernova. For if one percent of the supernova progenitor star's mass were composed of ferrous metals that later condensed to form this shower of pellets, this amounts to only 0.2 nanograms per cm^2 if uniformly spread over a 250 light year sphere. So, to get the kind of tusk peppering they observed they would have needed one hundred thousand times more matter than it was possible to get out of their supernova explosion. Again, they could assume that Earth had the misfortune of being hit by a high density cluster of this supernova buckshot, but this proportionately reduces the likelihood that this would have happened.

Problem 8: Such high speeds not needed for tusk pitting. A speed of 10,000 km/s is far higher than needed to explain the hypervelocity impact craters found in the mammoth tusks. While experiments showed that the tusks could not be penetrated by pellets fired from a shotgun at 1000 kilometers per hour (i.e., at 0.3 kilometers/second), speeds an order of magnitude greater such as a few kilometers per second, typical of micrometeorite velocities, should have been sufficient. This seems quite reasonable considering that Topping (1999) determined that speeds of just 340 meters per second were sufficient to create pits in cherts. It is apparent that speeds 10,000 fold higher, of the sort proposed by Firestone and West, are entirely uncalled for. They seem to have chosen this 3% c relativistic velocity primarily as a desperate attempt to make their supernova model account for the C-14 peaks present in the Icelandic marine record.

Problem 9: Supernova remnant observations do not support their hypervelocity speed model. The Firestone-West supernova remnant expansion scenario has the problem that 7000 year old supernova remnants are not observed to have such high ejecta speeds (10^4 km/s). Such speeds are over two orders of magnitude too high for remnants of this age. Neither would the ejecta in a 28,000 year old remnant (41,000 years BP minus 13,000 years BP) be expected to have speeds as high as 2100 - 2700 km/s, as required by the Firestone-West theory. Delaney and Rudnick (2003) have simulated the expansion of Cassiopeia A, a 335 year old supernova remnant that is currently 11 light years in diameter and that was formed by a relatively energetic supernova explosion. Its initial expansion rate is projected to have been on the order of 15,000 km/s which at its present age of 335 years has dropped to about 4000 to 9000 km/s. They project that at an age of 1000 years Cas A's expansion rate will have dropped to about 2000 km/s. Projecting this trend into the future one would expect the expansion rate to continue to drop reaching only some tens of kilometers per second by the time it reaches an age of 7000 years. So a similarly low speed would be expected for a 7000 year old remnant in the Sun's vicinity.

If Firestone and West had a good reason to assume a relativistic remnant expansion velocity at the time of terrestrial impact, they should have proposed a much more compact and much younger supernova remnant, say one positioned 60 times closer to Earth (4 light years away), placing it as close as the nearest star Alpha Centauri. Although an explosion this close to Earth would statistically have been a million times less probable, it would be entirely permissible for them to postulate high velocity supernova ejecta coming from a supernova remnant shell as compact and young as this. However, a 10,000 km/s blast would then take only 100 years to reach Earth and if this was followed by their proposed secondary 2700 km/s blast, this second onslaught would arrive only 300 years later. So their hopes of simultaneously accounting for three C-14 anomalies in the geologic record, at 41 kyrs BP, 34 kyrs BP, and 13 kyrs BP would be entirely dashed.

<u>Problem 10: No evidence of the alleged hypervelocity supernova shell</u>. There is also the concern that Firestone and West present no evidence for the current location in the heavens of their alleged supernova remnant shell. If ionized supernova remnant material were traveling outward at thousands of kilometers per second, this redshift signature would have been easily detected and should have been known to astronomers. By now, the forefront of the remnant, if it continued outward at 10,000 km/s should have produced a shell diameter of some 350 light years and its inner surface should be positioned about 80 light years away. But there have been no reports of such. By comparison the North Polar Spur remnant, which the superwave theory assumes as the source of the cometary material currently surrounding the solar system, is a remnant whose existence is very well documented.

Firestone, West, and Warwick-Smith (2006) suggest that the Geminga supernova which they propose for this 41,000 year old event swept out a low density pocket in the interstellar medium and they identify this with the the Local Bubble that surrounds the Sun. As mentioned earlier under Problem 2, sweeping out such a cavity would have substantially decelerated their remnant, raising the problem of delaying the remnant's arrival. It seems more plausible that the Sun itself created this cavity, the bubble being the aftermath of a high velocity solar wind that once blew with extreme ferocity at the close of the last ice age. For as we know from the lunar rock evidence of Zook, et al. (1977), the Sun's flaring activity was extremely high at that time. A highly energetic solar wind, strong enough to clear out a low density region around the Sun would explain why this bubble has its long axis aligned with the Sun's poles. For the solar wind moves outward at its highest velocity at the Sun's poles, being least impeded there by the solar magnetic field.

<u>Problem 11-a: Geminga is too old to be a candidate for a 41 kyrs b2k supernova</u>. Their suggestion that the alleged supernova be identified with Geminga is also problematic. The Geminga neutron star is estimated to lie about 500 (+200, -100) light years from the Sun, which is about twice as far as Firestone, et al. suggest for their supernova scenario. Also their suggestion that Geminga's progenitor star was as close as 200 light years from the Sun when it exploded is also very unlikely. Observations of Geminga's proper motion indicate that it is moving transverse to us at the rate of about 0.4 light years per millennium. Hence if it were to be receding from us at a similar speed, it would have been only 17 light years closer at the time of Firestone's proposed

supernova. Furthermore the supernova that gave birth to the Geminga pulsar is conventionally believed to have occurred 350,000 years ago, almost nine times longer ago than Firestone, et al. need for their scenario.

Problem 11-b: North Polar Spur remnant is too old to be a candidate for a 75 kyrs b2k explosion. Others such as C. P. Sonett have postulated a somewhat older date for a supernova occurring close to the Sun, suggesting that it occurred 75,000 years ago, instead of 41,000 years ago. He chose his date in order to explain the large beryllium-10 peaks evident in the polar ice record at 41 and 60 kyrs b2k (Sonett, 1992). He identifies the source of the supernova with the 2 million year old North Polar Spur remnant, citing a paper by Davelaar, et al. to justify a younger date for the explosion. However, Davelaar and his associates were led to assign the remnant the relatively young age of 75,000 years because of its soft X-ray emission. But, as mentioned in my dissertation, other researchers have interpreted this X-ray emission as being due to recent cosmic ray reheating of a relatively old NPR remnant shell. So the notion that the NPS remnant is that young is a rather difficult position to defend.

The value of a priori reasoning. Like Sonett, Firestone and West were encouraged to propose their supernova theory to explain the presence of Be-10 peaks that were already evident in the polar ice record. By comparison, the superwave theory was proposed before Raisbeck, et al. had published their high resolution Be-10 data showing these peaks. Like the C-14 data, the Be-10 confirmed a prior prediction made in 1983 that evidence of recurrent cosmic ray superwave episodes should be found in Earth's beryllium-10 record. This success should not be attributed just to good luck, but to the fact that a good case had already been made for the superwave theory based on astronomical data available at that time.

Problem 12: The 41 kyrs b2k rise in beryllium-10 concentration does not have a supernova signature. Figures 2 and 3 chart the atmospheric beryllium-10 production rate as normalized to the Holocene average as seen in the Vostok and Byrd Station, Antarctic ice core records, data taken from publications by Raisbeck, et al. and Beer, et al. If the Earth had been exposed 41,000 years ago to a gamma ray flash from a nearby supernova, we would expect to see a sharp beryllium-10 spike at this date, the whole event being registered within several centimeters of ice comparable to the atmospheric residence time for Be-10 ions which is on the order of a few years. Instead, we see that beryllium-10 flux began to climb several thousand years prior to this date reaching a peak around 40 to 41 kyrs b2k with the entire event spanning 6,000 to 7,000 years. Certainly, this does not match the signature of a gamma ray flash. But a superwave cosmic ray volley could last that long. Interestingly, this major superwave peak correlates with the disappearance of Neanderthal Man (LaViolette, 1990).

Problem 13: The 40 kyrs b2k radiocarbon anomaly does not have a supernova signature. The supernova theory encounters the same difficulty in explaining the radiocarbon anomaly that occurred around that time. Figure 4, adapted from Hughen (2004), charts the change in atmospheric C-14 concentration over the past 60,000 years as measured at Cariaco Basin. It shows that radiocarbon concentration began to rise 4000 years prior to the proposed 41 kyrs b2k Geminga supernova date and continued to rise, reaching a peak around 40 kyrs b2k.* Certainly, such a long-term increase does not match the signature of a supernova gamma ray flash whose secondary

* Although the rise in C-14 concentration between 45 and 40 kyrs b2k (100% increase) was far larger than the rise at 12.9 kyrs b2k (7% increase), the instigating cosmic ray intensity in each case may have been comparable. The reason that C-14 rose to such high levels for the earlier event is that the event lasted longer allowing a greater quantity of radiocarbon to accumulate in the atmosphere. In each instance C-14 rose on the order of 3 percentage points per century.

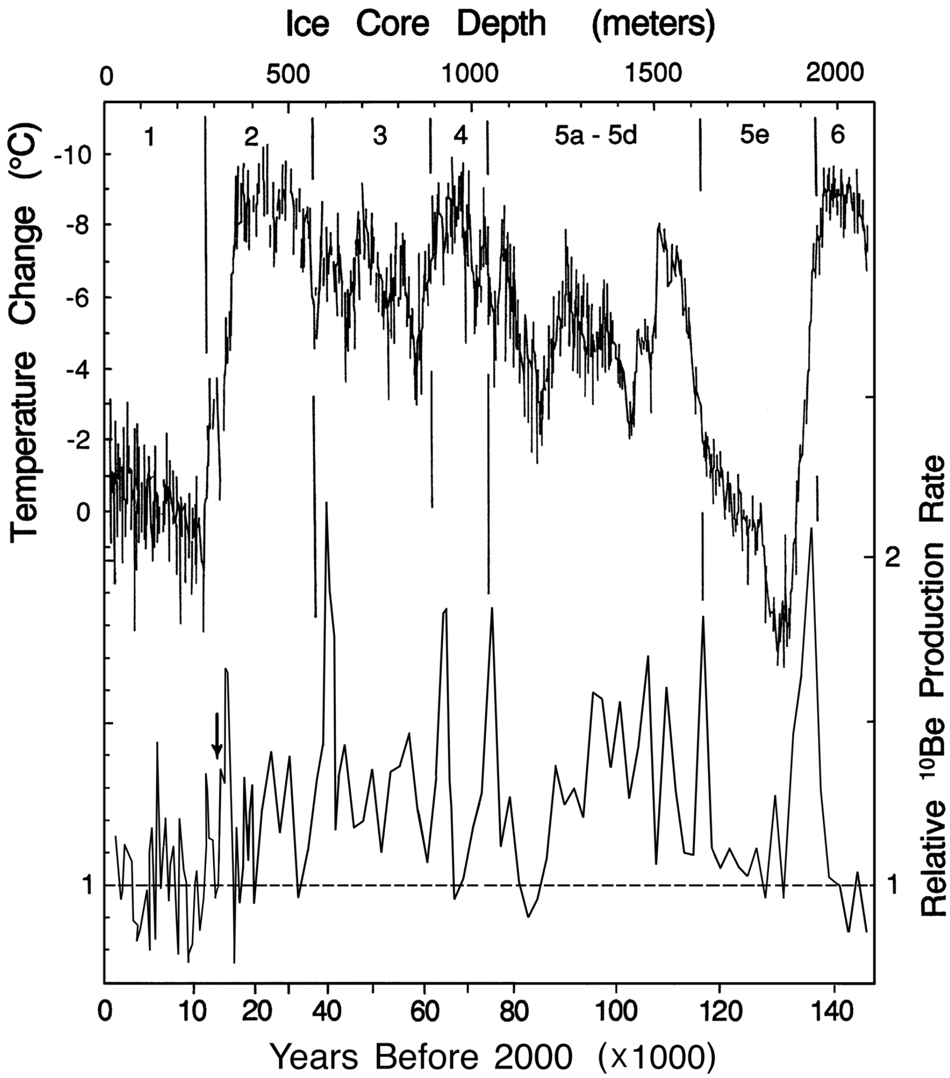


Figure 2. Upper profile: Ambient air temperature at Vostok, Antarctica as indicated by ice deuterium content (from Jouzel, 1987). Lower Profile: Beryllium-10 production rate at the Vostok ice core site normalized to the Holocene average. This profile was produced by adjusting the Be-10 concentration data of Raisbeck, et al. (1987, 1992) for changes in ice accumulation rate according to the ice accumulation rate model described in LaViolette (2005c). Arrow indicates the 12.9 kyrs y2k boundary.

particle barrage would have lasted on the order of years, not millennia. Also note that there are a total of six major events in which C-14 significantly increased (marked by arrows). Besides the large peak at 40 kyrs b2k and the smaller peaks at 35 and 13 kyrs b2k, we see peaks also at 30, 52, and 59 kyrs b2k. The two earlier events precede the time of the proposed supernova date. It is very difficult to explain C-14 anomalies repeating so frequently with a phenomenon as rare as nearby supernova explosions. However, Galactic superwaves could arrive frequently enough to explain these findings. The other possibility is that many of the peaks may be due to a rise in solar flare activity, but as described earlier, such increases are likely associated with the arrival of superwaves and their ability to fill the solar system with cometary dust.

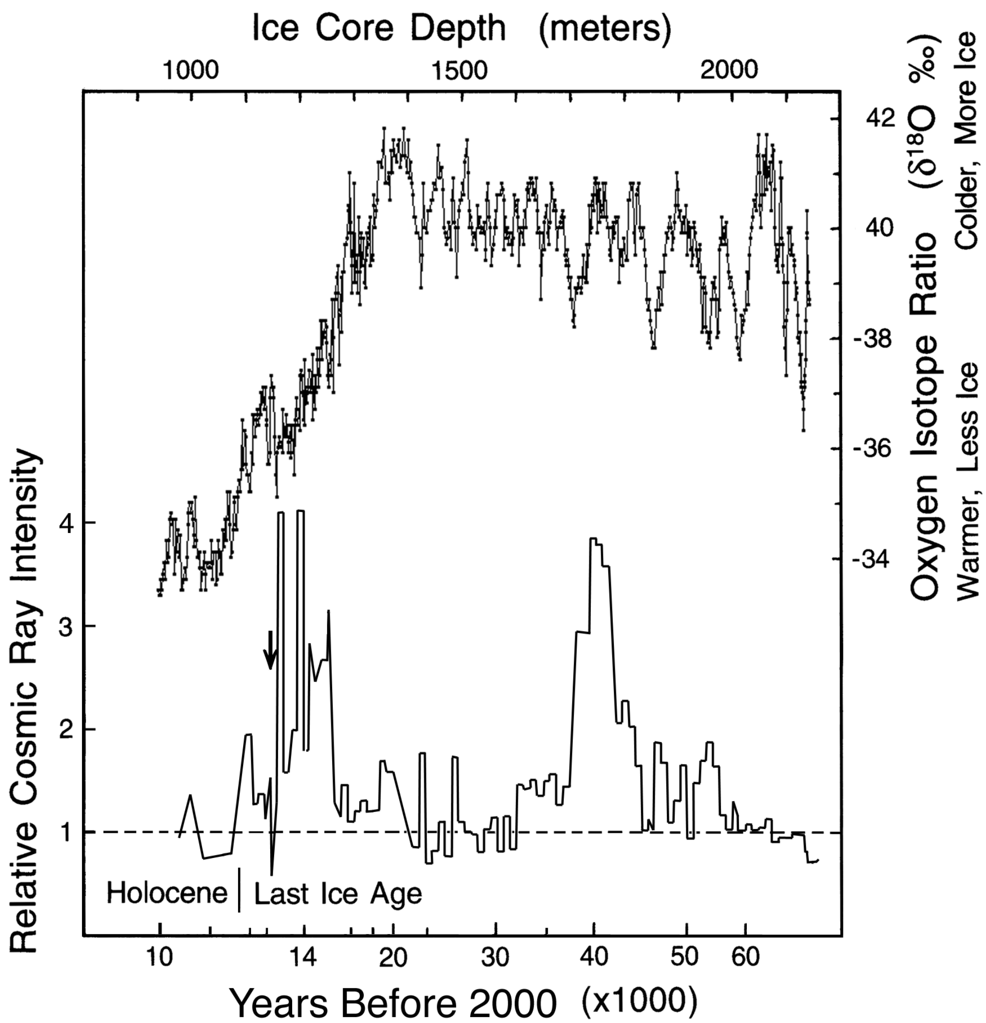


Figure 3. Upper profile: Ice core oxygen isotope ratio at Byrd Station, Antarctica, an indicator of ambient temperature (courtesy of W. Dansgaard). Lower profile: Beryllium-10 production rate at Byrd Station normalized to the Holocene average. This profile was produced by adjusting the Be-10 concentration data of Beer, et al. (1987) for changes in ice accumulation rate according to the ice accumulation rate model described in LaViolette (2005c).

Problem 14: Supernova explosions don't occur frequently enough to explain so many Be-10 peaks. Multiple cosmic ray events are also evident in the Vostok Be-10 record. At least a dozen Be-10 production rate spikes are present there, eight of which precede Firestone and West's proposed 41,000 year b2k supernova date. Moreover, both beryllium-10 records show a set of cosmic ray peaks falling at the beginning of the last deglaciation and spanning the period of the megafaunal mass extinction. At one event every million years, supernovae just don't occur frequently enough to explain this kind of recurrence. More specifically, an energetic type-II supernova would occur even more rarely. So they cannot adequately account for the multiple events recorded in the geologic record. Superwaves, however, can account for this degree of frequency.

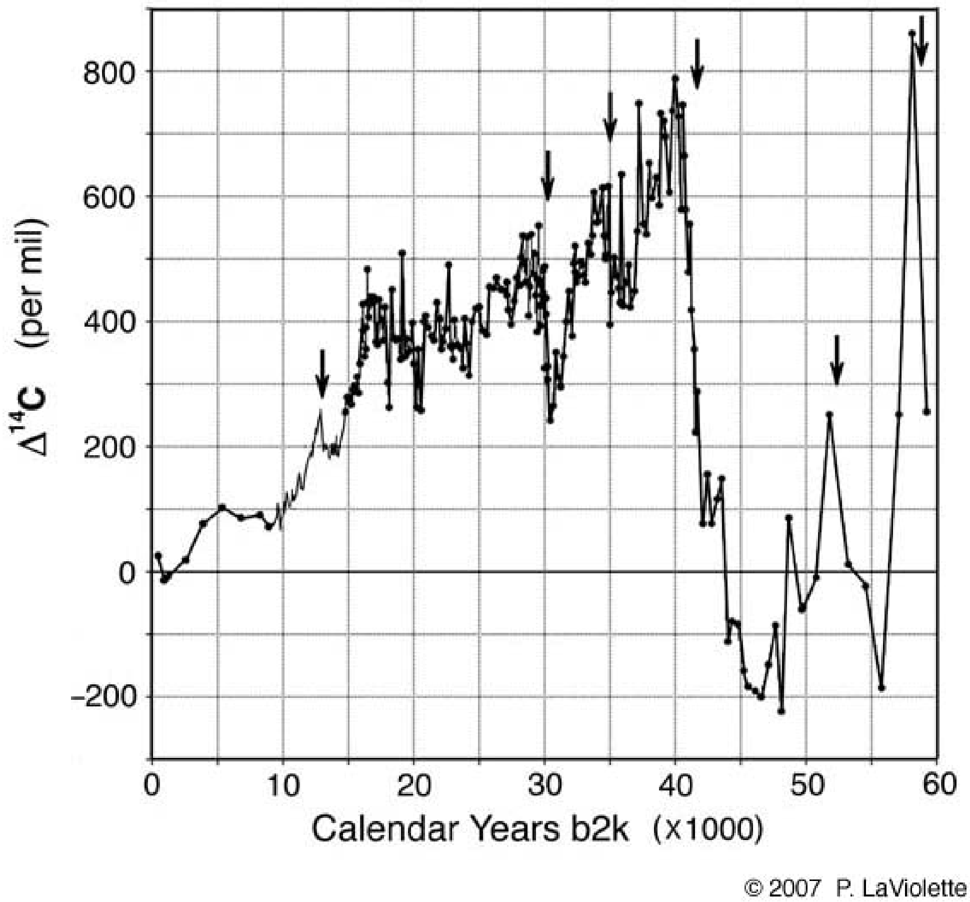


Figure 4. Radiocarbon abundance excess relative to trend line in a Carioca Basin sediment core (after Hughen, et al., 2004).

Since there is a considerable amount of evidence that points to the past passage of a superwave cosmic ray volley at the end of the last ice age, there is no need to seriously consider a supernova explosion as a cause either of the beryllium-10 peaks or of the megafaunal extinction. Why invent another explanation when we already have a good, well documented explanation already in hand? This is not to say that nearby supernova do not produce hazardous effects on our planet from time to time. But, without hard astronomical evidence of a nearby supernova shell expanding at the alleged speed of thousands of kilometers per second, it is difficult to make the case. Moreover, as is explained in section 6 below, the superwave theory is able to account for many aspects of the Pleistocene extinction that are difficult to account for on the basis of a cometary explosion.

Problem 15: Insufficient dust to induce elevated solar flare activity. In their book, Firestone, West, and Warwick-Smith (2006, p. 246) propose that "the debris wave of the supernova could have seriously disrupted the sun, causing a prolonged period of flare eruptions." In reference to this they cite the lunar rock evidence of Zook et al. which indicates that the Sun was particularly active during the deglacial period. However, the amount of supernova debris that would have entered the solar system would have been at least a billion times too small to have had this kind of effect on the Sun. Let us suppose that half of the material in the remnant shell was in the form of comets and the other half in the form of dust and gas that could be more easily drawn in and accreted by the Sun. Based on our earlier calculations (Problem 2), this amounts to a total of about 10 ng/cm^2. Distributing this over a 44 light year thick remnant shell (passing the Sun for 6000 years at a speed of 2200 km/s), we get a debris density of only 10^{-27} g/cm^3, or about 10 million times smaller than the current interplanetary dust density. So there would have been a negligible effect compared with the effects of the current dust influx to the Sun. The superwave theory, by comparison, proposes cometary dust concentrations over 100 million times higher than this, and mass influx rates over 1000 times higher (LaViolette, 1983a, 1985).

5. Corroboration of Early Discoveries of Extraterrestrial Tin Particles in Polar Ice

Tin found in YD boundary samples. Another very important finding that the YDB group announced at the 2007 Acapulco AGU meeting is their discovery of large concentrations of tin at the YD boundary. Darrah, et al. (2007) conducted SEM analysis of magnetic separates taken from the 12,950 years b2k boundary at several C-14 dated Clovis sites across the U.S. They found that these separates contained ET markers such as platinum (Pt) and nickel (Ni), but also certain of these particles were found to contain ET indicators in association with volatile metals such as tin (Sn) and copper (Cu). Metal combinations found included Fe-Ni, Cu-Ni, Fe-Sn-Ni, with particles in various examples containing 25 - 28% Sn, 12 - 90% Cu, 1 - 11% Ni, and 5 - 98% Pt. The grains were found to be in a metallic state and relatively unoxidized.

Findings of the 1983 Portland State University study. As mentioned earlier, in the early 80's at Portland State University I had conducted neutron activation analysis of polar ice dust as a test of my superwave hypothesis; see figures 5 and 6. As disclosed in my 1983 dissertation and in subsequent publications, out of the eight Greenland ice samples I tested that ranged in age from 38.7 to 78.5 kyrs b2k, six contained high concentrations of ET metallic indicators such as Ir and Ni, and four also contained high concentrations of volatile metals such as Sn, Sb, and Ag. In fact one 50,000 year old sample was found to consist of 60±15% tin (LaViolette, 1983a, 1983c). The tin and iridium abundances found in these samples are presented in Table I. Gold was also found to be present in the 50 kyrs b2k sample at a concentration of about 19 parts per million. Correspondingly, gold was found at 2 ppm in clear nonmagnetic particles taken from the Gainey Clovis site, hence at a level 10^3 times higher than normal crustal abundance.

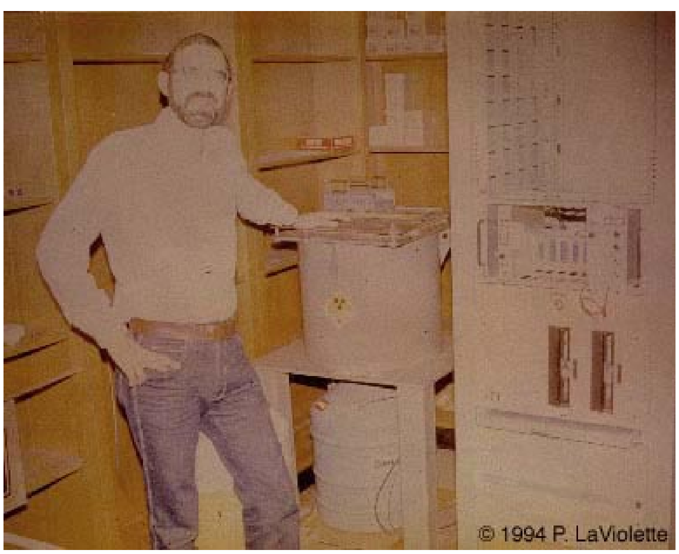


Figure 5. The author standing next to the Portland State University gamma ray detector used in his neutron activation analysis study of ice age polar dust.

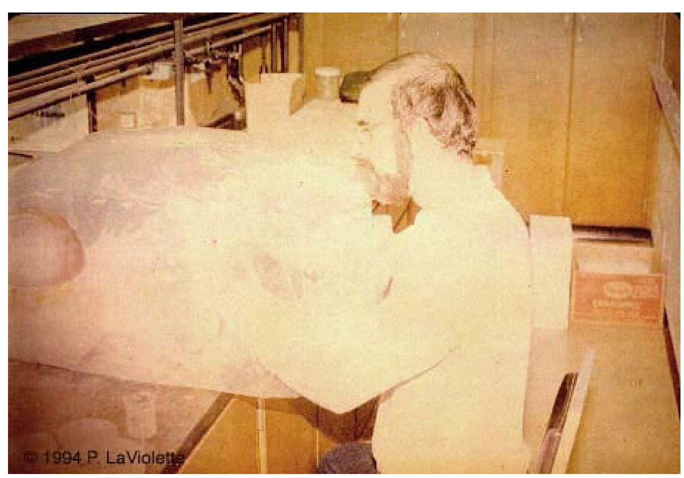


Figure 6. The author processing his irradiated samples inside a glove bag prior to counting.

Table I
Ice Age Cosmic Dust Events

North America

Age (kyr b2k)	Sn Concentration	Ir Concen.	Researcher
12,950	25% to 28%		Darrah, et. al. (2007)

Greenland

Ice Depth (m)	Age (kyr b2k)	Sn Concentration	Ir Concen.	Researcher	
1166	17,000	45% 1 of 8 particles		Thompson	(1977)
1212	38,650	710 ppm	16.6 ppb	LaViolette	(1983)
1221	45,000		24 ppb	LaViolette	(1983)
1227.7	49,500	24 ppm	6.9 ppb	LaViolette	(1983)
1230.5	50,500	2-30% 6 of 7 particles		Thompson	(1977)
		60 ± 15%*	56 ppb	LaViolette	(1983)
1241	58,700		96 ppb	LaViolette	(1983)
1275	78,500	690 ppm	6.3 ppb	LaViolette	(1983)
1342	125,000	3 of 5 particles		Thompson	(1977)

Antarctica

1585	31,500	<58 ppm	156 ppb	LaViolette	(1983)

Note: Ice core depths and ages listed above are updated from values given in the 1983 and 1985 publications. Core depths given here record real depth rather than log book depth and ages are older than previously published ages due to improvements in ice core chronology.□

Although the Sn, Sb, Au, and Ag in the polar ice samples were at ratios far higher than are observed in carbonaceous chondrites, I concluded at the time that they were nonetheless extraterrestrial and most likely of cometary origin. Whereas carbonaceous chondrite meteorites lose much of their volatile elements during entry through the atmosphere due to frictional heating, such would not have happened to particles dispersed in space as a result of comets being vaporized by superwave cosmic rays. Micron sized particles such as these would have been able to enter the Earth's atmosphere at a relatively low velocity and reach the Earth's surface unheated in their natural state. Hence they would be expected to retain their volatile element components. The recent discovery by Darrah, et al. that certain ferromagnetic particles present at the YD boundary contain tin along with other ET indicators should be considered in light of this prior ice core data. For it is apparent that the tin-bearing dust particles they found came from the same compositionally anomalous source that produced the earlier cosmic dust incursions recorded in polar ice.

Problem 16: Multiple cosmic dust and Be-10 events are problematic for the supernova theory. Five of the eight Greenland polar ice dust samples I studied had been filtered from the ice by glaciologist Lonnie Thompson as part of his 1977 microparticle study and three I filtered myself from Camp Century polar ices. In his study, Thompson had found tin-bearing particles in 3 out of the 11 Camp Century, Greenland ice core samples he analyzed. My study confirmed the high Sn level he had previously observed in the 50,500 year b2k sample and also reported high concentrations in two other samples from his collection, (dating 38.65 and 78.5 kyrs b2k) which had levels too low for him to detect with his electron microprobe technique. Low levels of Sn, but again far above crustal abundance, were present in one other sample (49.5 kyrs b2k) that I had filtered from Camp Century ice. I also found high concentrations of iridium, nickel, and in some cases high levels of tin, in three Antarctic polar ice core samples, including a 31,500 year old dust band which I have listed in Table I along with the Greenland ET dust samples I processed as well as two samples (dating 17 and 125 kyrs b2k) for which Thompson had reported high levels of Sn in his 1977 study. I include these two in the list as well on the assumption that the Sn is an indicator for cosmic dust of anomalous composition. All together these comprise 9 cosmic dust horizons additional to the event found at the YD boundary.

This evidence of multiple past cosmic dust incursion events raises a serious problem for the Firestone-West supernova-comet-explosion theory. For example, six of the dust events listed in Table I take place prior to the time of their proposed 41,000 years b2k supernova explosion date, which leaves these earlier events unaccounted for. Furthermore we should also add to the list of possible ET events the beryllium-10 concentration peaks present in the Vostok ice core record which date around 57, 64, 76, 97, 106, 117, and 133 kyrs b2k. So in all there may be at least 16 cosmic dust/cosmic ray volley events that have occurred in the last 140,000 years.

As I pointed out in 1983, comet and asteroid impacts occur far too infrequently to explain such multiple cosmic dust incursion episodes (LaViolette, 1983a). Impacts by comets having a diameter of several kilometers, the size being suggested for the YDB event, occur about once every 30 million years unless triggered to enter by some other galactic event, and nearby energetic supernova, as mentioned earlier, occur less frequently than once in a million years. The superwave theory, though, offers an appropriate explanation for them since galactic explosions are a recurrent phenomenon. The cores of spiral galaxies are estimated to spend approximately 15% - 20% of their time in an active cosmic ray radiating mode. A spectral analysis study conducted by Liritzis and Grigori (1998) indicates recurrence intervals of 5 k, 12 k, 19 k, 25 k, and 40 k years in the Vostok Be-10 record. A study conducted by Omerbashich (2006) indicates a period as short as 3600 years may also be present. So if these Be-10 peaks reflect times of past superwave arrivals, it is clear that they arrive frequently enough to explain the observed cosmic dust events.

Interestingly, one of the samples in which I found high levels of iridium correlates with the tail end of the 40 kyrs b2k cosmic ray event and another falls at the time of the 76 kyrs b2k event. The 40 kyrs b2k correspondence may be seen in figure 7 which compares the iridium deposition rates in these polar ice samples to the Be-10 data of Beer, et al. Furthermore, one should not overlook the fact that the cosmic dust influx that occurred at the time of the megafaunal extinction also coincided with a Be-10 cosmic ray peak, as I note below. So one can make a good case for a connection between cosmic ray volley events and cosmic dust incursions.

<u>Problem 17: Past cosmic dust deposition events last too long to be accounted for by comet impacts</u>. Another difficulty to ascribing a comet impact origin to these past ET dust peaks is that in some cases more than one iridium peak is found, suggesting that the ET material influx lasted several hundred years. For example, analysis of YDB sediments taken from Blackwater Draw, New Mexico and Lake Hind, Manitoba show two iridium peaks, one falling close to the AL/YD boundary and a second occurring about 200 years later; see figure 8. The peaks are separated by 4 cm of sediment at Blackwater and 17 cm of sediment at Lake Hind. The finding that the upper Ir peak at the Lake Hind site has a sediment date more recent than the peak below it gives reason to believe that the peaks are not contemporaneous. This evidence contradicts the claim made by Firestone et al. (2007c) that iridium was found only at the YD boundary and neither below or above it. If the extinction were due to a cometary explosion or impact, only one peak should have been formed, most of the dust being expected to settle out within a few years. Multiple peaks would require multiple impact events with the consequent problem that it is highly improbable that impacts would recur with such frequency. Multiple peaks, however, do not pose a problem for the

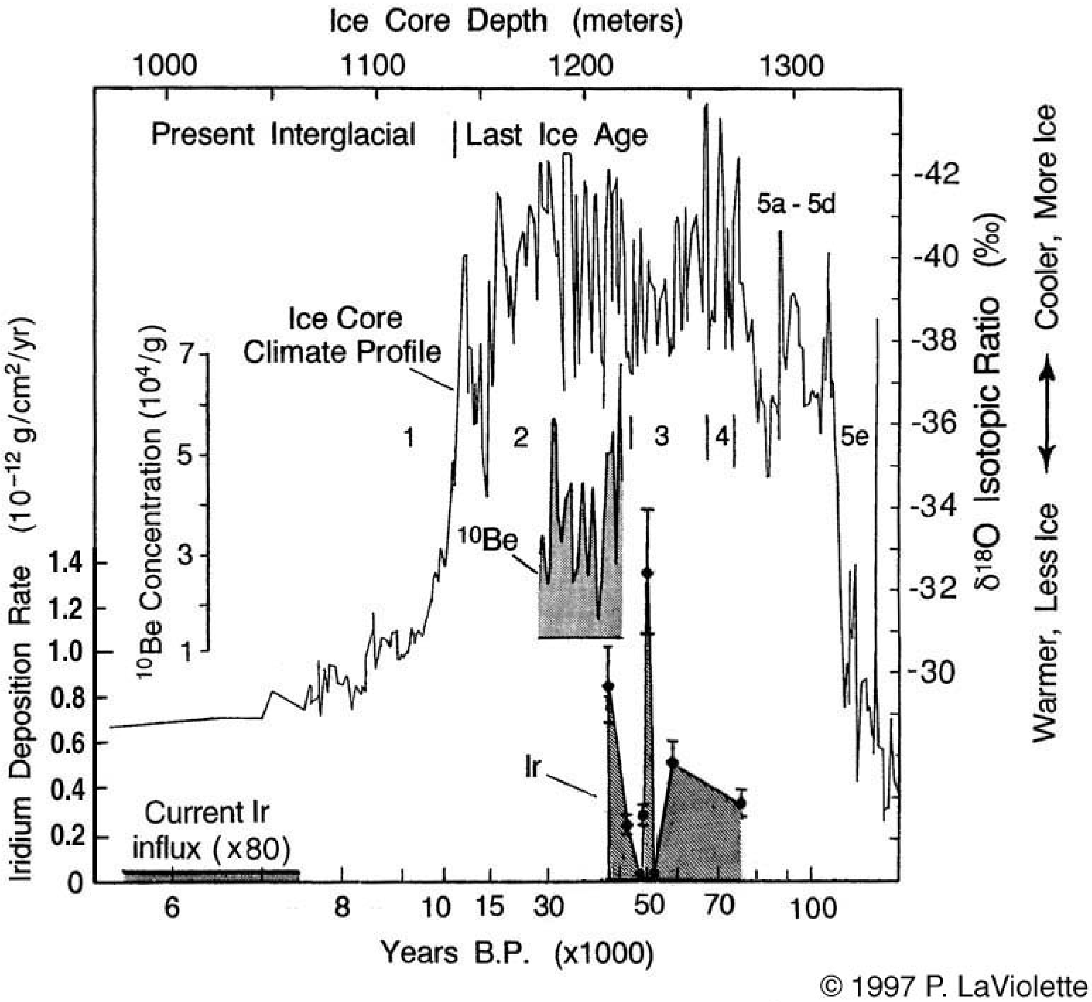


Figure 7. Figure 7. Upper profiles, oxygen isotope ratio and Be-10 concentration. Lower profile, iridium deposition rate (data from LaViolette, 1985b, 2005a)

superwave interpretation since a superwave would have pushed cosmic dust into the solar system over a period lasting hundreds of years.

Additional evidence that cosmic dust was being deposited over an extended period of time is seen in the case of the 50.5 kyrs b2k tin dust event registered in Greenland ice. The dust in this sample was filtered from a 35 centimeter long ice core sample which represents an ice accumulation time span of at least 360 years. Thompson, who initially analyzed this sample, divided the ice core section into 35 consecutive samples each representing one centimeter of core depth and counted the number of particles in each sample using a Coulter counter. He found that while the particle count varied from one increment to the next this variation for the most part did not exceed 100% of the mean number count; see figure 9. Only one sample had a count about three times the mean value, but this sample represented only about 15% of the particle count for all 17 samples totaled together. This indicates that this tin-rich dust, which was later found to be mostly of extraterrestrial origin, was entering the Earth's atmosphere at a relatively constant rate during this 360 year period. This negates the possibility that the dust originated from a cometary explosion or cometary impact event. For, if it had originated in this fashion, it should have remained airborne for no more than a few years before settling and hence should have formed a single dust band within a single increment of

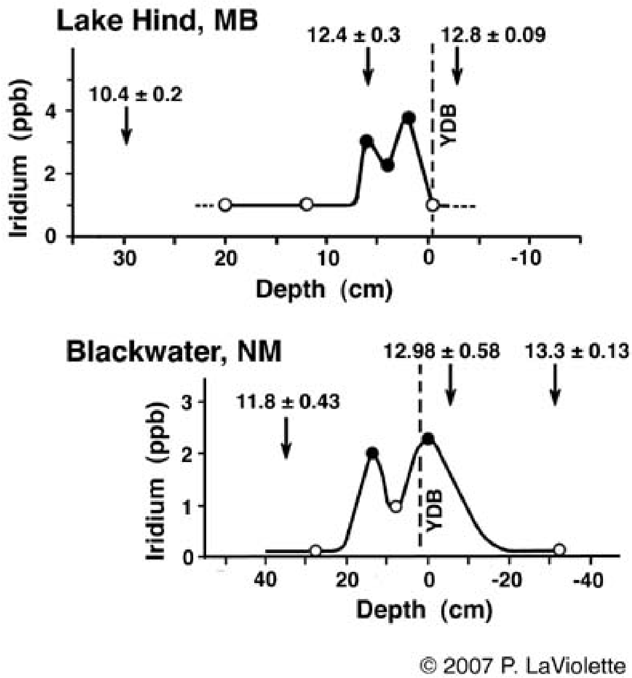


Figure 8. Iridium concentration in sediments from Lake Hind, Manitoba (top) and Blackwater Draw, New Mexico (bottom); after Firestone, et al. (2007c).

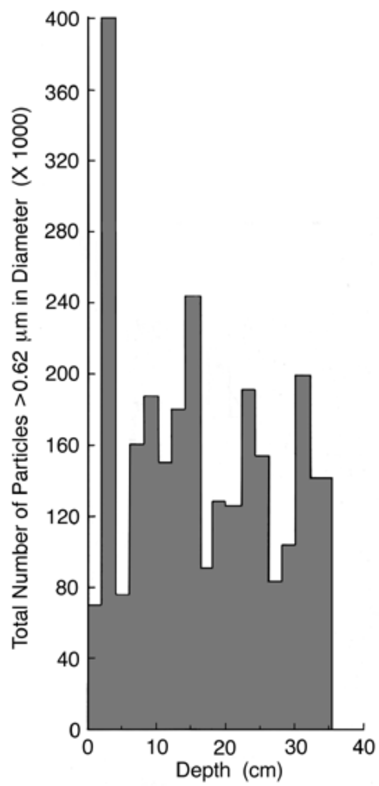


Figure 9. Particle count versus depth in Camp Century, Greenland ice core sample at a depth of 1230.5 meters dating from 50,500 years b2k. (after Thompson, 1977, p. 128)

the 35 cm long section. It is reasonable to infer that the other ice core depths containing high Sn concentrations (discovered both in Thompson's study as well as in my own) also involved a relatively continual dust particle influx over periods of hundreds of years. In other words, what is evident from analysis of the 50.5 kyr b2k event may be typical of other tin influx events as well. So cometary impact explanations for those events seem unlikely.

Another important point is that microspheres were relatively absent in the 50.5 kyr b2k dust sample. The tin-bearing dust particles are irregular in shape and have a flat, plate-like appearance. To maintain this shape during entry through the Earth's atmosphere without melting into microspheres indicates that they must have been entering at a low velocity and experienced essentially no heating or atmospheric ablation. So while microspheres discovered at the 12.9 kyr b2k boundary, as well as those found embedded in PaleoIndian artifacts, might point toward the occurrence of one or more comet explosions or impacts at that time, some other kind of mechanism must be put forth to explain the earlier dust events. They require a theory that explains how large quantities of dust manage to enter the solar system in particulate form. The superwave theory is one such theory.

Some microtektites and cosmic microspheres could have a noncometary impact origin. Although Firestone and West make a good case for a comet explosion origin for the high concentration of microtektites and microspheres observed at the YD boundary, we might venture that melted particles of this sort discovered at the YD boundary may not all have originated from a comet explosion/impact. Although spherules can be produced during atmospheric heating and ablation of impacting bodies such as meteors, comets, or asteroids, and also in the fireball of an exploding comet, as happened in 1908 at Tunguska, in reality, they are most commonly produced in space, not on Earth. They can be produced when interplanetary dust particles pass within Mercury's orbit and are melted by exposure to the Sun's radiation. Chondrules (microspheres) found in meteorites are also believed to be a component of cometary ice and would be released along with the more friable cosmic dust particles when cometary ice material is vaporized. Such vaporization may occur either when the comet is sufficiently heated by the Sun during its entry into the inner solar system, or in the case of a superwave event, when a comet passes through a high intensity region of Galactic cosmic ray radiation, as would exist in the heliopause sheath and surrounding shock front region during a superwave encounter. Evidence that cosmic spherules more commonly enter our atmosphere already in spherical form, as opposed to originating from the explosions or impacts of comets or asteroids, is discussed in my dissertation (LaViolette, 1983a, ch. 8); see posting at http://starburstfound.org/downloads/superwave/Ch-8.pdf.

Also during this terminal Pleistocene period, when the zodiacal cloud is theorized to have contained high concentrations of cosmic dust, the Earth during this time would have accumulated a dense shroud of electrically charged dust particles forming a kind of meteoric veil (LaViolette, 1983a). Particles trapped in this veil, as well as dust particles present in the dust conjested interplanetary environment would have melted during exposure to the intense radiation of a major solar coronal mass ejection (CME). We know that solar flare activity was exceedingly high during the extinction event, as indicated from the rapid rise in C-14 at this boundary (figure 1) and from studies of solar flare tracks in lunar rocks. So it would have been quite possible that spherules were being produced by very intense CMEs. If the Earth's magnetopause had been impacted by a very large CME, temperatures in the Earth's storm-time radiation belts could have risen high enough to melt into spherules many of the dust particles residing in its meteoric veil. Furthermore the shock of the CME impact and the collapse of the geomagnetic field would have caused this spherule-bearing dust to become precipitously deposited on the Earth's surface, thereby creating a concentrated layer of ET bearing debris. So a solar coronal mass ejection event could mimic a comet impact.

In discussing the YD boundary, one must also be aware that glacier waves, floods of glacial meltwater, issuing at that time in many places would have caused catastrophic sedimentary deposition at this boundary resulting in sediments being stratigraphically graded with the heavier higher density fraction concentrated at the bottom. Thus even though metallic dust particles and spherules may have had a history of gradual deposition over hundreds of years, during a meltwater flood the sediments would become stratified giving the false impression that their cosmic material fraction had been abruptly deposited.

<u>Helium-3 evidence also supports the superwave theory</u>. Along a similar line, the helium-3 findings that the YDB group sites as evidence for their comet explosion theory need not necessarily originate from an incoming comet, at least not all the helium-3 reported at the YD boundary. For helium-3 is a common component of interplanetary dust particles. It becomes implanted in the particles during their exposure in space to the solar wind. So if there was an enhanced influx of cosmic dust at that time, one would expect to see elevated levels of helium-3 in soil sediments as well.

<u>Additional cosmochemical evidence that the tin particles are extraterrestrial</u>. Further support of the extraterrestrial origin of the polar ice tin rich particles came in 1984. I had sent a piece of the tin-bearing polar ice dust to a laboratory in Australia for isotopic analysis. The sample had previously been stored in a safe place away from radiation sources. Three of the ten isotopes of this tin were found to contain isotopic anomalies, the abundance ratio for one of these, Sn-115, deviating by over three standard deviations from the terrestrial ratio. Hence these early results provided quite strong confirmation that the Sn was in fact of ET origin. Additional corroboration came in 1985 when the German cosmochemist Franz Rietmeijer (1985) announced finding tin oxide grains in interplanetary dust particles captured from the Earth's stratosphere. Although the Sn abundance was not anywhere near the abundance I had reported in one of my polar ice samples, it was nevertheless six times higher than concentrations typically found in carbonaceous chondrites.

<u>Claims that the tin arose from contamination were successfully rebutted</u>. My discovery of volatile elements being found in polar ice dust in combination with high levels of ET indicators challenged accepted beliefs in the field of cosmochemistry. Previous studies on chemical composition of extraterrestrial material were derived primarily from analyses of meteorites. Hence any report of compositions different from standard meteorite abundances were looked upon with skepticism. In 1972, Hemenway, et al. reported finding unusually high concentrations of heavy metals in submicron sized dust particles collected from the stratosphere. But other than this, no researcher had previously reported the presence of high concentrations of such volatiles in cosmic dust.

As a result, my findings encountered considerable resistance from certain conservative scientists in the cosmochemistry community. For example, in 1988, the French geochemist Claude Boutron published a paper in the journal *Monthly Notices* questioning the validity of my polar ice cosmic dust measurements (Boutron, 1988). He claimed that my samples must have been contaminated since I had reported that tin was present in many of them at substantially enhanced concentrations. I rebutted his paper that same year (LaViolette, 1988) giving detailed reasons why sample contamination was unlikely and arguing in support of an ET origin for the particles. So I am quite pleased to learn that high concentrations of tin have been discovered in YD boundary sediments alloyed with ET markers. For this gives even more reason to believe that I have been right in maintaining an ET origin for the tin found in polar ice.

6. Considering the Paleontological Evidence

Problem 18: The comet explosion theory does not account for the two millennium duration of the Pleistocene extinction. Firestone and West propose that their comet explosion catastrophe occurred at the Alleröd/Younger Dryas boundary. Hence according to their theory most of the casualties should have occurred at this time within a matter of a day or so. However, the mass extinction did not transpire just in a matter of days as their theory suggests. It had already been underway for at least two thousand years prior to that date. For example, Donald Grayson and David Meltzer (2003) note that of the 35 genera involved in that extinction, only 15 can be shown to have lasted beyond 12,000 C-14 years ago (13,900 calendar years b2k) with the implication that the majority became extinct over a millennium prior to the AL/YD transition. While these authors advance this as an argument against the Prehistoric overkill hypothesis, it is equally valid against a terminal comet event. In a May 2007 news interview, Dr. Meltzer noted that the earlier extinction dates for certain genera give reason for doubting the Firestone-West comet theory (Roach, 2007).

Evidence of the extended character of the Pleistocene extinction may be seen in figure 9 which has been adapted from a "death rate" histogram published in 1983 by Drs. Meltzer and Mead. It charts the temporal distribution of dates on the remains of extinct megafauna taken from various North American sites and shows the number of remains found in each of a consecutive series of time slots, plotted here in terms of calendar years instead of radiocarbon years. The dark histogram bars represent dates occurring prior to the Allerod/Younger Dryas boundary date while the light bars represent dates occurring more recently than that boundary date. The lower pixilated bars represent the subset of more reliable radiocarbon dates. As can be seen here, the megafaunal death rate rose precipitously around 14,350 calendar years b2k, and for 1400 years maintained a relatively high mortality level up to the 12,950 years b2k Younger Dryas boundary date. This poses a problem for the Firestone-West comet theory which attempts to explain the extinction with a short-term comet explosion event or events occurring at the AL/YD boundary.

Geophysical correlations with the death rate histogram. In viewing the Meltzer-Mead histogram, one notes a striking correlation between the onset of increased mortality and climate. The peak spanning the interval 14,350 to 13,800 years b2k coincides with a time of peak warmth during the Bolling Interstad, which coincided with a sharp rise in meltwater discharge from the ice sheets, evident in Gulf of Mexico salinity records. The Bölling/Allerod warming was not restricted just to the Northern Hemisphere, but was a period of global warming that is not easily explained as arising due to endogenous fluctuations of the Earth's climatic system (LaViolette, 2005c). In other words, some external effect must have been perturbing the Earth to cause temperatures during this period to rise to levels typical of interglacial periods at a time when the ice sheets were near their maximum extent. It is difficult to pass off the association of this warm period with the rise in megafaunal death rate as a coincidence. The superwave theory proposes that the megafaunal extinction arose because of hazardous effects from a highly active flaring Sun. It also suggests that the glacial meltwater flooding which occurred during this period of global warming posed an additional hazard. As noted earlier, this also was related to the superwave cosmic dust incursion.

Evidence that supersized solar flares played an important role in the megafaunal extinction is indicated by the highly elevated radiocarbon production rate that occurred from 13,500 to 12,800 years b2k and which is evident in figure 1. As seen in figure 10, this period spanned the highest peak in the megafaunal extinction histogram. Spurts of C-14 production are also found to coincide with earlier peaks in the histogram, including one close to the time of the Gothenburg geomagnetic excursion. We also have evidence from the lunar data of Zook et al (1977) that the deglacial period was marked by highly elevated solar flare activity.

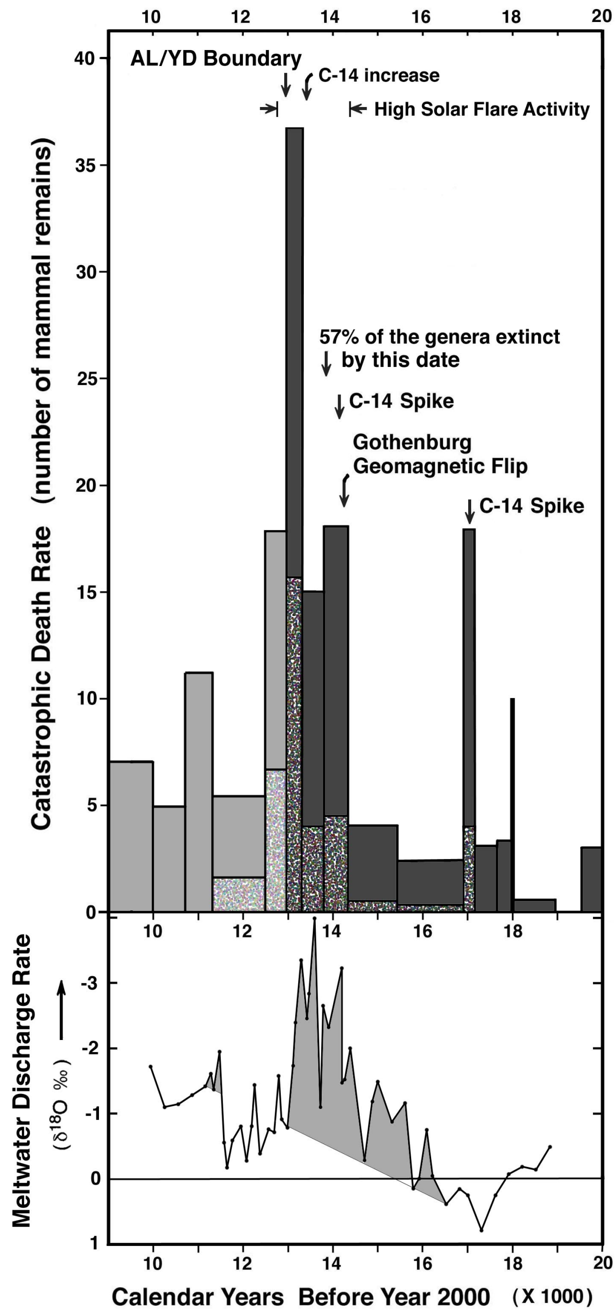


Figure 10. Chronological distribution of calendar dates on remains of extinct land mammals from 163 North American locations. Black bars indicate dates earlier than 12.9 kyrs b2k. Pixilated bars indicate the subset of more reliable dates. Adapted from radiocarbon histograms published by Meltzer and Mead (1985) and Martin (1987). Lower profile: The rate of meltwater discharge from the North American ice sheet as indicated by the oxygen isotope profile for Gulf of Mexico core EN32-PC4 (after Broecker et al., 1989).

Problem 19: The progressive rise in atmospheric radiocarbon and the progressive YD cooling does not fit the abrupt signature of a comet explosion. As mentioned earlier, it is unlikely that a comet explosion or impact would itself produce such a large increase in radiocarbon. Besides if this were the case, there should have been an abrupt spike in C-14 of a few years duration, a time comparable to the atmospheric residence time of dust from a comet explosion.. Instead we see a progressive rise with most occurring over the 200 year period that coincides with the YD cooling. Also we see that an early phase of the rise actually began around 13,500 years b2k, well before the time proposed for the comet explosion. The short duration of an impact event also has difficulty explaining why climate progressively cooled for two centuries. Dust from an impacting comet would have settled out within a few years. So why did climate continue to cool and why was this cooling accompanied by a progressive increase in C-14? The comet theory has no answer.

Problem 20: A firestorm induction of the YD climatic cooling does not conform to ice core evidence. According to the supernova/comet theory, fires were ignited at the time of the YD boundary comet explosion (or impact), aggravating and likely extending the cooling due to the aerial dispersal of cometary dust. The theory's backers claim that evidence of this firestorm is to be found in the "black mat" also termed the "Usselo Horizon," a sooty layer formed both in North America and Europe during this AL/YD transition and attributed to the widespread occurrence of forest fires. However, ice core evidence suggests that this conflagration occurred over a century after the YD cooling had already commenced. Ion data from the GRIP Greenland ice core record registers this burning as a many fold increase in formate and oxylate ions, both indicators of biomass combustion. But, it shows that this rise occurred somewhere between 30 to 100 years after the date when climate first began to cool, as indicated by the date when the oxygen isotope ratio began its progressive decrease to cooler temperatures.

Atmospheric dust, and possibly soot, also increased about the time of this increase in oxylate and formate, as indicated by a decrease in the light transparency of the GISP2 Greenland ice core. Ice core transparency declined about 125 ± 15 years after the isotope decline indicating the onset of the YD cooling. Based on this, we may peg the onset of this conflagration to around 12,825 years b2k relative to a YD boundary date of 12,950 years b2k. Interestingly, this falls close to the time of the largest C-14 production spurt in the entire Cariaco Basin record which dates at 12,826 ± 4 years b2k. If this is not just a coincidence, it implicates a super-sized solar storm as being the cause of this ignition, and not necessarily a comet impact.

This global conflagration, then, cannot be blamed as the cause of the YD cooling since by that time climate had already cooled almost to the YD temperature low. The cooling, which had already been in progress for 125 years prior to that time, must be attributed to a cause other than a comet impact and its proposed firestorm. Solar flare cosmic rays appear to be the most likely choice. Solar cosmic rays striking the atmosphere would have ionized the atmosphere, producing large quantities of condensation nuclei which would have seeded cloud formation. The resulting global increase in cloud cover would have resulted in a global climatic cooling. In support of this, we find that periods when atmospheric radiocarbon was increasing, i.e., periods of high solar activity, coincide with times of climatic cooling. Furthermore such a solar flare-climate connection explains why dust peaks in the polar ice record recur with the solar cycle period (Ram and Stolz, 1999; Donarummo, 2002). Solar cosmic rays would have induced the formation of clouds having droplets too small to produce rain, resulting in a period of greater aridity and atmospheric dustiness.

Problem 21: Proposed thermal neutron flux intensities way too high. When Firestone first discussed the YD boundary extinction in 2001, he had suggested that the C-14 anomaly was produced by cosmic rays from a supernova explosion. At that time he did not give a date for the supernova explosion, but four years later he and West (LBNL, 2005) suggested that the event took place 41 kyrs b2k with cosmic rays and high-velocity extraterrestrial material from the outburst arriving around 34,000 and 12,900 years ago. Firestone and Topping (2001) had proposed that on the AL/YD boundary date thermal neutron fluxes reached as high as 10^{17} neutrons/cm^2, and Firestone (2002) later quoted fluxes as high as 10^{20} neutrons/cm^2. Based on the calculations of Southon and Taylor (2002), these levels would translate into the equivalent absorption of between 10^6 and 10^9 rads per hour, or to an energy influx of 10^5 to 10^8 ergs/cm^2/s. This is between 10% and one hundred times the level of insolation that the Earth receives from the Sun. If this were the case, it is difficult to understand how the proposed four kilometer diameter frozen cometary mass would have made its 250 light-year journey to the solar system intact. For if it were accompanied on its journey by such high cosmic radiation intensities, it should have been entirely vaporized. The Earth, then, should have been struck by a hot nebular wind, not by a frozen cometary mass.

Moreover, in their critique of Firestone and Topping's article, Southon and Taylor have pointed out that if the Earth's atmosphere had been exposed to neutron fluxes even as high as 10^{17} neutrons/cm^2, over a 1000 km diameter region, radiocarbon produced from neutron bombardment of Earth's nitrogen atmosphere should have increased atmospheric C-14 levels globally by a millionfold, leaving current C-14 levels thousands of times higher than are actually observed. This is not to say that cosmic ray radiation did not play a critical role in the terminal Pleistocene megafaunal extinction, but not quite in the fashion that Firestone, Topping, and West have suggested.

<u>Problem 22: No evidence for a continent-wide thermal gradient</u>. The theory of Firestone and West suggests that an aerial explosion or impact of a comet in the vicinity of eastern Canada delivered a shock to the North American ice sheet causing the catastrophic release of glacial meltwater producing floods that spread over the continent. Micrometeorite crater depths evident in PaleoIndian chert samples are found to decrease 20 fold when one proceeds from Michigan to Arizona. So one would expect to see a decline in flooding intensity as well with increased distance from the explosion or impact site. However, there is no indication that flooding intensity declined from eastern North America to Siberia on the west or to Europe on the east.

Also their proposal that the heat of the explosion would have created a ground level firestorm and that this would account for the formation of the black mat must explain why it appears as well in Europe as the Usselo Horizon. In fact, iridium levels in the European horizon were found to be higher than those found in the North American black mat (Firestone et al., 2007b; Firestone, et al., 2006, p. 352). The comet explosion theory could circumvent this by proposing simultaneous impacts in various parts of the globe. However, as was demonstrated earlier, comets from such a supernova would have been few and far between. So, it is difficult to imagine a worldwide barrage, at least with the supernova theory.

<u>The superwave explanation for the mass extinction</u>. In contrast to the comet theory, the superwave theory predicts an extended hazardous period, one that transpires over thousands of years with varying intensity. Hence it is able to account for the extended duration of the megafaunal die-off evident in Meltzer and Mead's histogram. As seen in figure 11, the rise in cosmic ray intensity coincided with the rise in megafaunal death rate. As a result of its injection of cometary and interstellar dust, and through its effect on the Sun and Earth, a superwave cataclysm would have been able to abruptly alter the Earth's climate (e.g., produce stadials and interstadials). It would also have increased the Sun's luminosity and level of flaring activity. These effects would have adversely affected biological organisms over several millennia and would all have contributed to the demise of the megafauna.

A diagram of the various ways in which a superwave event would have been hazardous to life is presented in chapter 3 of my dissertation (LaViolette, 1983a); see posting at

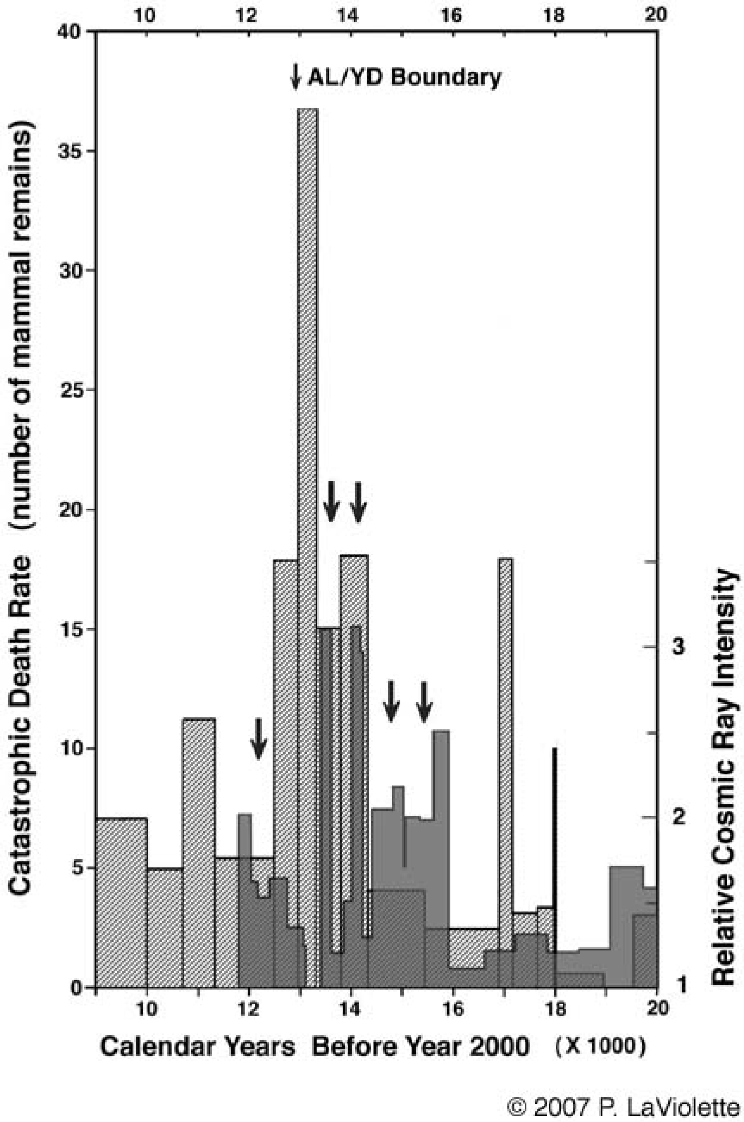


Figure 11. Megafaunal death rate histogram (hatched profile) compared to beryllium-10 flux in the Byrd ice core (lower gray graph). Be-10 peaks are indicated by arrows.

http://starburstfound.org/downloads/superwave/Ch-3.pdf. Interestingly, the model I had proposed in 1983 postulated two cosmic ray peaks arriving during the deglacial interval, one beginning around 14,200 years BP and lasting for 500 years and a second beginning around 13,500 years BP and lasting for 1000 years. The timing of these peaks turned out to be not far off from what the polar ice record shows.

A superwave cause would explain why unusual climatic, hydrologic, geomagnetic, and radiological events were taking place during this period of mass extinction. In particular, the geomagnetic flip that occurred at the first death-rate peak and the unstable geomagnetic field that persisted throughout this extinction episode would be a direct result of the opposing polarity imposed by the ring-current magnetic field. The ring current field is the magnetic field generated by the equatorial drift of solar cosmic rays trapped in the Earth's storm-time radiation belts and becomes particularly strong during the arrival of an intense solar proton event (LaViolette, 1983a, 1987a, 1990).

As mentioned earlier, the C-14 rise at the Allerod/Younger Dryas boundary may be attributed to the intense solar flare storms that were occurring at that time. The Be-10 flux is observed to dip during the interval 13,400 to 12,750 years b2k; see arrow markers in figure 2 and figure 3. Since this period coincides with the rise in C-14 concentration during the AL/YD transition, we may infer that the cosmic ray screening effect of the Sun's enhanced solar wind strength was able to overcome the propensity for Galactic cosmic rays to elevate the Be-10 flux during this interval, suggesting that solar flare activity was quite high at that time.

The apparent termination at the Clovis horizon could have been due to a particularly powerful solar proton event that was sufficiently strong to overpower the geomagnetic field and contact the Earth's atmosphere (LaViolette, 1990). The four largest C-14 production spurts to occur over the extent of the 4,000-year Cariaco Basin C-14 record (figure 1), occurred on 13,027 ± 4, 12,958 ± 4, 12,891 ± 4, and 12,695 ± 4 cal yrs b2k (Cariaco Basin chronology). They are spaced from one another by intervals of 69 ± 4 years, 67 ± 4 years, and 196 ± 4 years, that is, by three, three, and nine 22-year solar cycle intervals. Three of these events occurred during the Alleröd-to-Younger Dryas climatic transition. The earliest occured about 15 years prior to the beginning of the YD cooling trend, while the 12,891 years b2k event, which was one of the two largest C-14 spurts in this record, occurred about 125 years after the beginning of the YD cooling. Solar proton events causing either of these increases could have delivered the final blow in this extinction episode.

During the 12,891 and 12,695 years b2k events, C-14 jumped 2 percent. Based on the time interval between successive sediment samples, these jumps each occured within 8 to 12 years. This is 5 times the rise in radiocarbon produced during the course of a typical solar cycle in modern times. By comparison, the solar proton event that impacted during the 1956 solar maximum, which was one of the largest in modern times, produced a C-14 increase of only 0.016 percent (4% of the variation produced over the course of a typical solar cycle) (Usoskin, et al., 2006). So, we may infer that the 12,891 and 12,695 years b2k C-14 spurt events were 125 times more intense than this record breaking 1956 event. Since the 1956 solar proton event was able to produce a 1% decrease in the geomagnetic field, it stands to reason that these ice age events, which were 125 times stronger, would have entirely overpowered the Earth's field, allowing the full intensity of their solar cosmic ray barrage to contact the Earth's atmosphere. On the other hand, if either of these C-14 increases was produced by elevated solar flare activity spanning an entire half of a solar cycle, the C-14 increase produced by a single solar proton event during this time would have been insufficient to overpower the Earth's magnetic field. To know for sure, a detailed study should be performed on Cariaco Basin sediments spanning the 12,891 and 12,695 years b2k events.

Also as I suggested in 1983, the anomalously young dates found in many megafaunal remains could be evidence of exposure to an intense flux of solar cosmic rays. I had proposed that excess C-14 may have been created in situ when solar flare proton primaries produced thermal neutron secondaries within the plant or animal tissues, these in turn becoming captured by nitrogen atoms present there transmuting them into excess C-14 (LaViolette, 1983a, ch. 10); see posting at http://starburstfound.org/downloads/superwave/Ch-10.pdf. Topping subsequently proposed a similar in situ C-14 production mechanism to explain the anomalously young dates found at PaleoIndian sites (Topping, 1998; Firestone and Topping, 2001). However, one difference is that my 1983 model postulates that the majority of the incident particles were protons, not neutrons. These would have passed through the Earth's nitrogen atmosphere without producing excessive amounts of C-14, thereby avoiding the problem that Southon and Taylor were concerned about in their critique of the Firestone-Topping paper. Topping (2007) has long preferred the giant solar flare alternative over Firestone's supernova theory as the cause of the extinction. Although the article he coauthored with Firestone in 2001 emphasized the supernova alternative, he advocates a ground contacting SPE as the cause of the elevated radioactivity levels he found at the Clovis horizon. However, he proposes the event occurred 400 years later around 12,500 years ago.

It is likely that the Earth's surface would have received nonuniform exposure to solar flare cosmic rays during a ground-contacting SPE. Particles confined by the collapsing geomagnetic field lines could have been dumped at high intensities in some localities leaving others weakly exposed. This could explain why date anomalies vary in magnitude from one place to another or from one animal remain to another.

In summary, the superwave theory is compatible with the idea that cometary masses had impacted the Earth during the period of the megafaunal extinction. As mentioned earlier, the theory predicts that such bodies would have been injected into the solar system at an increased rate during that time. But it is apparent that a comet impact was not the sole cause of the extinction. The agent causing both the disappearance of large animals and triggering the influx of comets at that time was not a supernova, but more likely a Galactic superwave.

References

Beer, J., et al. "^{10}Be measurements on polar ice: Comparison of Arctic and Antarctic records." *Nuclear Instruments and Methods in Physics Research*, **B29** (1987): 203−206.

Boutron, C. *Mon. Not. R. Astr. Soc.* **233** (1988):215.

Burns, M. "New theory: Did a prehistoric comet kill North America." *Santa Barbara Newsroom*, June 4, 2007.

Darrah, T H, et al. "Mineralogical and noble gas evidence for an ET impact at the Younger Dryas." Paper PP41A-04, May 2007 AGU Conference, Acapulco, Mexico. [http://www.agu.org/meetings/sm07/sm07-sessions/sm07_PP41A.html]

Delaney, T. and Rudnick, L. "The first measurement of Cassiopeia A's forward shock expansion rate." *Ap.J.* **589** (2003):818-826.

Donarummo, J., et al., "Sun/dust correlations and volcanic interference." *Geophysical Research Letters* **29** (2002): GL014858.

Firestone, R. B. and Topping, W. "Terrestrial evidence of a nuclear catastrophe in Paleoindian times." *Mammoth Trumpet* **16**(2) March 2001, pp. 9 - 16. [http://abob.libs.uga.edu/bobk/nuclear.pdf]

Firestone, R. B. West, A., and Warwick-Smith, S. *The Cycle of Cosmic Catastrophes*. Rochester, VT, Bear & Co., 2006.

Firestone, R. B., et al. "Evidence for an extraterrestrial impact event 12,900 years ago that contributed to megafaunal extinctions and the Younger Dryas cooling." Poster paper PP43A-01 (May 2007a) AGU Conference, Acapulco, Mexico. [http://www.agu.org/meetings/sm07/sm07-sessions/sm07_PP43A.html]

Firestone, R. B., et al. "Evidence for a massive extraterrestrial airburst over North America 12.9 ka ago." Paper PP41A-01 (May 2007b) AGU Conference, Acapulco, Mexico. [http://www.agu.org/meetings/sm07/sm07-sessions/sm07_PP41A.html]

Firestone, R. B., et al. "Evidence for an extraterrestrial impact 12,900 years ago that contributed to the megafaunal extinctions and Younger Dryas cooling." *Proceedings of the National Academy of Sciences* **104**, October 9, 2007c, 16016 -16,021. [http://www.pnas.org/cgi/doi/10.1073/pnas0706977104].

Grayson, D. K., and Meltzer, D. J. "A requiem for North American overkill." *Journal of Archaeological Science* **30** (2003): 585-593.

Hughen, K. A. et al. "Synchronous radiocarbon and climate shifts during the last deglaciation." *Science* **290** (2000):1951-1954.

Hughen, K. A. et al. "^{14}C Activity and global carbon cycle changes over the past 50,000 years." *Science* **303**, January 9, 2004.

Jouzel, J. et al. "Vostok ice core: a continuous isotope temperature record over the last climatic cycle (160,000 years)." *Nature* **329** (1987): 403-407.

Kobres, R. et al. "Formation of the Carolina Bays: ET Impact vs. Wind-and-Water." Poster paper PP43A-10, May 2007 AGU Conference, Acapulco, Mexico. [http://www.agu.org/meetings/sm07/sm07-sessions/sm07_PP43A.html]

LaViolette, P. A. *Galactic Explosions, Cosmic Dust Invasions, and Climatic Change*. PhD dissertation, Portland State Univ., (1983a) Portland, Oregon, pp. 763 (Univ. Micro. No. 83-24,329); [http://adsabs.harvard.edu/abs/1983PhDT.........9L]
Later published as *Galactic Superwaves and Their Impact on the Earth Environment* (includes more recent supporting evidence being added between 1994 and 2007).
Excerpts: http://starburstfound.org/downloads/superwave/Ch-1.pdf
http://starburstfound.org/downloads/superwave/Ch-3.pdf
http://starburstfound.org/downloads/superwave/Ch-3-a.pdf
http://starburstfound.org/downloads/superwave/Ch-4.pdf
http://starburstfound.org/downloads/superwave/Ch-8.pdf
http://starburstfound.org/downloads/superwave/Ch-10.pdf

LaViolette, P. A. "The terminal Pleistocene cosmic event: Evidence for recent incursion of nebular material into the solar system." (abs.) *Eos* **64**, p. 286; Spring AGU meeting, Baltimore, May 1983b.

———. "Elevated concentrations of cosmic dust in Wisconsin stage polar ice." (abs.) *Meteoritics* **18**, p. 336; 46th meeting of the Meteoritical Society, Mainz, September 1983c. [http://starburstfound.org/downloads/superwave/Meteoritics1983.pdf]

———. "Galactic superwaves and their effect on the Earth and Solar System." (abs.) Presented at the Galaxy and Solar System Conference, Tucson, Jan. 1985a.

———. "Evidence of high cosmic dust concentrations in late Pleistocene polar ice." *Meteoritics* **20** (1985b): 545-558. [http://adsabs.harvard.edu/abs/1985Metic..20..545L]

———. "Cosmic ray volleys from the Galactic center and their recent impact on the Earth environment." *Earth, Moon, and Planets* **37** (1987a): 241-286. [http://adsabs.harvard.edu/cgi-bin/nph-bib_query?bibcode=1987EM&P...37..241L&db_key=AST&high=40c54fe18502618]

———. "The cometary break-up hypothesis re-examined." *Monthly Notices Royal Astronomical Society* **224** (1987b): 945-951. [http://adsabs.harvard.edu/cgi-bin/bib_query?1987MNRAS.224..945L]

———. "Regarding the validity of polar trace metal data: A response." *Monthly Notices of the Royal Astronomical Society* **233** (1988): 221-224. [http://adsabs.harvard.edu/abs/1988MNRAS.233..221L]

———. "Galactic core explosions and the evolution of life." *Anthropos* **12**, 1990, pp. 239 - 255. [http://home.earthlink.net/~gravitics/Downloads/Anthropos1990.pdf]

———. "Anticipation of the Ulysses interstellar dust findings." *Eos* **74**(44) (1993): 510-11.
[http://home.earthlink.net/~gravitics/Downloads/Eos.pdf]
http://adsabs.harvard.edu/abs/1993EOSTr..74..510L

———. *Earth Under Fire*. Rochester, VT: Bear and Co., 1997, 2005a.

———. "A galactic superwave hazard alert." *Nexus* **8**(2) February - March 2001, pp. .

———. "Solar cycle variations in ice acidity at the end of the last ice age: Possible marker of a climatically significant interstellar dust incursion." *Planetary and Space Science* **53**(4) (2005b): 385 - 393; [arxiv.org/abs/physics/0502019]

———. "Evidence for a global warming at the termination I boundary and its possible cosmic dust cause." 2005c. [http://starburstfound.org/downloads/superwave/TPI.pdf]

LBNL, "Supernova may have caused mammoth extinction." Sept. 23, 2005 Lawrence Berkeley National Laboratory press release, September 23, 2005. [http://www.lbl.gov/Science-Articles/Archive/NSD-mammoth-extinction.html]

Liritzis, I., and Grigori, E. "Astronomical forcing in cosmogenic Be-10 variation from East Antarctica coast?" *J. Coastal Research* **14** (1998): 1065-1073.

Martin, P. S. "Late Quaternary extinctions: The promise of TAMS ^{14}C dating." *Nuclear Instruments and Methods in Physics Research* **B29** (1987): 179 – 186.

McKie, R. "Diamonds tell tale of comet that killed off the cavemen." *The Observer*, May 20, 2007.

Meltzer, D. J., and Mead, J. I. "The Timing of Late Pleistocene Mammalian Extinctions in North America." *Quaternary Research* **19** (1983): 130.

Omerbashich, M. "Galactic bursts signature in Antarctica ^{10}Be." (2006). Eprint at: http://arxiv.org/abs/physics/0612185.

Raisbeck, G.M., Yiou, F., Bourles, D., Lorius, C., Jouzel, J. and Barkov, N.I., "Evidence for two intervals of enhanced ^{10}Be deposition in Antarctic ice during the last glacial period." Nature, **326** (1987): 273-277.

Raisbeck, G. M., et al. "^{10}Be deposition at Vostok, Antarctica during the last 50,000 years and its relationship to possible cosmogenic production variations during this period." In *The Last Deglaciation: Absolute and Radiocarbon Chronologies* (Proc. NATO ASI Series, vol. 12), edited by E. Bard and W. Broecker, pp. 127-139. Heidelberg: Springer-Verlag, 1992.

Ram, M., and Stolz, M. R. "Possible solar influences on the dust profile of the GISP2 ice core from Central Greenland." *Geophysical Research Letters* **26** (1999): 1043-1046.

Rietmeijer, F. J. "Tin in a chondritic interplanetary dust particle." *Meteoritics* **24** (1989): 43 – 47.

Roach, J. "Comet wiped out early North American culture, animal study says." *National Geographic News*, May 23, 2007; http://news.nationalgeographic.com/news/2007/05/070523-comet-impact.html.

Sonett, C. P. "A supernova shock ensemble model using Vostok ^{10}Be radioactivity." *Radiocarbon* **34** (1992):239-245.

Southon, J. R., and Taylor, R. E. "Brief comments on 'Terrestrial evidence of a nuclear catastrophe in Paleoindian times'," *Mammoth Trumpet* **17** (March 2002). [http://www.centerfirstamericans.com/mt.php?a=61&h=firestone]

Thompson, L. G. *Microparticles, Ice Sheets and Climate*. Institute of Polar Studies, Report No. 64. Columbus: Ohio State University, 1977. [http://adsabs.harvard.edu/abs/1976PhDT........15T□]

Topping, W. "Cosmogenic radiocarbon as a source of error at Paleo-Indian sites and evidence for a giant solar flare in prehistory." June 26, 1998, website posting.

Topping, W. "The evidence (some inferential) for a cosmic event in Paleo-Indian times." February 1, 1999, website posting.

Topping, W. "The evidence for neutrons in an ET/ELE (extraterrestrial/extinction level event) in prehistory about 12,500 yrs ago." April 2007, website posting. [http://joehaydn.org/prehistoric_neutrons.htm□]

Usoskin, I. G., et al. "Solar proton events in cosmogenic isotope data." *Geophysical Research Letters* **33** (2006): 2006GL026059.

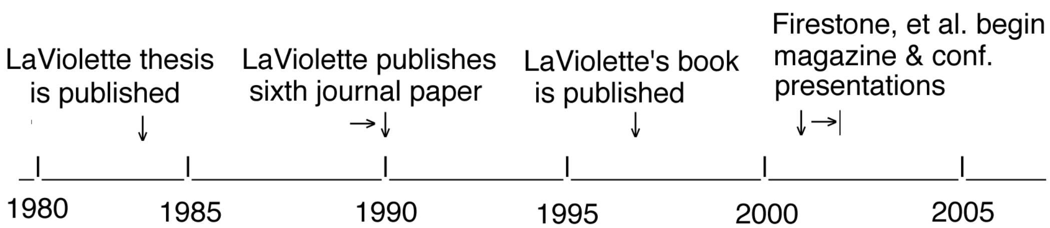
Voelker, A. H. L., et al. "^{14}C levels in the Iceland sea from 25 - 53 kyr and their link to the Earth's magnetic field intensity." *Radiocarbon* **40** (1998): 517.

West, A, "Extraterrestrial markers found at Clovis sites across North America." Paper PP41A-02, May 2007 AGU Conference, Acapulco, Mexico. [http://www.agu.org/meetings/sm07/sm07-sessions/sm07_PP41A.htm]

Wolbach, W. S., et al. "Is there evidence for impact-triggered fires at the end Pleistocene?" Paper PP43A-03, May 2007 AGU Conference, Acapulco, Mexico. [http://www.agu.org/meetings/sm07/sm07-sessions/sm07_PP43A.html]

Zook, H. A., Hartung, J. B., and Storzer, D. "Solar flare activity: Evidence for large-scale changes in the past." *Icarus* **32** (1977): 106.

Development History of the Superwave Theory
and Firestone-West Comet Explosion Theory



Timeline

1969 Thomas Gold presents lunar evidence which indicates that the Earth-Moon system has been exposed to a solar nova outburst or to a very large solar flare within the last 30,000 years.

1977 Herbert Zook, et al. present lunar evidence that the Sun's solar flare activity was extremely high at the end of the ice age, reaching a peak around 16,000 years ago. They propose this was somehow associated with the retreat of the ice sheets.

1977 Wdowczyk and Wolfendale propose that very rare, extremely large solar flare events could be responsible for producing mass extinctions.

1979 LaViolette begins doctoral research on the Galactic superwave hypothesis and its possible cause of abrupt climatic change and mass extinction, with special focus on the deglacial interval occurring between 11,000 and 15,000 years BP.

1981 - 1982: LaViolette conducts a cosmochemical study of ice age polar ice and reports the occurrence of several cosmic dust concentration peaks. This was the first study of its kind to be carried out and the first discovery of high iridium and nickel levels in ice age polar ice.

1983 LaViolette publishes his Ph.D. dissertation and presents papers on its conclusions at the American Geophysical Union meeting and Meteoritical Society meeting; see abstracts.

1983 (August) LaViolette begins applying for funds to do additional ice core research to continue to explore his discovery of high cosmic dust concentrations in polar ice.

1984 LaViolette heads the Starburst Foundation, a research institute dedicated to the study of Galactic superwave catastrophes and increasing public awareness about them.

1984 One year after receiving a copy of LaViolette's dissertation, Victor Clube and Bill Napier publish a paper in *Monthly Notices* proposing a comet breakup and terrestrial bombardment as the cause of the elevated Ir and Ni concentrations LaViolette had found in polar ice.

1985 - 1993 LaViolette publishes 6 papers in refereed journals communicating various aspects of his doctoral findings. Submits more than 50 proposals seeking funding to do cosmic dust ice core studies of the period spanning the Pleistocene megafaunal extinction. No funding was obtained.

1985 LaViolette presents his findings on Galactic superwaves and their cause of the climatic change and mass extinction at the end of the last ice age at the Galaxy and Solar System Conference. He also begins to present public lectures on this subject.

1987 LaViolette publishes a paper in *Monthly Notices* challenging Clube and Napier's 1984 paper. He points out the flaws in their comet debris bombardment interpretation and demonstrates that his Ir and Ni findings are more likely due to a superwave induced cosmic dust influx.

1988 LaViolette is granted 17 Vostok ice core samples from the Soviet Union ice core program, thereby initiating the first ice core exchange program between the U.S. and U.S.S.R. Funding requests made to the National Science Foundation and NASA for conducting a cosmic dust analysis of the samples.

1989 LaViolette heads the Foundation's International Outreach Project to make governments around the world aware of hazards associated with the possible arrival of a Galactic superwave event. Organizations post his superwave alert write-up on the internet.

1990 LaViolette publishes a paper in *Anthropos* which among other things elaborates on the idea that the megafaunal demise was due to a coronal mass ejection catastrophe and associated flood cataclysm.

1990 Clube and Napier publish their book *The Cosmic Winter* attributing the catastrophe at the end of the ice age to the breakup of a giant comet.

1997 LaViolette publishes his book *Earth Under Fire,* which is written for a general audience and presents the Galactic superwave theory and supporting evidence with its main focus on the mass extinction event at the end of the ice age. Here he also discusses ancient myths and legends reporting about this event.

1997 - present: LaViolette presents many conference lectures about the superwave theory and its impact at the end of the ice age. He is also invited to speak about it on many radio talk shows.

1998 Conscious Wave Productions produces a video on Dr. LaViolette's superwave theory, graphically illustrating the demise of the Pleistocene megafauna as arising from a coronal mass ejection impact conflagration and ensuing glacier wave meltwater deluge. The video, titled *Earth Under Fire*, is aired on TV and sold widely.

1998 William Topping posts webpages summarizing doctoral research he had begun 7 years earlier in which he found evidence of anomalous radiocarbon dates and unusual pitting in Paleo-Indian artifacts. His findings led him to conclude that the megafaunal mass extinction at the Allerod/Younger Dryas boundary was caused by a conflagration induced by a solar coronal mass ejection.

2001 Richard Firestone and William Topping publish a general reader article in the paleontological magazine *Mammoth Trumpet* attributing the terminal Pleistocene megafaunal extinction to the occurrence of a supernova 250 light years away which they claim exploded around 41,000 years ago. They claim that the radiation influx was so intense as to reset the artifact radiocarbon dates to values 25,000 to 30,000 years younger than their actual age and allege that the artifacts actually date from around 39,000 to 55,000 years B.P.

2002 Southon and Taylor rebut the Firestone-Topping article. They note that if the Earth had been exposed to such high radiation levels current radiocarbon date levels should be thousands of times higher than actually observed. Indeed, this pointed out a major flaw in the Firestone-Topping theory.

2005 LaViolette publishes a paper in *Planetary & Space Science* that provides additional supporting evidence for his cosmic ray/cosmic dust/solar activity scenario. This shows that the Main Event acidity spike found in 15,800 year old Antarctic polar ice registers a major long-term incursion of cosmic dust into the solar system. He proposes this influx may have been responsible for triggering the subsequent increase in solar activity that was partly responsible for the catastrophic events ending the last ice age.

2005 Richard Firestone teams up with Alan West and the two present a modified version of the Firestone supernova explosion theory at the 2nd International World of Elephants Conference. In this version the supernova is accompanied by the impact of a 10 km diameter comet causing the demise of the Pleistocene megafauna around 12,900 years B.P. The claim for major resetting of radiocarbon dates is judicially avoided. However, in this version around 34,000 years B.P. the supernova showers the Earth with iron rich micrometiorite grains that have traveled 250 light years and also passed through the Earth's atmosphere at relativistic speeds, i.e., 3% of the speed of light. Their incredible announcement is preceded by a Lawrence Berkeley Laboratory press release.

2006 Firestone, West, and Warwick-Smith publish their book *Cycles of Cosmic Catastrophes* describing their supernova/comet explosion theory.

2007 The Younger Dryas Boundary (YDB) group, led by Firestone and West, present evidence for the Firestone-West supernova/comet theory with some additional modifications. The comet size is now reduced to 4 km in diameter and claimed to have exploded over the northern ice cap showering debris across the continent. Debris from this explosion is proposed to have produced the Carolina Bays.

2007 (Sept) LaViolette points out 20 major flaws in the supernova/comet theory of Firestone, West and Warwich-Smith, published in their 2006 book.