Response to the Comments by J.R. Southon and R.E. Taylor on "Terrestrial Evidence of a Nuclear Catastrophe in Paleoindian Times".

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Southon and Taylor have commented on the enormity of the cosmic ray events reported in our Mammoth Trumpet paper[1] and questioned whether a common problem with radiocarbon dates at Paleoindian sites even exists. The magnitude of the events that we reported is based on neutron fluxes derived directly from uranium and plutonium abundance anomalies that were measured by reputable independent laboratories. Recent new results now exclude the massive neutron irradiations that we reported. Nevertheless, the cosmogenic isotope record, coupled with recent astronomical observations, provides direct evidence for the likely influence of nearby supernovae on radiocarbon dates at Paleoindian sites.

In our paper we reported measurements of depleted ^{235}U in cherts and sediments using Neutron Activation Analysis (NAA) at the McMaster Reactor. These results, summarized in Table 1, were consistent with a cosmic event that would have produced a terrestrial neutron flux of ~10^{20} neutrons/$cm^2\cdot s$. We also measured ^{239}Pu concentrations with radiochemical methods at Nuclear Technology Services that were consistent with a 10^{17} neutrons/$cm^2\cdot s$ event. At the USGS in Menlo Park[2], additional $^{235}U/^{238}U$ ratios were measured using Thermal Ionization Mass Spectroscopy (TIMS). The TIMS results for representative cherts and a uraninite standard are shown in Table 1. In each case ^{235}U depletion was found to be less than 1%, consistent with a neutron flux <10^{19} neutrons/$cm^2\cdot s$. TIMS is a more direct method for the analysis of isotope ratios. McMaster has not provided additional information to support their results, although corrections for fast neutrons produced by fission within the samples may have been important. The TIMS results indicate that large uranium depletions can no longer be considered credible.

The measured $^{239}Pu/^{238}U$ ratios are also summarized in Table 1. An additional result for Bayport chert flake from the Leavitt site has been added. Although these measurements are consistent with a large enhancement over expected background ^{239}Pu concentrations, no correction for contamination from fallout was applied. The measured ^{239}Pu activity was typically ~0.2 Bq/kg in both sediments and cherts. However, ^{239}Pu activity in surface sediment from nuclear testing is typically ~5 Bq/kg[3,4,5,6] at 40-50° latitude. The ^{239}Pu activity is maximal at that latitude although activity is expected to decline sharply with depth. Our original observation of ^{235}U depletion inferred the production of excess ^{239}Pu, but in the absence of evidence for depleted uranium it is more reasonable to assume that modern ^{239}Pu must have invaded the chert and an anomaly is unlikely. There is no longer compelling evidence for a massive neutron event.

Another argument for a major cosmic event prior to 12,500 BP exists in the radiocarbon record shown in Figure 1 of our paper[7,8]. ^{10}Be data[9] and numerous other results also indicate that cosmogenic isotope abundances were

Table 1. Summary of actinide data from Paleoindian sites.

Sample	Uranium(ppb)	USGS[a] $^{235}U/^{238}U$(%)	McMaster[b] $^{235}U/^{238}U$(%)	$^{239}Pu/^{238}U$(ppb)
Uraninite Standard	-	0.726±0.007	0.73±0.04	~0.003[c]
Bayport Chert	7.17±0.13	0.724±0.005	0.42±0.06	32±16
Gainey Chert	0.7±0.2	0.725±0.009	<0.4	~90
Gainey Sediment	1.76±0.09	-	0.94±0.09	43±4
Upper Mercer Chert	3.58±0.16	0.726±0.019	0.17±0.12	-
Chuska Chert	45.8±0.3	0.727±0.005	0.60±0.03	-
Fossil Hill Chert	0.27±0.02	0.732±0.005	-	-
Onondaga Chert	0.185±0.006	-	-	-
Taylor Chert	8.2±0.5	-	0.59±0.06	10±1 .

[a] Measured using Thermal Ionization Mass Spectroscopy (TIMS). The natural $^{235}U/^{238}U$(%) ratio is 0.7253.

[b] Measured by Neutron Activation Analysis (NAA).

[c] Value assuming no contamination from nuclear testing. Measured activities were ~0.2 Bq/kg. ^{239}Pu from nuclear testing is typically is ~5 Bq/kg in the top 10 cm of sediment at 40-50° latitude.

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much higher before 12,500 BP than now. Radiocarbon rapidly reaches equilibrium between the air, land, and ocean reservoirs, so elevated concentrations of ^{14}C over many millennia must indicate higher cosmic ray rates before 12,500 BP. There is ample evidence for sudden cosmic events at about 41,000 BP, 33,000 BP and 12,500 BP when radiocarbon suddenly increased by several tens of percent and then decayed with the ^{14}C half-life. Since radiocarbon is produced only in the atmosphere, where about 1.8% of global carbon resides[10], a 50% increase in global ^{14}C would correspond to a 3000% increase in atmospheric radiocarbon. Assuming this increase was due to a nearby supernova, it would take place over several decades as cosmic rays of different energies arrived. Plants and animals living then would absorb ^{14}C at an anomalous rate leading to radiocarbon dates that are too young by many thousands of years. They would also experience a cosmic radiation dose exceeding 100 rem for an extended period of time, placing great stress on many species and possibly leading to mutations and extinctions.

Recent astronomical evidence is compelling for the occurrence of many nearby, recent supernovae. The sun lies in the middle of a small local bubble of space swept clear of nearly all gas by these supernovae explosions[11]. Ben?ez *et al* estimate that about 20 supernovae occurred within 40-130 parsecs (130-420 light years) of earth during the past 11 million years[12]. Sonnet has shown that each supernova gives rise to a series of forward, reverse, and reflected shockwaves arriving thousands of years apart[13]. It is inescapable that these nearby events would periodically produce cosmic rays that irradiate earth. Anomalous radiocarbon dates are thus expected to occur in concert with major ecological upheavals following each supernova event.

It is perplexing that Southon and Taylor don't acknowledge that there is a common problem with young radiocarbon dates at Paleoindian sites near the Great Lakes region. We reported seven dates from 160-3810 BP for Paleoindian sites. Unless Paleoindians persisted into modern times, this is clear evidence of a problem, whatever the cause. A similar problem exists in the Northeast where Fluted Point Site (Munsungun Lake) yielded 20 dates from 35-3405 BP yet Debert (Nova Scotia) yielded 23 dates from 5033-11,120 BP of which only two were less than 10,000 years old. Bonnichsen and Will suggest[14] the young dates might be due to forest fires and tree throws, but they could also be the result of a nearby supernova. Southon and Taylor also reference unnamed archaeologists who allege that all of the Great Lakes sites were compromised by the intrusion of surface material. Henry Wright has indicated that the Michigan sites were carefully excavated and material below the plow zone at Leavitt yielded unrealistically young dates[15]. Wright indicated there is a common problem with the Paleoindian dates that may be open to various explanations. Allegation of sample misidentification is hardly evidence that this occurred and is an rather unscientific method of eliminating data that fails to meet expectations.

There are two thermoluminescence measurements for the Gainey site reported by Rowlett that give comparable values of 12,360$\pm$1224 BP and 11,420$\pm$400 BP. These results are consistent with expectation for a fluted point site, so it is hard to comprehend why Southon and Taylor would have problems with them. However, there is other information about the age of the Great Lake sites that they ignore. As we have stated, the artifacts associated with these sites contained cemented sediments deposited before spodosols ceased in the area indicating their association with the old C horizon and thus a very old date. This confirms that there is a clear discrepancy between the radiocarbon dates and the true dates for Great Lake Paleoindian sites. Southon and Taylor insist without proof that this is the result of misidentification of charcoal stratification. That might be true in some cases, but evidence for nearby supernovae suggest that there must also be anomalous dates are associated with those events. This distinction might be difficult to resolve except that we also provided evidence that the Paleoindian artifacts from seven sites were subject to a traumatic bombardment while still exposed on the ground. A high density of particle tracks, pits, and chondrules were found embedded on only one side of chert artifacts. Adjacent sediments were enriched in magnetic spherules. No terrestrial process could have produced these features, yet a supernova would provide the relativistic cosmic rays and dust that could have impacted the landscape.

Southon and Taylor correctly point out that the event as published was too extreme to be reasonable. New data presented here should place us in general agreement on this issue. However, I suggest that a gentler form of catastrophe occurred which is consistent with cosmogenic isotope record. This event would have had a profound impact on any Paleoindian who observed it, and similar occurrences must have occurred frequently over the past millennia with dire consequences. While mistakes in sampling can be important, as Southon and Taylor suggest, it is not prudent to assume this occurs whenever results defy expectations. Sites with anomalous radiocarbon dates may be especially interesting when they can be related to the times of cosmic events. We should all agree that more research is needed to unfold the events of the late Pleistocene.

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