

THE PALEOINDIAN OCCUPATION of North America, theoretically the point of entry of the first people to the Americas, is traditionally assumed to have occurred within a short time span beginning at about 12,000 yr B.P. This is inconsistent with much older South American dates of around 32,000 yr B.P.¹ and the similarity of the Paleoindian toolkit to Mousterian traditions that disappeared about 30,000 years ago.² A pattern of unusually young radiocarbon dates in the Northeast has been noted by Bonnichsen and Will.^{3,4}

Our research indicates that the entire Great Lakes region (and beyond) was subjected to particle bombardment and a catastrophic nuclear irradiation that produced secondary thermal neutrons from cosmic ray interactions. The neutrons produced unusually large quantities of ²³⁹Pu and substantially altered the natural uranium abundance ratios (²³⁵U/²³⁸U) in artifacts and in other exposed materials including cherts, sediments, and the entire landscape. These neutrons necessarily transmuted residual nitrogen (¹⁴N) in the dated charcoals to radiocarbon, thus explaining anomalous dates.

The evidence from dated materials

We investigated a cluster of especially young radiocarbon dates concentrated in the north-central area of North America. For example, at the Gainey

Terrestrial Evidence of a Nuclear Catastrophe in Paleoindian Times

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Sites discussed in this article

site in Michigan a 2880 yr B.P. radiocarbon date was reported, while the thermoluminescence date for that site is 12,400 yr B.P.⁵ Other anomalous dates

found at Leavitt in Michigan,⁶ Zander and Theford in Ontario,⁷ Potts in New York,⁸ Alton in Indiana,⁹ and Grant Lake in Nunavut¹⁰ are summarized in Table 1. The Grant Lake Paleoindian site is most remarkable because its 160 [rc] yr B.P. age is nearly contemporary, while adjacent and

deeper samples give ages of 1480–3620 [rc] yr B.P.

Stratigraphic associations place Paleoindian occupations at depth on the prehistoric North American landscape on sediments that form the old C horizon composed of parent material, Wisconsinan deposits that predate Holocene sediment buildup.^{11,12,13} The young Paleoindian dates cannot be correct, particularly since there are no patterned anomalies noted in later-period prehistoric assemblages relating to higher stratigraphic positions. In a pioneering study of the Paleoindian site at Barnes, Michigan, Wright and Roosa observed that Paleoindian artifacts were deposited before the formation of spodosols ceased in this area about 10,000 yr B.P.¹⁴ This conclusion was based on observing that cemented sediments on artifacts, found outside their original context, defines their original stratigraphic position.

Table 1. Site and particle impact data for Paleoindian artifacts, charcoals, and cherts.

Site	Coordinates	Particle/track/pit			¹⁴ C date (yr B.P.)	Comments
		Density /mm ²	Depth (μm)	Angle (approx.)		
Baker, N.M.	34.5° N, 106.4° W	130 ± 60	10	90°		pits; artifact
Alton, Ind.	38.7° N, 86.2° W	700 ± 300	60	90°	1860	particles; chondrules; unaltered flake with embedded particles
Taylor, Ill.	39.1° N, 88.2° W	c. 400	60	90°		particles; chondrules; outer flake
Shoop, Pa.	40.4° N, 76.5° W	130 ± 60	5	5°		tracks; flake
Butler, Mich.	42.4° N, 84.3° W					particles; flake
Leavitt, Mich.	42.4° N, 84.3° W	400 ± 90	120	90°	2830 ± 115	particles; tracks; no chondrules; flake
Gainey, Mich.	42.6° N, 83.4° W	460 ± 70	120	90°	2880 ± 175 [▼]	pits; particles; tracks; no chondrules; flake
Theford, Ont.	43.1° N, 81.5° W				2130 ± 230	
Potts, N.Y.	43.2° N, 76.2° W				3810	
Zander, Ont.	43.4° N, 79.2° W	200 ± 140	60	85°	3380 ± 420	particles; no chondrules; flake
Grant Lake, Nun.	63.4° N, 100.3° W				160 ± 65	

[▼]12,360 ± 1240 yr B.P. date determined by thermoluminescence

The evidence from particle bombardment

Sediment profiles were taken at Paleoindian sites and at numerous widely separated control locations in Michigan. The C sediment horizon is clearly recognized by its transitional color and confirmed by elevated concentrations of potassium and other isotopes. Color and chemistry are key indicators of this very old soil^{11,12,13} derived from parent materials and associated postglacial runoff.¹⁵ At Gainey, large quantities of micrometeorite-like particles appear to be concentrated near the boundary between the B and C sediment horizons. They can be separated with a magnet and are identified by the presence of chondrules and by visual evidence of sintering and partial melting. These particles, dissimilar to common magnetites, are found in association with a high frequency of “spherules.” The depth profiles for potassium and particles at the Gainey site are compared in Fig. 1. Minor vertical sorting of particles is apparent, with a shallow spike of particles near the surface probably resulting from modern agricultural or industrial activity. Total gamma-ray counting of sediment profiles in the various locations invariably showed increased radioactivity at the B-C boundary consistent with enhanced potassium (⁴⁰K) and possibly other activities.

Microscopic examination of chert artifacts from several widely separated Paleoindian locations in North America revealed a high density of entrance wounds and particles at depths that are evidence of high-velocity particle bombardment. Chondrules were identified visually; their presence necessarily indicates heating during high-speed entry into the atmosphere. The depth of penetration into the artifacts implies that the particles entered with substantial energy.¹⁶ Field simulations with control cherts for large particles (100–200 microns) suggest an entrance velocity greater than 0.4 km/s, and experiments at the National Superconducting Cyclotron Laboratory indicate that the smaller particles left tracks comparable to about 526 MeV iron ions (⁵⁶Fe) in Gainey artifacts. Similar features are not observed in later-period prehistoric artifacts or in bedrock chert sources. Track angles were estimated visually; track densities were measured with a stage micrometer; track depths were found by adjusting the microscope focus through the track. These data are summarized in Table 1.

Track and particle data in Table 1 suggest that the total track volume (density times depth) is highest at the Michigan, Illinois, and Indiana sites and decreases in all directions from this region, consistent with a widespread catastrophe concentrated over the Great Lakes region. The nearly vertical direction of the tracks left by particle impacts at most sites suggests they came from a distant source.

The evidence from uranium and plutonium

Natural uranium, which is ubiquitous in cherts, has a ²³⁵U/²³⁸U isotopic ratio of 0.72 percent, which varies by less than 0.1 percent in natural sources.¹⁷ Significant variations in the isotopic ratio do not occur because of chemical processes; however, a thermal neutron bombardment depletes ²³⁵U and thus alters the ratio. Solar or galactic cosmic rays interacting with matter produce fast secondary neutrons that become thermalized by scattering from surrounding materials. Thermal neutrons see a target of large cross section (681 barns)^A for destroying ²³⁵U, compared with a target of only 2.68 barns for neutron capture on ²³⁸U. Therefore, despite the low abundance of ²³⁵U, about 1.8 times as many ²³⁵U atoms are destroyed as ²³⁸U atoms by thermal neutrons.

If a large cosmic-ray bombardment impacted the earth and irradiated the prehistoric landscape with thermal neutrons, the ²³⁵U/²³⁸U ratio would be changed; ²³⁹Pu would be produced from neutron capture on ²³⁸U, followed by the decay of ²³⁹U. Neutrons colliding with nitrogen (1.83 barns) would create ¹⁴C in exactly the same way ¹⁴C is normally produced in the upper atmosphere, necessarily resetting the radiocarbon dates of any organic materials lying near the surface on the North American prehistoric landscape—including charcoals at Paleoindian sites—to younger values. ²³⁹Pu produced during the bombardment will also be partly destroyed by thermal neutrons with 1017 barn cross section. Assuming ²³⁹Pu doesn't mobilize, it will

^AA barn is a unit of area equal to 10⁻²⁴ cm², used in nuclear physics. The fraction of isotopes that are transformed by a nuclear reaction is given by $\sigma \times I$, where σ is the cross section in cm² of the target presented by an atom, and I is the neutron flux per cm² impinging on the target. Most neutron-induced reactions involve the capture of a neutron to produce a heavier isotope of the same element. Exceptions include ¹⁴N, which captures a neutron and emits a proton to produce ¹⁴C; and ²³⁵U, which mainly fissions into two lighter elements. The relative size of isotopes in chert is shown in figure “A neutron's view of chert.”

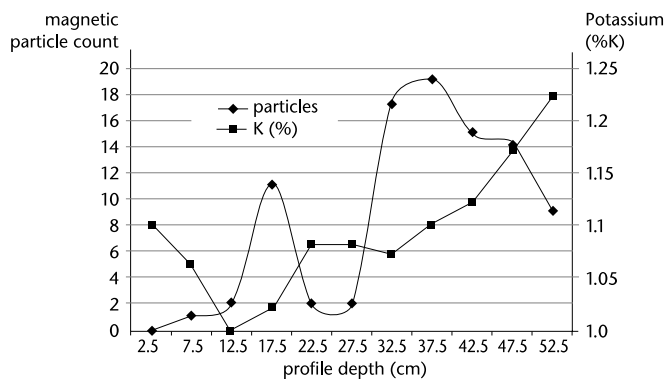


Figure 1. Sediment profile showing the number of magnetic particles and the potassium concentration at the Gainey site. The potassium concentration was determined by ⁴⁰K gamma-ray counting; the uncertainty is within the plotted points. Particle frequencies were counted under a microscope for 0.25-ml samples at each interval.

decay back to ²³⁵U (half-life 24,110 yr), partially restoring the normal abundance.

Paleoindian artifacts from Gainey, Leavitt, and Butler, and two later-period artifacts from the same geographic area of Michigan were analyzed for ²³⁵U content by gamma-ray counting at the Phoenix Memorial Laboratory, University of Michigan. They were compared with identical chert types representative of the source materials for the artifacts. Control samples were extracted from the inner core of the purest chert known to be utilized by prehistoric people. The Paleoindian artifacts contained about 78 percent as much ²³⁵U as the controls and later-period artifacts, suggesting substantial depletion. *Depletion of ²³⁵U necessarily indicates that thermal neutrons impacted these artifacts and the surrounding prehistoric landscape.*

Various artifacts, cherts, sediments, and a control sample containing about 0.2 percent uranium obtained from uraninite were sent to the McMaster University Centre for Neutron

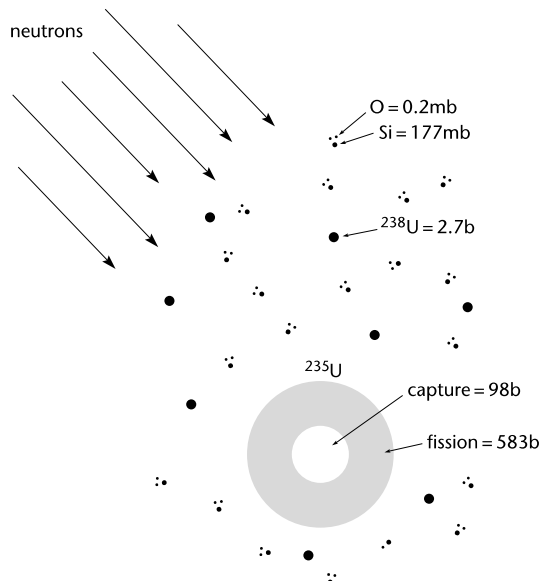
Activation Analysis to determine ²³⁵U concentration by delayed neutron counting and ²³⁸U concentration by activation analysis. These results are shown in Table 2. The ²³⁵U/²³⁸U ratios for all samples except the control deviated substantially from the expected ratio. McMaster ran additional calibration standards and has considerable expertise analyzing low-level uranium. This analysis was sensitive to a few ppb for ²³⁵U and 0.1–0.3 ppm for ²³⁸U, more than sufficient to precisely analyze the uranium-rich chert samples (0.7–163.5 ppm). Most samples were depleted in ²³⁵U, depletion increasing geographically from the southwest (Baker, Chuska chert, 17 percent) to the northeast (Upper Mercer, 77 percent), as shown in Table 2. This is consistent with cosmic rays focused towards northern latitudes by Earth’s magnetic field. Only a very large thermal neutron flux, greater than 10²⁰ n/cm², could have depleted ²³⁵U at all locations.

Samples of unaltered flakes from Taylor and sediment originally adjacent to Gainey artifacts showed ²³⁵U enriched by 30 percent. Both samples were closely associated with the particles described above. The position of these samples appears to be related to the enrichment, which cannot be explained by thermal neutrons from the bombardment. To test this, we bathed another Taylor flake in 48-percent HF at 60°F for ten minutes to remove the outer 70 percent of the sample and the attached particles. Analysis showed the “inner” flake depleted in ²³⁵U by 20 percent, consistent with the other depleted cherts.

Samples of Gainey sediment and Taylor flakes were analyzed for plutonium by Nuclear Technology Services, Inc., of Roswell, Georgia, which specializes in radiochemistry using standard methodology. The plutonium, with an aliquot of NIST-traceable ²⁴²Pu added, was chemically separated on an anion exchange resin column and counted on an alpha-particle spectrometer. The ²³⁹Pu/²³⁸U ratios in both samples were approximately 10 ppb, vastly exceeding the expected ratio of 0.003 ppb.¹⁸ The results of this analysis are shown in Table 2.

Chert is a glass-like material highly impervious to penetration by any nuclear fallout that might also contribute ²³⁹Pu. We

A neutron’s view of chert



Chert (SiO₂, silicon dioxide or silica) is an interesting material. Because silicon and oxygen present small cross sections to neutrons, neutrons are only slowly absorbed in chert. Atoms of uranium, a natural impurity in chert, have much larger cross sections for neutron capture. ²³⁵U has a cross section so large that, although it constitutes only 0.72 percent of all uranium, it presents a larger target and is therefore nearly twice as likely to be destroyed by neutrons as ²³⁸U, which is 99.28 percent of all uranium. This is why ²³⁵U becomes depleted in uranium when bombarded by neutrons. (The cross section for ¹⁴N—to produce ¹⁴C—is about the same as for ²³⁸U to capture a neutron.) Since uranium is only a trace impurity in chert, most of the neutrons are captured by silicon atoms, but the neutron flux is attenuated slowly with sample depth. Half the neutrons will penetrate 150 cm of chert, compared with 100 cm for CaCO₃, 60 cm for H₂O, and 6 cm for FeO. Thus, in the event of a thermal neutron-producing event, buried artifacts would be irradiated uniformly and would not attenuate neutrons. Carbon in associated charcoals used for radiocarbon dating has a very small cross section for neutron capture (0.0035 barn), which is only 0.02 percent of the cross section for residual ¹⁴N (1.83 barn). Thus, even small amounts of ¹⁴N in charcoal will disproportionately absorb neutrons, producing ¹⁴C and resetting their radiocarbon clocks.

Table 2. Uranium and plutonium data for Paleoindian artifacts, cherts, sediments, and standards. Sites are ordered by increasing latitude.

Site	Sample	Total uranium (ppm)	²³⁵ U/ ²³⁸ U Ratio (%)	²³⁵ U Depletion (%)	²³⁹ Pu/ ²³⁸ U (ppb)
Control	uraninite	2269 ± 112	0.73 ± 0.04	< 5	
Baker	artifact	163.5 ± 7.6	0.59 ± 0.03	19 ± 4	
Baker	Chuska chert	129.0 ± 6.5	0.60 ± 0.03	17 ± 4	
Alton	flake	56.3 ± 2.7	0.60 ± 0.03	17 ± 4	
Alton	Wyandotte chert	7.7 ± 0.5	0.51 ± 0.06	30 ± 8	
Taylor	outer flake	note a	0.95 ± 0.03	note b	10 ± 1
Taylor	inner flake	8.2 ± 0.5	0.59 ± 0.06	19 ± 8	
Butler	flake	4.6 ± 0.5	0.37 ± 0.12	49 ± 17	
Leavitt	flake	0.6 ± 0.2	<0.5	>30	
Leavitt	Bayport chert	8.1 ± 0.5	0.42 ± 0.06	42 ± 8	
Gainey	sediment	1.39 ± 0.09	0.94 ± 0.09	note b	43 ± 4
Gainey	flake	0.7 ± 0.2	<0.4	>45	c. 90
Gainey	inner artifact [■]	1.6 ± 0.2	<0.15	>79	
Gainey	Upper Mercer chert	1.8 ± 0.3	0.17 ± 0.12	77 ± 17	
Zander	flake	1.0 ± 0.2	<0.25	>65	

^a 3–13 ppm U, weighted average of six measurements.

^b Enriched in ²³⁵U.

[■] Acid-reduced flake core with micrometeorites removed.

analyzed a long-exposed piece of Bayport chert by gamma-ray counting at the LBNL low-background facility for the presence of cesium-137 (¹³⁷Cs), a key indicator of fallout (from nuclear testing), and found none. The B-C interface typically lies sufficiently deep that contamination by fallout is improbable. It is important to note that *fallout cannot explain the depletion of ²³⁵U.*

Since the depletion of ²³⁵U must have resulted from bombardment by thermal neutrons, the presence of ²³⁹Pu from irradiation of ²³⁸U is expected. The total thermal neutron flux required to produce the observed ²³⁹Pu concentration can be calculated from the relative concentrations of ²³⁹Pu (corrected for the decay) and ²³⁸U, and the thermal neutron-capture cross section for ²³⁸U. This neutron flux can then be used to estimate the amount of additional ¹⁴C that would have been produced in charcoal by neutrons colliding with ¹⁴N (¹⁴N cross section = 1.83 barns). The corrected radiocarbon age can then be estimated by comparing the current amount of ¹⁴C in the dated charcoals, determined from their measured radiocarbon age, with the amount of ¹⁴C that would have been produced by the bombardment. For these calculations we assume that charcoal contains 0.05 percent residual nitrogen¹⁹ and that initial ¹⁴C concentrations were the same as today (one ¹⁴C atom for 10¹² ¹²C atoms).

We derive a thermal neutron flux of c. 10¹⁷ n/cm² at Gainey, which corresponds

to an approximate date of 39,000 yr B.P. No radiocarbon date is available for the more southerly Taylor site, but for the conventional range of accepted Paleoindian dates the neutron flux would be c. 10¹⁶ n/cm², giving a date of about 40,000 yr B.P. These calculations necessarily neglect differences in the neutron flux experienced by the dated charcoal and the artifacts, the effects of residual ²³⁹Pu from previous bombardments, and loss of ²³⁹Pu due to leaching from chert over time.

The neutron flux calculated from the ²³⁵U/²³⁸U ratio is more than 1000 times that implied by the level of ²³⁹Pu. Since ²³⁹Pu decays to ²³⁵U, partly restoring the natural abundance, it appears that substantial quantities of ²³⁹Pu have migrated out of the chert. This mobility is demonstrated at the Nevada Test Site, where plutonium, produced in nuclear tests conducted by the U.S. between 1956 and 1992, migrated 1.3 km.²⁰ It has also been shown that atoms produced by radioactive decay or nuclear reaction become weakly bound to the parent material and pass more readily into solution than isotopes not affected.²¹ Both ²³⁹Pu and ²³⁵U are thus expected to be mobile, complicating any analysis. This is consistent with the enrichment of ²³⁵U in the two external samples where migrating ²³⁹Pu or ²³⁵U may have been trapped, thus enriching the relatively uranium-poor outer regions. Alternatively, excess ²³⁵U may have been carried in by the particles. Ra-

diocarbon produced in situ by irradiation should also be mobile. If ¹⁴C is more mobile than ²³⁹Pu, then the dates calculated above should be decreased accordingly.

Redating North American sites

The 39,000 yr B.P. date proposed for the Gainey site is consistent with the prevailing opinion among many archaeologists about when the Americas were populated. It is also commensurate with dates for South American sites and with a Mousterian toolkit tradition that many see as the Paleoindian precursor. The proposed date for the Gainey site also falls closer in line with the radiocarbon date for a Lewisville, Texas, Paleoindian site of 26,610 ± 300 yr B.P.^{22,23} and radiocarbon dates as early as c. 20,000 yr B.P. for Meadowcroft Rockshelter.²⁴ Since the Lewisville and Meadowcroft sites were likely exposed at the same time to thermal neutrons, we estimate that their dates should be reset to c. 55,000 yr B.P. and c. 45,000 yr B.P., respectively.

It is likely that Paleoindians occupied low latitudes during the full glacial and migrated to more northerly areas as the ice front retreated. Therefore the pattern of dates makes sense from the archaeologist's point of view. Dates for North American sites should generally be reset by up to 40,000 years, depending on latitude and overburden.

Geologists believe that before c. 15,000 yr B.P. the Wisconsinan glaciation covered the more northerly locations where Paleoindian sites have been found.²⁵ The ice sheet would have shielded the landscape and any artifacts from an irradiation. (The Gainey thermoluminescence date of 12,400 yr B.P. is probably a result of the heat generated by the nuclear bombardment at that time, which would have reset the TL index to zero.) The modified dates for Paleoindian settlements suggest that the timetable for glacial advance sequences, strongly driven by conventional radiocarbon dates, should be revisited in light of the evidence presented here of much older occupations than previously thought."

The evidence from tree rings and marine sediments

A large nuclear bombardment should have left evidence elsewhere in the radio-

carbon record. It is well known that radiocarbon dates are increasingly too young as we go back in time. The global Carbon Cycle suggests that ^{14}C produced by cosmic rays would be rapidly dispersed in the large carbon reservoirs in the atmosphere, land, and oceans.²⁶ We would expect to see a sudden increase in radiocarbon in the atmosphere that would be incorporated into plants and animals soon after the irradiation; after only a few years, most of the radiocarbon would move into the ocean reservoirs. The ^{14}C level in the fossil record would reset to a higher value. The excess global radiocarbon would then decay with a half-life of 5730 years, which should be seen in the radiocarbon analysis of varved systems.

Fig. 2 plots ^{14}C from the INTCAL98 radiocarbon age calibration data of Stuiver et al. for 15,000–0 yr B.P.²⁷ and Icelandic marine sediment ^{14}C data measured by Voelker et al. for 50,000–11,000 yr B.P.²⁸ Excess ^{14}C is indicated by the difference between the reported radiocarbon dates and actual dates. Sharp increases in ^{14}C are apparent in the marine data at 40,000–43,000, 32,000–34,000 and c. 12,000 yr B.P. These increases are coincident with geomagnetic excursions^B that occurred at about 12,000 (Gothenburg), 32,000 (Mono Lake), and 43,000 yr B.P. (Laschamp),²⁹ when the reduced magnetic field would have made Earth especially vulnerable to cosmic ray bombardment. The interstitial radiocarbon data following the three excursions were numerically fit, assuming exponential decay plus a constant cosmic ray-produced component. The fitted half-lives of 5750 yr (37,000–34,000 yr B.P.), 6020 yr (32,000–16,000 yr B.P.), and 6120 yr (12,000–0 yr B.P.) are in good agreement with the expected value.

We also determined that contemporary radiocarbon contains about 7 percent residual ^{14}C left over from the catastrophe. The constant cosmic ray production rate was about 34 percent higher for the Icelandic sediment than the INTCAL98 samples, perhaps implying higher cosmic ray rates farther north. Disregarding fluctuations in the data from variations in ocean temperatures and currents, the results are clearly consistent with the decay of radiocarbon following the three geomagnetic excursions.

In Fig. 2, the sharp drop in ^{14}C activity before 41,000 yr B.P. suggests that global radiocarbon increased by about 45 percent at that time and by about 20 percent at 33,000 and 12,000 yr B.P. The results are remarkably consistent with Vogel's comparison of ^{14}C and U-Th dates of a stalagmite that indicates global radiocarbon increased about 75 percent from 30,000 to 40,000 yr B.P. and about 30 percent around 18,000 yr B.P.³⁰

McHargue et al. found high levels of ^{10}Be in Gulf of California marine sediments at 32,000 and 43,000 yr B.P.^C that could not be explained by magnetic reversal alone and were attributed to cosmic rays, possibly from a supernova.²⁹ The geomagnetic excursion at 12,500 yr B.P. coincides with the thermoluminescence date from Gainey, and additional evidence for a cosmic ray bombardment at that time is found in the increases of ^{10}Be ,³¹

^BThe alignment of magnetic particles in sediment indicates that the Earth's magnetic poles have repeatedly reversed their polarity in the past. Complete magnetic excursions occurred about 10 times in 4.5 million years; the last reversal occurred about 700,000 years ago. Magnetic excursions occur every 10,000–20,000 years when the Earth's magnetic field becomes weak, and the poles may even reverse for a short time.

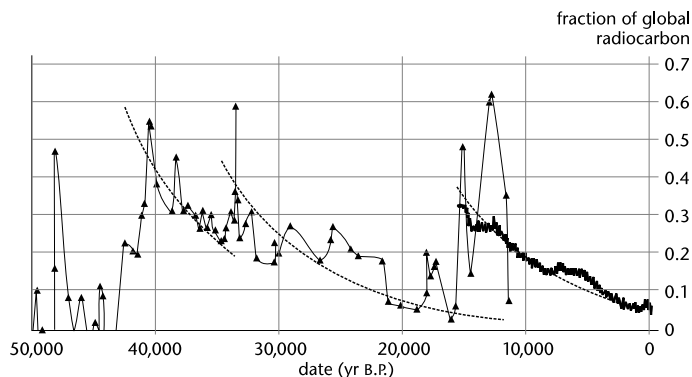


Figure 2. INTCAL98 radiocarbon age calibration data from Stuiver et al. (jagged curve), and Icelandic marine ^{14}C data (Voelker et al.³¹) for 50,000–11,000 yr B.P. (triangles) were independently fit assuming a constant galactic cosmic ray-induced ^{14}C background plus residual radiocarbon decaying from nuclear events at 41,000, 33,000, and 12,500 yr B.P. The residual ^{14}C is plotted as a fraction of total observed ^{14}C (global radiocarbon), assuming equilibrium was rapidly achieved over the time scale of the measurements. Global carbon, primarily dissolved in the oceans, thoroughly mixes over a time scale of centuries. The smooth curves show the expected decay curves for the three events assuming ^{14}C half-life = 5730 yr. The fit to the data gives 6120 yr (12,000–0 yr B.P.), 6020 yr (32,000–16,000 yr B.P.), and 5750 yr (37,000–34,000 yr B.P.). Fluctuations in the measurements from the decay curves may result from variations in ocean temperatures and currents. The sharp drop in ^{14}C activity before 41,000 yr B.P. suggests that this series of events was initiated by an event that increased global ^{14}C by about 45 percent, followed by two events each increasing ^{14}C by about 20 percent. About 7 percent of modern radiocarbon is residue from these early events. The galactic cosmic ray ^{14}C background component was about 34 percent larger for the Icelandic data, consistent with a higher expected cosmic ray flux at Northern latitudes.

Ca,³² and Mg³² in Greenland ice cores around 12,500 yr B.P. Similar increases are also seen in the data for NO_3^- , SO_4^- , Mg^+ , Cl^- , K^+ , and Na^+ ions in Greenland ice cores.³³ This occurrence can be dated precisely to 12,500 ± 500 yr B.P., an average of the remarkably consistent concentration peak centroids in the Greenland ice core data. Significant increases at that time are not found in comparable data for the Antarctic, which indicates that the cosmic ray irradiation was centered in the Northern Hemisphere. Weak evidence of an occurrence at 12,500 yr B.P. is seen in the radiocarbon record for marine sediments near

^CBeryllium occurs naturally as ^9Be . ^{10}Be is produced by cosmic rays, mostly protons, striking the atmosphere and breaking apart nitrogen and oxygen. It has a half-life of 1.5 million years. Unlike ^{14}C , which is caught up in the global Carbon Cycle, ^{10}Be is inert and falls as dust. ^{10}Be is produced almost entirely by galactic cosmic rays, which are much higher in energy than solar cosmic rays. Thus any increase in ^{10}Be would be cosmic in origin; and the cosmic ray rate could only change if there were a nearby supernova. During the last Ice Age the ^{10}Be deposition rate in ice at both poles was much higher than today. Gulf of California marine sediments clearly show strong ^{10}Be peaks at 32,000 and 43,000 yr B.P. McHargue argues that these peaks can only be explained by a supernova.

Venezuela,³⁴ confirming that the cosmic ray bombardment was most severe in northern latitudes.

Lunar cosmogenic data also show evidence of increased solar cosmic ray activity at or before 20,000 yr B.P.^{35,36} although these data are not sensitive to earlier irradiation.

The effect of a supernova on Earth

Sonett suggests that a single supernova would produce two or three shock waves, an initial forward shock and a pair of reverse shocks from the initial expansion and a reflected wave from the shell boundary of a more ancient supernova.^{39,40} Fig. 2 shows that each episode in a series produced a similar amount of atmospheric radiocarbon. The sun lies almost exactly in the center⁴¹ of the Local Bubble, believed to be the result of a past nearby supernova event. A candidate for the reverse shock wave is the supernova remnant North Polar Spur, with an estimated age of 75,000 years and a distance of 130 ± 75 parsecs (424 light years),⁴² conveniently located in the north sky from where it would have preferentially irradiated the Northern Hemisphere. Assuming the Taylor flux is average and 1,000 neutrons are produced per erg of gamma-ray energy,⁴³ the catastrophe would have released about 10^{16} erg/cm² (2×10^8 cal/cm²), corresponding to a solar flare of 10^{43} ergs or a gamma-flash of 10^{54} ergs from a supernova about 1 parsec away.

The geographical distribution of particle tracks, ²³⁵U depletion, and ²³⁹Pu concentration shown in Fig. 3 are quite consistent, although the particle tracks seem to be confined to a smaller geographic area. They indicate energy released over the northeastern sector of the U.S., with maximum energy at about 43° N, 85° W, the Michigan area of the Great Lakes region.

A history of suspected cosmic cataclysms over the ages

Wdowczyk and Wolfendale⁴⁴ and Zook³⁶ propose, based on the existing record of solar flare intensities, that solar flares as large as 3×10^{38} ergs should be expected every 100,000 years. Clark et al. estimate that supernovas release 10^{47} – 10^{50} ergs within 10 parsecs of Earth every 100 million years.⁴⁵ Brackenridge suggests that a supernova impacted the earth in Paleoinidian times.⁴⁶ Damon et al. report evidence from the ¹⁴C tree ring record that SN1006, which occurred at a distance of 1300 parsecs, produced a neutron shower of 2×10^8 n/cm².⁴⁷ Castagnoli et al. report evidence of the past six nearby supernovae from the thermoluminescence record of Tyrrhenian sea sediments.⁴⁸ Dar et al. suggest that a cosmic ray jet within 1000 parsec would produce 10^{12} muons/cm² (greater than 3×10^9 eV) and 10^{10} protons and neutrons/cm² (greater than 10^6 eV) and deposit

over 10^{12} erg/cm² in the atmosphere every 100 million years.⁴⁹ A cosmic ray jet is also predicted to produce heavy elements via the r-process and could be a source of ²³⁵U enriched up to 60 percent in uranium.

The Paleoinidian catastrophe was large by standards of all suspected cosmic occurrences. Normal geomagnetic conditions would focus cosmic rays towards the magnetic poles, concentrating their severity in those regions. However, low magnetic field intensity during a geomagnetic excursion may have allowed excessive cosmic rays to strike northeastern North America. (Whether the geomagnetic excursion admitted cosmic radiation, or the radiation caused the excursion, is uncertain. Given our present state of knowledge, cause and effect in this instance are unclear.) The presence of a nearby small and dense interstellar cloud may explain the origin of the particle bombardment.⁵⁰ The size of the initial catastrophe may be too large for a solar flare, but a sufficiently powerful nearby supernova or cosmic ray jet could account for it. It appears that the catastrophe initiated a sequence of events that may have included solar flares, impacts, and secondary cosmic ray bombardments.

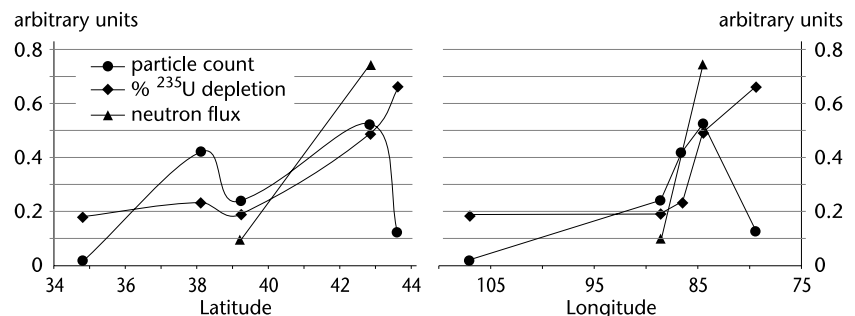
A devastating effect on Earth

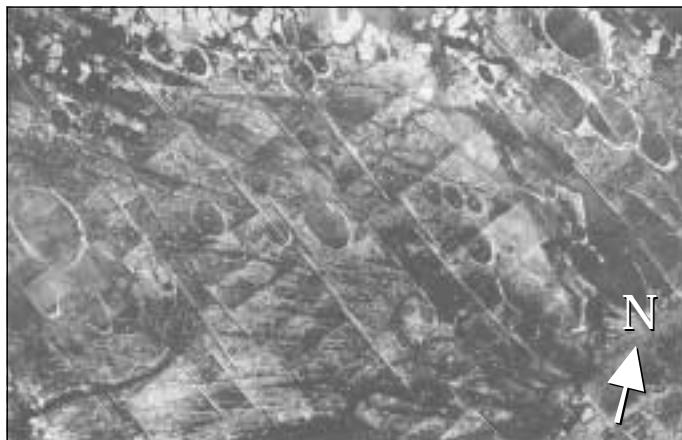
The enormous energy released by the catastrophe at 12,500 yr B.P. could have heated the atmosphere to over 1000°C over Michigan, and the neutron flux at more northern locations would have melted considerable glacial ice. Radiation effects on plants and animals exposed to the cosmic rays would have been lethal, comparable to being irradiated in a 5-megawatt reactor more than 100 seconds.

The overall pattern of the catastrophe matches the pattern of mass extinction before Holocene times. The Western Hemisphere was more affected than the Eastern, North America more than South America, and eastern North America more than western North America.^{51,52,53} Extinction in the Great Lakes area was more rapid and pronounced than elsewhere. Larger animals were more affected than smaller ones, a pattern that conforms to the expectation that radiation exposure affects large bodies more than smaller ones.^{54,55} Sharp fluctuations of ¹⁴C in the Icelandic marine sediments at each geomagnetic excursion are interesting; because global carbon deposits in the ocean sediments at a rate of only about 0.0005 percent a year, a sudden increase in sediment ¹⁴C may reflect the rapid die-off of organisms that incorporated radiocarbon shortly after bombardment.

Massive radiation would be expected to cause major mutations in plant life. Maize probably evolved by macro-mutation at

Figure 3. Comparison of relative particle volume, depletion of ²³⁵U, and neutron flux as a function of latitude and longitude. The neutron flux is calculated from the measured ²³⁹Pu activity and ²³⁸U concentration in the chert. The data have been renormalized to a common scale for comparison.





A shock wave of the magnitude that would be expected from a supernova may have gouged out the Carolina bays, 500,000 depressions spread over an area of 100,000 square miles on the Atlantic coast from North Carolina to Florida. First noted in aerial photographs in the 1930s, they date to Paleoindian or late glacial times.^{37,38} At least 16 hypotheses involving terrestrial and extra-terrestrial causes have been postulated to explain their origin. In this mosaic of 1930s aerial photos shot in the vicinity of Myrtle Beach, S.C., the large depression at extreme left measures about a mile along its major axis. It is noteworthy that the elliptical depressions are all oriented with their major axes pointing towards the Great Lakes region.

FROM THE ORIGIN OF THE CAROLINA BAYS, BY DOUGLAS JOHNSON.
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that time,^{55,56} and plant domestication of possibly mutated forms appears worldwide after the Late Glacial period. For example, there was a rapid transition from wild to domesticated grains in the Near East after the catastrophe.⁵⁷

Implications for future study

Much of what we assume about the Paleoindian period and the peopling of the Americas has been inferred from conventional radiocarbon chronology, which often conflicts with archaeological evidence. This work mandates that conventional radiocarbon dates be reinterpreted in light of hard terrestrial evidence of exposure of the radiocarbon samples to a cosmological catastrophe that affected vast areas of North America and beyond. A nuclear catastrophe can reset a group of unrelated artifacts to a common younger date, creating gaps and false episodes in the fossil record. Geographical variation and complicated overburdens may further confuse the interpretation. Scrutiny of Paleoindian artifacts and the North American paleolandscape, associated stratigraphic sediments, coupled with continued radiological investigations, may provide more evidence for the cosmic catastrophe and new clues to the origin of Paleoindians.

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Acknowledgments

This paper results from dissertation research that began in 1990, most

recently funded by a National Science Foundation Physics Division, by William Topping. Support of Richard Firestone by the Director, Office of Energy Research, Division of Nuclear Physics, of the Office of High Energy and Nuclear Physics of the U.S. Department of Energy is greatly appreciated. The contributions of particular individuals over the years have been invaluable. Tony Baker, Kurt Carr, Chris Ellis, Mima Kapches, Ronald Leshner, Donald B. Simons, James Taylor, Curtis Tomak, John Tomenchuk, and Henry Wright in particular should be thanked for their contributions of artifacts which provided essential information. Alan Smith contributed important experimental data for this paper. We particularly acknowledge the participation of the Royal Ontario Museum and the Smithsonian Institution. In addition, there have been many invaluable contributions of time, analysis, and commentary by physicists, archaeologists, and geologists from the National Superconducting Cyclotron Laboratory at Michigan State University, Phoenix Memorial Laboratory and the Department of Physics at the University of Michigan, Departments of Anthropology and Geology at Wayne State University, Department of Physics at Washington University in St. Louis, Museum of Anthropology at the University of Michigan, Department of Physics at the University of Arizona, Harvard Cyclotron at Harvard University, Oak Ridge National Laboratory, Los Alamos National Laboratory, Johnson Space Center, the State University of Pennsylvania, Lawrence Livermore National Laboratory, and the Lawrence Berkeley National Laboratory.

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