# Who Or What Destroyed Our Mammoths?

## (A Bedtime Story for Visitors at the Hot Springs, South Dakota, Mammoth Site)

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Two-thirds of the large mammals native to North America have disappeared during the last 40,000 years. North America was, and for millions of years had been, much richer in large mammals than most people realize. America was the home of much more than buffalo, deer, and antelope, resembling in its diversity the wealth of large animals to be seen in an African game park. The radiocarbon dates on mammoth and other well-dated megafauna indicate no gradual decline or shrinkage in range until a catastrophe terminated all around 11,000 years ago. Whether caused by Clovis hunters, climatic change, or some other upset, the extinctions radically transformed the face of the land.

Sometime close to 11,000 years ago, the West, including the High Plains and South Dakota, lost most of its megafauna. Animals that had been native for millions of years disappeared under circumstances that were suspiciously sudden. The lost fauna was typically, although not exclusively, of large size. Most of the animals were plant eaters, and apart from some large birds including many scavenging or predatory birds, most were mammals. A rough idea of what was lost can be deduced by the hundreds of bones of mammoths on public exhibit and under scientific study in the remarkable elephant graveyard at the Mammoth Site of Hot Springs, South Dakota.

### INTRODUCTION

When George Hanson's bulldozer sliced into mammoth bones at the south edge of town in June of 1974 and developer Phil Anderson decided to defer construction until geologist Larry Agenbroad could render a judgement on their scientific worth, the world was saved an intimate view of ice-age North America "B.C." (Before the Catastrophe). In my dictionary, a catastrophe is "a sudden calamity, a great misfortune." In this case, the "great misfortune" is the loss of over thirty genera of large mammals including mammoths and mastodonts, horses, camelids, tapir, ground sloths, sabertooth "cats," and many other species of large animals (see Table 1) in North America alone. While horses survived in the Old World, and camelids and tapir survived in both the Old World and in South America, North America forever lost many species of its native megafauna of which the mammoth was the hallmark. Mentioning only buffalo, deer, and antelope, President Franklin Roosevelt (along with millions of other Americans) never imagined that his favorite song "Home on the Range" might sell America short. Until not long ago, barely yesterday geologically speaking, this continent was three times richer in large animals than it is now. The heartland, including South Dakota, was stocked with mammoths, native species of horses-large and small, camels (*Camelops*), bison much larger than modern bison, and the extinct bear (*Arctodus*)—one of the trophies of the Hot Springs dig-an animal larger, rangier (and meaner? we don't know) than a grizzly. "Home on the Range" needs three more stanzas to cover the various natives that deserve billing (see Table 1). Before extinction, the native American megafauna has been compared with what one finds in East African reserves such as the Serengeti Plain. For lovers of wildlife, it was, or could have been, a veritable Garden of Eden. The loss was indeed a catastrophe.

### CATASTROPHIC EXTINCTION OF MEGAFAUNA

"Catastrophe" is a red flag to paleontologists who know how tempting it is to slip into sensationalism and how very difficult it is to make an effective case for sudden change. Many alleged paleontological catastrophes have flunked the hard test of evidence. I will defend my wave of the red flag shortly by examining the chronology of extinction in some of the few and intriguing cases where we can probe it carefully. I may or may not persuade the skeptics.

They are in good company. Darwin was one. Catastrophes never had his sanction. What might Charles Darwin say, if we could resurrect him and give him a guided tour of the Hot Springs site? Darwin would have loved it. He had found similar Quaternary-age fossils of extinct large mammals in his travels in South America and in the "Voyage of the Beagle" (1855). He admits his rush of enthusiasm, the same excitement many of us would experience if our tramps up an arroyo were to lead to an unexpected find of the buried bones of extinct animals. Such discoveries underlie our basis of reconstructing the biota of the lost world of the Late Pleistocene.

"It is impossible to reflect on the changed state of the American Continent without the deepest astonishment," Darwin wrote in "Voyage of the Beagle" (1855). After claiming that no one marveled at extinction more than he, he tempered that enthusiasm with a rationalization: *"The extinction of species has been involved in the most gratuitous mystery"* (my italics; Darwin 1859). Darwin argued that when species become extinct they have been gradually disappearing for some time, first in one spot, then another, and finally throughout their range (Darwin 1859). In both the "Voyage" and in "Origin," Darwin used the analogy of a sick man gradually dying. Eventual death is no basis alone to suspect that the man died suddenly by some deed of violence. In other words, Darwin implies, we are being

**Table 1: Checklist of North American extinct Late Pleistocene megafauna (>100 pounds [40 kg] adult body weight). *Genus survives on another continent.**

| Order / Family | Genus | Common name |
|---|---|---|
| EDENTATA | | |
| Dasypodidae | | |
| | *Pampatherium* | Extinct pampathere |
| | *Propraopus* | Extinct giant armadillo |
| Glyptodontidae | | |
| | *Glyptodon* | Glyptodont |
| | *Glyptotherium* | Glyptodont |
| Megalonychidae | | |
| | *Megalonyx* | Megalonychid ground sloth |
| Megatheriidae | | |
| | *Eremotherium* | Giant ground sloth |
| | *Nothrotheriops* | Shasta ground sloth |
| Mylodontidae | | |
| | *Glossotherium* | Big-tongued sloth |
| CARNIVORA | | |
| Ursidae | | |
| | *Arctodus* | Short-faced bear |
| | **Tremarctos* | Spectacled bear |
| Felidae | | |
| | *Homotherium* | Scimitar cat |
| | *Smilodon* | New World sabertooth |
| | **Acinonyx* | Cheetah |
| RODENTIA | | |
| Castoridae | | |
| | *Castoroides* | Giant beaver |
| Hydrochoeridae | | |
| | *Neochoerus* | Giant capybara |
| PERISSODACTYLA | | |
| Equidae | | |
| | **Equus* | Horse, ass |
| Tapiridea | | |
| | *Tapirus* | Tapir |
| ARTIODACTYLA | | |
| Tayassuidae | | |
| | *Mylohyus* | Long-nosed peccary |
| | *Platygonus* | Flat-headed peccary |
| Camelidae | | |
| | *Camelops* | Western camel |
| | *Hemiauchenia* | Long-legged llama |
| | *Palaeolama* | Short-legged llama |
| Cervidae | | |
| | *Cervalces* | Stag-moose |
| | *Navahoceros* | Mountain deer |
| | **Blastocerus* | Swamp deer |
| Antilocapridae | | |
| | *Tetrameryx* | Large four-horned pronghorn |
| Bovidae | | |
| | *Bootherium* | Woodland musk ox |
| | *Euceratherium* | Shrub ox |
| PROBOSCIDEA | | |
| Mammutidae | | |
| | *Mammut* | Mastodont |
| Gomphotheriidae | | |
| | *Cuvieronius* | Gomphothere |
| Elephantidae | | |
| | *Mammuthus* | Mammoth |

suckered if we overreact to the drama of extinction by supposing that it was sudden.

Nevertheless, in recent years a revolution in paleontology has followed new discoveries that do not support the classic idea of gradual extinctions as envisioned by Darwin. Paleontologists now seek to discover how slow or how fast extinctions may occur, rather than assuming they always occur in one particular way. They wish to know the tempo and mode of extinction, no less than of evolution.

Thanks to radiocarbon dating of events within the last 40,000 years, we can come to grips with the matter of whether or not there was a gradual dying, and to see what might be the fate of America's mammoths (or other large animals) on their way to extinction. What about the case in point, the Hot Springs mammoths?

According to Larry Agenbroad and Bob Laury (1984), the Hot Springs mammoth trap, whose slippery walls proved treacherous to young male mammoths, soon filled up with mud. Judging by the sediments, the process took only a few hundred years. Unfortunately, the hot spring water which insured such high-quality mineralization and preservation of the bones themselves, guaranteeing a splendid display for the public, was totally unsuitable for preservation of organic residues. Collagen, the organic fraction of bone needed for reliable radiocarbon dates, is absent. Inorganic carbon in the form of bone apatite has yielded a radiocarbon date of 26,000 yr B.P. This may or may not be an accurate age estimate, given the uncertainties of dating of bone apatite. So we cannot determine with confidence just when the Hot Springs mammoths met their fate. Presumably they died considerably before their species became extinct for reasons that were not related to the cause of extinction itself. While the bones reveal fascinating aspects of mammoth activity, the magnificent deposit, along with most others, says nothing about how suddenly America's largest land mammals and their Ice Age associates met their doom.

Another point is important. Looking backward beyond radiocarbon time (the last 40,000 years), the fossil record discloses no heavy losses of mammals for a long time. Mammoths had been in North America for over one million years; and elephants (the order Proboscidea) for over ten million. The fossil record of extinctions in North America during the Quaternary shows that more mammals disappeared toward the end of the last Ice Age than in the previous three million years combined (Martin 1984a, 157). We have to go back roughly five million years to find an interval with such an extreme overturn in fossil mammal faunas, a time which saw the extinction of native American rhinoceros and other families (Webb 1984). But the five-million-year-old extinctions differ in two important ways. For one thing, we can't be sure they were as sudden as in the last Ice Age. For another, as many small (under 100 pounds) as large mammals were involved, rather than a predominance of large ones alone.

## RADIOCARBON DATING

Thanks to radiocarbon dating, historical ecologists of the last few decades have been able to investigate the end of the last Ice Age on a much finer scale than was possible in Darwin's day. They can determine to within a few thousand radiocarbon years or less when a given taxon was still present. Under favorable circumstances, they can gauge whether the range of an extinct animal or plant was expanding or contracting prior to extinction and get some idea of whether or not it was becoming rare before vanishing entirely.

The radiocarbon dating method is based on the natural production of $^{14}C$ by cosmic-ray bombardment of the upper atmosphere. Thermal neutrons are produced which transform $^{14}N$, by the release of a proton, to $^{14}C$.

$^{14}C$ atoms are radioactive. They slowly decay back into $^{14}N$, releasing a beta particle which can be detected with a Geiger counter. Living organisms are in balance with the atmosphere and are continuously replenished in $^{14}C$. On death, no further atmospheric exchange occurs and all $^{14}C$ in the carcass begins to disappear. In 5700 years, about half of the $^{14}C$ will have decayed back to $^{14}N$; in 11,400 years, only one-quarter will remain, and so on (see Taylor 1987). Tree-ring samples of known age are used to calibrate the $^{14}C$ measurements. Careful results have revealed departures from a perfect one-to-one ratio of dated wood to radioactivity. For example, 7000-year-old samples dated by the tree-ring method are too young by about 10% when their radioactivity is measured.

Despite this and other known kinks in the calibration curve, the method is quite effective for the purpose at hand. The goal of accurate bone dating, which has taken several decades to perfect, was held up not by calibration, but by the geochemical history of the sample to be dated. Some samples, as we have seen, may never be suitable.

The most common fossils of extinct animals are either bones, tusks, teeth, or antlers. Exceptionally, the fossils found in large dry desert caves will include dung (Figures 1 and 2), desiccated tissue, hair, keratinous horn sheaths (Figure 3), beaks (Figure 4), or hooves. Despite misgivings about bone from open sites as an uncontaminated source of carbon, many measurements were run in the early days without necessarily determining the nature of the residues or the geochemical reliability of the organic fraction that is the source of the date. To be sure, in many cases, there was nothing better to submit. Any data were better than none, some felt. Let the consumer beware.

Early radiocarbon dates on extinct animals, which I extracted from the literature in an initial and uncritical attempt at building chronology (Martin 1958), seemed remarkably young, although at the time no one knew quite what to expect. Mammoths, mastodonts, and other extinct beasts appeared to have lasted longer in Alaska, Florida, and Mexico than elsewhere. Horses, camels, and ground sloths supposedly lingered into the Holocene, the last 10,000 years. Archaeologists were aghast. They never found extinct animals in Holocene-age deposits, at least not in an association that inspired confidence. The only cultural deposits clearly harboring extinct mammals (mainly mammoth) were Clovis sites. My tentative conclusion (Martin 1958, 1963) that the extinct animals lingered into the last 10,000 years soon crumbled. The youngest reliable, geochemically defensible radiocarbon dates on extinct megafauna are 11,000 to 10,000 years old (Meltzer and Mead 1983). Only on oceanic islands (those beyond the continental shelf) is it apparent that

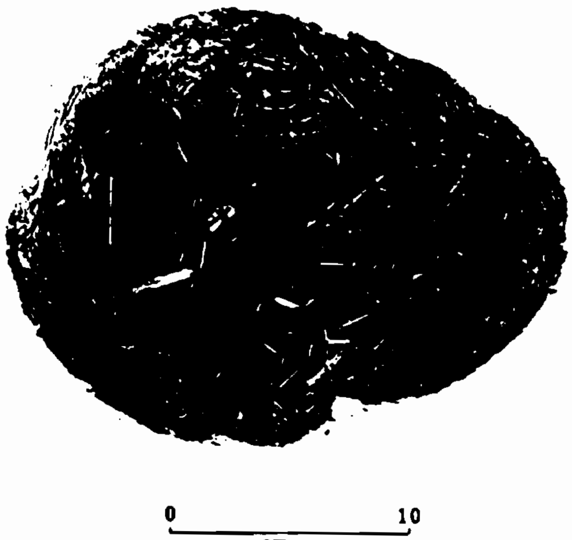


Figure 1. Bechan Cave, Utah, mammoth dung; note coarse grass culms.

Figure 2. Rampart Cave sloth dung blanket. NPS photo, 1938. This deposit was destroyed by fire in July 1976.

Figure 3. Harrington's extinct mountain goat skull from Stevens Cave in the Grand Canyon. Note horn sheaths attached.


Figure 4. Condor skull from Stevens Cave in the Grand Canyon. Note beak attached. 12,000 years old.

extinctions of a variety of animals, large and small, occurred as late as 1,000 years ago.

The trouble with the first batch of radiocarbon dates that led me astray was the uncertainty of exactly what was being dated. When dissolved in weak acid, fresh bone, which is rich in collagen, will yield a rubbery residue in the shape of the original sample, a "bone pseudomorph." While this organic residue is highly desirable for dating purposes, it is all too seldom attainable in fossil bone. For example, no bone pseudomorphs can be expected from the collagen-depleted Hot Springs mammoths.

By dating the charcoal in Clovis archaeological sites, Haynes (1987) was on better ground. If the charcoal was truly cultural in origin, it would date both the artifacts (stone tools, flakes, debris and, of course, Clovis points) and the bones of the inferred prey (mammoth). Recently, new and sophisticated methods of pretreatment developed by Stafford *et al.* (1988) have made it possible to remeasure bones once considered unsuitable by dating them at the molecular level. The results have been very effective at dating some (not all) Clovis sites, as in the case of the Dent Mammoth in Colorado. At others, as at Escapule, Arizona, nothing helps. Whatever organic residues remain in the Escapule mammoth bone are largely secondary, that is, contaminants.

Since mammoth were not known from Folsom age or younger alluvial deposits, even those postdating Clovis by only a few hundred years, and since all dates on Clovis centered around 11,000 years ago, Haynes could surmise (although this was not his primary concern) that mammoths vanished in Clovis time.

Dated Clovis sites yielding mammoth extend from Wyoming to Arizona and east to Oklahoma. Thus, the last mammoths in western North America that have been carefully dated by radiocarbon seem to have disappeared at essentially the same time, presumably within less than one thousand years of each other. The abrupt departure of mammoths certainly justifies more than ordinary interest.

## GROUND SLOTHS, EXTINCT MOUNTAIN GOATS, CONDORS, AND SABERTOOTH CATS

Using fossils found in desert caves in Arizona and adjacent states, my geochemist colleague Austin Long helped me exploit a much easier approach to determining the last occurrence of the extinct fauna. We took advantage of the unusual opportunity mentioned above, the desiccated or mummified remains of extinct animals, including Shasta ground sloth dung (see Figure 2 for a vew of a ground sloth dung deposit). At first, the thought of collecting specimens from a bed of fossil manure (dung balls and trampled dung) may sound unappealing, but for those searching for geochemically reliable samples of extinct animals, samples rich in uncontaminated organic carbon in convincing association with an extinct animal, the prospect of dating ground sloth dung and studying its contents for dietary information was as inviting as seeking gold in the tombs of the pharaohs! As an aside, it should be understood that, while pungent, the ancient sloth dung deposits do not stink or smell bad.

We dated a total of forty-three dung balls of the Shasta ground sloth from seven different caves between west Texas and southern Nevada (Martin *et al.* 1985). Many specimens originated at or near the top of the deposits. The youngest measurements (discounting five rejected on methodological grounds) were just under and perhaps not significantly younger than Haynes' 11,000-year-old dates on charcoal with mammoths in Clovis sites (Martin 1984b, Martin *et al.* 1985; Figure 5). Unlike the mammoths, no extinct ground sloths have been found in an archaeological context. An early claim of such an association was refuted by radiocarbon dating (Heizer and Berger 1970).

Weighted averages of the youngest dates from each cave we sampled were not identical (Martin *et al.* 1985), but they were close. It was hard to visualize Darwin's analogy of these extinct animals slowly vanishing over a long interval of time, becoming increasingly rare as their range shrank, and finally going extinct like a sick person slowly fading away to an inevitable death. Admittedly, we can't determine how the ground sloths were doing in all parts of their range in their last 100 years, but based on the abundance and age of dung in various caves from Texas, New Mexico, Arizona, and Nevada, there is no suggestion of a species in a poor state of health prior to our last trace of them roughly 11,000 years ago.

Desert caves in the Grand Canyon had more secrets to disclose. They yielded a rich source of valuable specimens for direct $^{14}C$ dating on another type of extinct animal, Harrington's extinct mountain goat. Named for Mark Harrington, the former curator of the Southwest Museum in Los Angeles, who began the search for early man and extinct animals in many desert

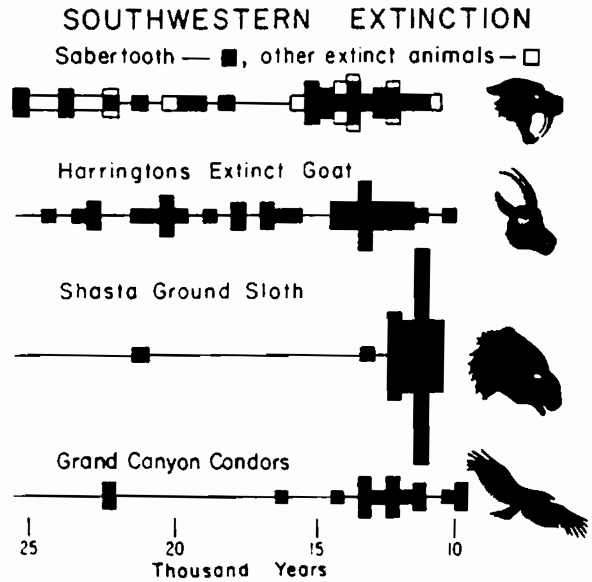


Figure 5. Chronology of sloth-goat-condor-sabertooth extinction in southwestern U.S.A. Each block represents a radiocarbon date.

caves, the extinct goat (*Oreamnos harringtoni*) was smaller and more robust than its near relative *Oreamnos americanus*, the living Rocky Mountain goat.

For his dissertation at the University of Arizona, Jim I. Mead assembled a large collection of bones, horns, and (most unusual) perfectly preserved dung and horn sheaths of *Oreamnos harringtoni*. From associated fossil plant material, he determined that Harrington's extinct mountain goat did not occupy alpine tundra or subalpine spruce forest, the haunts of living Rocky Mountain goats. The extinct goat of the Pleistocene ranges and canyons lived in a world of juniper woodland or of mixed conifers (limber pine, bristlecone pine, Douglas fir). The regional climate was cooler and perhaps drier in summer than today.

The golden opportunity for reliable radiocarbon dating in this case came not only from dung deposits but also from detached mountain goat horn sheaths. On his return from one newly discovered cave in the Grand Canyon, Jim showed me an entire skull of a Harrington's mountain goat with dried tissues still attached and two black, keratinous horn sheaths still in place on its skull (Figure 3). Had the trophy been discovered in hunting season in the back of Jim's truck at an Arizona Game and Fish Department check point, I doubt that he could have talked his way out of a confiscation of the head and an arrest for illegal transport of an untabbed, freshly killed mountain goat. While undeniably a fossil, no one would have believed him, given the fresh appearance of the mountain goat skull.

The detached horn sheaths could not be safely dated by stratigraphy alone. Some were found in fossil packrat middens associated with twig figurines, archaeological trophies known to be only 4000 years old (Euler 1984). Could the goat fossils be that young? Could they be younger? They certainly looked fresh enough, as fresh as the Rampart Cave sloth dung had looked. But freshness alone was not proof of youthfulness, as we had learned at Rampart Cave. Again, radiocarbon measurements were the only hope.

Despite their ever-so-fresh appearance, the goat horn sheaths and dung pellets were all over 10,000 years old, some much older (Figure 5). All millennia between 10,000 and 23,000 years ago were represented in the sample series. Apparently, Harrington's extinct mountain goats and Shasta ground sloths left the Grand Canyon at the same time. If climatic change drove them out, one would expect them to depart under different climates at different times, since the ancestry of the ground sloths is tropical and that of the mountain goats is boreal. If conditions got too severe (too cool) for ground sloths, they should have been entirely suitable for mountain goats, and vice versa. There was no suggestion that goats were dying out before their extinction. The mode (the half-way point) in the number of dates was 2000 years younger than the mean, not what one would expect in a waning population (Mead *et al.* 1986).

A third test remained to be coaxed from Grand Canyon caves. The caves had long been known to contain bones of extinct birds, and an extinct *Teratorn* (a giant predatory bird) I collected in a fossil packrat midden in Stanton's Cave had been radiocarbon dated at 15,000 yr B.P. (Euler 1984). With the help of experienced rock climbers, Steve Emslie, a student from the University of Florida, began a very unusual research project for his dissertation. He explored virtually inaccessible Grand Canyon caves in search of ancient condor roosts.

Emslie's rope-dangling mountain climbers helped him descend cliff faces to gain entrance into virgin caves, some even inaccessible to the virtually ubiquitous, rock-climbing, crevice-haunting packrats. The results were spectacular. Not only did Emslie find many more fossil condor bones than had been known from the Grand Canyon previously, he found fossil feathers, egg shells, food remains, and in one cave, bones of fledgling condors, evidence that the giant birds once nested in the Canyon (Emslie 1986, 1987). To the surprise of some archaeologists, the condor nests were old, much older than the surficial position of the bones would suggest, matching the radiocarbon dates on ground sloths and extinct mountain goats. One cave roost yielded food remains, bone fragments of extinct horse (*Equus*), bison (*Bison*), camel (*Camelops*), extinct mountain goat (*Oreamnos harringtoni*), and even a fragment of the molar of mammoth (*Mammuthus*). Presumably, the condors soared above the rim of the Canyon and over the Kaibab Plateau in their search for carcasses, bringing back fragments or regurgitating them for nestlings, as do living condors. With the loss of the large herbivores, condors may have lingered in areas supporting bison and a few other large animals that survived the extinction crisis in dwindling numbers. Ultimately, only a relict population of condors persisted along the Pacific Coast. There the birds were dependent on carcasses of marine mammals until the introduction of domestic livestock.

As a final example, one turns to the sabertooth "cat" (actually a machairodont) from the tar pits of California, especially the most famous deposit at Rancho la Brea on Wilshire Boulevard in Los Angeles. This familiar large carnivore of the Quaternary left more of its bones in the tar pits than any other species, suggesting it was a scavenger.

At first, tar pit bones were viewed as totally unsuitable for radiocarbon dating. However, extractions with organic solvents were effective at removing contaminating petroliferous residues and the collagen yields of the tar-impregnated bone allowed reliable radiocarbon measurements to be made (Ho *et al.* 1969; Marcus and Berger 1984). Like bones from dry caves, animal bone preserved in petroleum is protected against groundwater leaching and contamination by fulvic and humic acids.

Sabertooths and other large meat eaters on the top of the ecological pyramid, should have been especially vulnerable to any decline in their food supply. If the local megafauna at Rancho la Brea that were scaveneged by the sabertooth was declining, dying out in the way Darwin implied, the sabertooth cats might be expected to show such stress first. If the sabertooths were in trouble, the radiocarbon dates on their bones might terminate several millennia before 11,000 years ago. They do not (Figure 5). Instead, the last sabertooth bones dated at Los Angeles are roughly the same age as the last extinct animals from the Grand Canyon. While 13 of the 31 extinct genera known in North America have yet to be dated to within one thousand years of the 9th millennium B.C. (Grayson 1987, 1989), no serious claim for a Holocene survival of the common species of extinct megafauna (as I once proposed) has been heard for some time. And, with the exception of the condor, no strong evicence has been forthcoming for any of the more common species of extinct animals shrinking in range or in numbers for thousands of years prior to their ultimate demise. Mammoths in particular seem to have been widespread up until the time they are last recovered as fossils. Their extinction is decidedly more sudden than gradualists would expect.

## WHAT HAPPENED TO THE MAMMOTH?

On occasion, the bones of extinct animals are found in deposits of Holocene Age. Close inspection usually shows these fossils to be rebedded from older deposits. According to Leidy (1852), an Indian was using the type skull of *Symbos (Bootherium) cavifrons*, obtained from a nearby riverbank, as a seat in his hut. My favorite example is the presence of a number of mammoth teeth in the prehistoric, multistory pueblo, Paquime, abandoned around 1400 A.D. and located just outside Casas Grandes, Chihuahua, Mexico. Along with Paleozoic fossils and semiprecious stones, the mammoth remains were positioned in the ruin in a room known to excavators as the "rock shop" (DiPeso *et al.* 1974). The prehistoric people that built Paquime had not found living mammoth, but fossil molars; evidently they treasured these remains no less than the townspeople of Hot Springs venerate their mammoth site.

So what did happen to the mammoth? Some deep meditation is in order for visitors viewing the remains of "Napoleon Bone-apart" and the other exhumed skeletons at the Hot Springs site. I believe the radiocarbon record I have reviewed above is sufficient to make the case for a sudden rather than a gradual loss, at least in the arid West, where ideal material for radiocarbon dating is more often available than in wetter parts of the continent. More to the point, if I am wrong, the method used (careful radiocarbon measurement of suitable specimens)—will disclose the error.

While mammoths are associated with Clovis sites, it is difficult for many to accept a human role in the extinctions since the magnitude of the event seems to require more fossil evidence, notably more kill sites, including associations with animals other than mammoth. Are there other explanations?

Extraterrestrial objects, either comets or asteroids crashing into planet Earth, are widely acclaimed as the cause for some of the largest, most monumental mass extinctions in the oceans, as at the end of the Cretaceous, and are increasingly implicated in plant and animal extinction on land. Whatever else one proposed for the end of the Pleistocene, the idea of a cosmic intruder can be ruled out. There are no huge craters dating to only 11,000 years ago and no iridium or other noble metals have been found as a signature of the impact of an extraterrestrial body rich in such elements. Finally, if the extinction of the mammoth and other large mammals were the outcome of some extraterrestrial accident on earth, one would expect heavy losses at the same time in all parts of the globe.

Pleistocene extinctions known elsewhere, for example, in Australia, Madagascar, and New Zealand (see Figure 6), did not happen at the same time as those we have been considering. The extinction of a rich megafauna in Australia preceded that in America. The extinction of giant birds in New Zealand and giant birds, giant lemurs, and a hippo in Madagascar was 10,000 years later than megafauna extinction in America. On oceanic islands, there seems to have been a very close relationship between extinction of endemic land vertebrates and the arrival of human colonists (Martin 1984b; Steadman 1989).

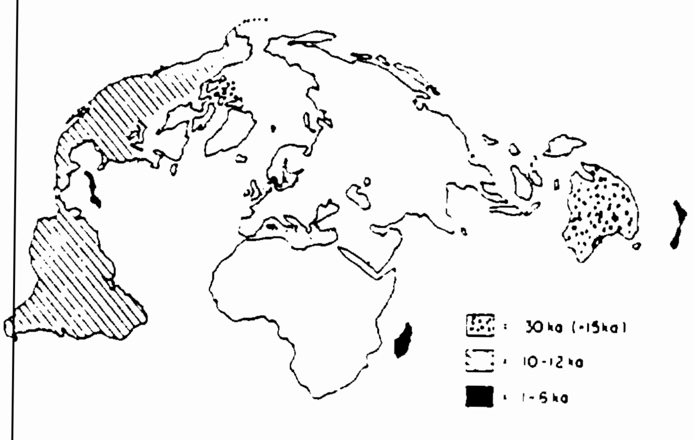


Figure 6. Global map of the timing of faunal extinctions in the last 40,000 years. Losses in Australia precede those in America, which in turn, precede those on major oceanic islands around the globe.

Thus far I have said nothing about the most obvious feature of the Ice Age, its intriguing record of climatic change. The mammoths and other large beasts, the hallmark of the Ice Age, lived at a time when climates were changeable. The global ice volume increased sufficiently during glacial times to drop sea level by 100 m or more as evaporation delivered moisture in the form of snow into the cold storage of the continental glaciers. Recent research on gases trapped in ice cores indicates that there was less $CO_2$ in a glacial interval than interglacial times. There was more dust in the atmosphere, and by virtue of wobbles of the planet on its axis and in its elliptic around the sun, there were changes in seasonality of climate through the time of the extinctions. However, such changes had occurred earlier in the ice ages and it is by no means agreed that any of them would be sufficient to drive megafaunal extinction even if they were unique to the Late Pleistocene.

The Great Extinction Debate continues, as participants at this conference fully realize, given the range of opinions voiced by various speakers (see also Martin and Klein 1984). The radiocarbon dates narrow the search to something that happened about 11,000 years ago, something that was unique to the Quaternary of North America, something that would have had the capacity to start a holocaust.

Placed in such terms, one potential cause especially draws our attention because its coincidence cannot be ignored and its potential impact has been underrated. That is the arrival of Stone Age people, the people we know as the Clovis hunters. Viewed from our high-tech cocoon of artificial climate, rapid transit, supermarket foraging, and soulless telecommunications overload, the lifeways of "primitive" foragers may unthinkingly be discounted as utterly ineffective and harmless. If so, it helps to recall that the first Americans got here by land through treeless arctic tundra, a major feat of survivorship that would have been impossible without sewn garments and remarkable skills at outdoor survival, including expert management of fire and of food procurement. Furthermore, the invaders had tens of thousands of years to perfect their hunting skills, while the New World megafauna, with the possible exception of some late-arriving Eurasian immigrants, like caribou and elk (which, of course, survived), had no experience at evading or adjusting to human predation.

It is worth recalling that 90 percent of the people that inhabited this planet lived "... not only during prehistory, but in that immensely long epoch before the domestication of plants and animals when hunting, fishing, and the collection of wild [plants] was the universal mode of production" (Harris 1980). Our comprehension is compromised by our technological baggage:

"... in the beginning of hunting, a minimum of apparatus was very probably counterbalanced by a maximum of knowledge, concentration, and the gift of empathy, just as nowadays a minimum of knowledge [of animal behavior] and concentration is counterbalanced by maximum technical perfection of weapons" (Lommel 1967).

## A BEDTIME STORY FOR PALEONTOLOGISTS

All that I have reviewed thus far is merely a preamble to the bottom line, the final word, the resolution of the outrageous circumstances in which sudden extinction of a fairly small but very impressive group of animals (small in total number of species, impressive in body size) happened as suddenly as radiocarbon dates can measure. Given the mysterious circumstances, the best guess of the man in the street may in this case be no worse than that of any paleontologist in dreaming up an explanation. After all, what scientists do is test various best guesses, or, to be blunt, "bedtime stories" that might explain the mystery. So I will end with a bedtime story that I think comes closest to what really happened. It begins, as all bedtime stories must, with "Once upon a time . . .," a good disclaimer that begs ignorance of some vital details and the untestability of others that inevitably must follow.

"Once upon a time 12,000 years ago, a small band of people physically very like us and speaking a common language trekked farther east than anyone had ever gone before. 'Beringia,' the low, flat, cold treeless land they entered, linking Asia to America, is now under the sea. They foraged near a base camp in the brief subarctic summer. In autumn, they followed their prey—mammoth, bison, and caribou—to wintering grounds. Helped in the hunt by opportunistic wolves or wolfish dogs, the hunters were expert at locating and tracking game, at killing it in excess of their needs, at butchering the carcass, and preserving the meat. They gathered old bones scattered in the treeless tundra of the Bering Platform to help construct their shelters. At 60° below, they dressed in warm furs and slept in bearskin bags. Diseases were few, enemies were absent, and no rival tribes blocked their passage east and south. By sharing food, there was always more than enough to eat and large animals were easily killed just for the fun of it, although wise elders spoke against this.

"As years became centuries, the people of the northern lights multiplied at an average of 3% or more per year, as people have always done when opportunity allowed. At an unheralded moment, without fanfare, they had been drawn by the prey they followed out of Asia and into North America, a moment of discovery whose profound ecological as well as historical meaning we have yet to acknowledge, much less to celebrate. Humankind had discovered the wildest wild America ever known. Our prehistory had begun.

"Spreading southward, the unwitting explorers found that they were in a hunter's paradise, a Garden of Eden vastly rich in resources of the kind they were so expert at hunting. Some of the animals they discovered were new to their experience and some of these, the great ground sloths, were slow-moving and extraordinarily easy to dispatch. The children of the hunters could use them for target practice.

"Generations passed. With time, the more desirable game animals became scarce. When starvation threatened, the wise old shamans sought guidance in the spirit world. Taboos had been broken, they said, and, until there was a sacrifice, all would suffer the displeasure of the Great Manitou. Unrepentant, the young hunters turned to a better solution. They broke camp and moved south to discover untouched new killing fields in greener pastures, successfully ignoring all taboos and warnings. With time, the game trails they found and followed led south by the shining mountains, west toward the land of little rain, and east through the forest primeval. The hunters were guided by tracks, chewed twigs, dung heaps, circling condors, and other unmistakable signs of a prey which they knew so well and dispatched so efficiently. When starvation stalked the land, laying claim to the old and weak, the young hunters escaped its clutches by moving on once again. Moving 200 miles in a generation was more than enough to insure a sufficient food supply without hampering childbearing.

"With the passage of centuries, no one noticed that over a vast area big game was growing scarce, and, in fact, the larger, more majestic animals had not been seen in a long time. In 500 years, they reached Tierra del Fuego, the end of the line. The Garden of Eden was stripped of its mammoths, ground sloths, and dozens of other easily hunted species of megafauna. The surviving game was restricted to a few less easily procured large animals, animals that were more resistant, that is, less huntable. Most of these had, like the hunters, Asian relatives. With the extinctions, human populations crashed. The few survivors broke into small tribes, became increasingly isolated and warlike. There was less to hunt and, of necessity, men and women both learned new skills in harvesting small game and fish, and especially in the arts of gathering, storing, and preparing edible plants. When skills of living off the land turned domestic and agriculture began, the new farmers had to make do with native plants. Most of the megafauna of potentially domesticable species was already extinct. The end."

Like all good bedtime stories, mine closes with a moral. Whether or not it is true that it was Clovis hunters who killed off the mammoth and other large beasts, it is important to recall that afterward, the fossil record stabilized. Over the last ten millennia, the 10,000 years since the end of the mammoths and ground sloths and other extinct megafauna, the fossil record reveals little additional loss of native wildlife. Grizzly bear, caribou, bison, elk, moose, white-tail and mule deer, mountain goat, mountain sheep, and pronghorn antelope all survived. From the fossil record of their last 10,000 years, native Americans can claim to have lived benignly in their environment, neither causing nor witnessing many additional losses after the catastrophe of 11,000 years ago. This conservation record is one that we would indeed be very, very fortunate to be able to emulate.

1992 will be the 500th anniversary since the first foreigner, Christopher Columbus, "discovered" America and its natives, whom he mistakenly called "Indians." More important, it is at least 11 millennia since the New World was, in fact, discovered. It is high time that we reexamine our ecology in terms of our prehistory. Today, we have postextinction remnants of the Garden of Eden embedded in our technoecosystem. The task before us is clear. It is to do with our native biota, into and beyond the next century, as native Americans did with theirs in the last ten milennia after recovery from the megafaunal extinctions. What happened 11,000 years ago is a small taste of what a catastrophe can do to the biota of the earth. Walt Kelly's words from Pogo the Possum never sounded more true: "We have met the enemy and they are us!".

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