PALEOBIOLOGY

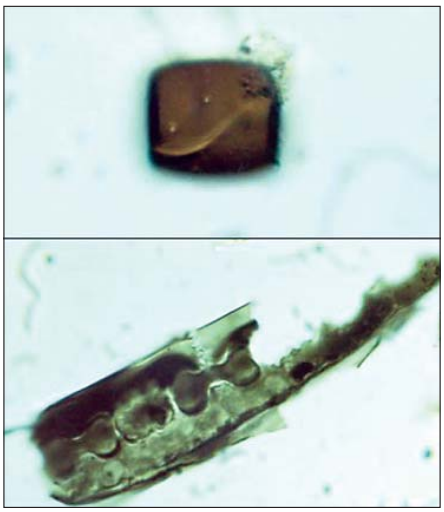
Megafauna Died From Big Kill, Not Big Chill

More than 10,000 years ago, when the last ice age was stumbling through its final years, both humans and viciously sharp climate change converged on North America just as three-quarters of the continent's biggest beasts—mammoths, mastodons, giant ground sloths, and saber-toothed tigers among them—disappeared forever. Both human hunters and wrenching climate shocks seemed to have the opportunity to cause extinction. But researchers have never been able to disentangle the lingering traces of humans, climate, and megafauna in enough detail to say who or what did in the great ice age beasts of North America. Now a group of paleoecologists has followed all three players through time, clearing one suspect of megafaunal mayhem and indicting another.

At a recent geoscience meeting,* paleoecologists Guy Robinson, David Burney, and Lida Pigott Burney of Fordham University in New York City, reported evidence that humans arrived on the scene damningly close to the time of the megafauna collapse, whereas climate change was such a latecomer that it could not have played a major role. The key to sorting out this extinction story was following a microscopic marker for each of the three players up through a single geologic record. A key marker was the spores of a fungus partial to dung. The work is a reminder that "it's the small things that are really important," says paleontologist Richard Laub of the Buffalo Museum of Science. "The approach is a very good one; I suspect they are on the right track."

Whether humans were behind the dramatic extinctions at the end of the ice age has been long debated. In 1967, geoscientist Paul Martin proposed the "blitzkrieg" hypothesis, in which humans pouring across the Bering land bridge into North America hunted down the great beasts. Pushed to the brink, the megafauna quickly slipped into extinction. As geographer Jared Diamond of the University of California, Los Angeles, has noted, studies in Australia, the Bismarck Archipelago, Cyprus, the West Indies, Fiji, Madagascar, and New Zealand have since shown that the indigenous megafauna in each case succumbed soon after humans first arrived. But those extinctions came anywhere between mid–ice age 50,000 years ago (*Science*, 8 June 2001, p. 1819) and just 700 years ago, so they were not closely correlated with severe climate change. To Diamond and many others, the consistent coincidence between first arrival of humans and megafaunal demise strongly implies causation.

But North America has proved to be a particularly difficult case. Both humans and an abrupt shift from relative warmth back to full glacial cold arrived about 11,000 years ago as measured by radiocarbon dating, as close as researchers could tell, which was indistinguishable from the timing of the extinctions.



Traces of victim and killer. The fungal spore (*top*) lingered from the dung of mastodons and other megafauna, and the charcoal marks a human presence.

The Fordham researchers sharpened the fuzzy North American extinction picture by using smaller and therefore far more numerous tracers than usually applied there. For climate, they did make traditional counts of tree pollen. These trace a sudden warming followed by an abrupt, millennium-long cold that punctuated the transition from the depths of the last ice age 20,000 years ago to the continuing warmth of the interglacial period beginning 10,000 years ago.

But instead of distinctive fluted projectile points scattered across the continent by the first humans, the Fordham group used microscopic bits of charcoal blown from large fires as a marker for humans. A sharp increase in such charcoal has marked the arrival of humans on islands around the world. And instead of megafauna bones, the researchers used microscopic fungal spores. Palynologist Owen Davis of the University of Arizona in Tucson pioneered the use of spores of the fungus *Sporormiella* that wash into ponds, lakes, and bogs from the dung left by watering large animals. Rather than crudely tying together macroscopic markers from different sites through radiocarbon dating, the Fordham researchers counted up their microscopic markers through mud layers at four sites in southeastern New York: three megafaunal sites and a cored lake-bottom mud.

Analysis of the four sites revealed a clear progression of events. First, the megafauna population collapsed, as indicated by an abrupt 10-fold decrease in *Sporormiella* spores to trace amounts. Soon after, microscopic charcoal abundance jumped 10-fold. And only later, something like a thousand years later, did the pollen of boreal forest trees such as alder, birch, and spruce reappear, marking a sharp cooling, the beginning of the last gasp of the latest ice age.

To the Fordham group, humans seem clearly implicated, but climate change looks to have been secondary. "There's an initial overkill" as in the blitzkrieg hypothesis, says Robinson. "The system is knocked out of balance, by human hunting probably." The human-induced collapse of the plant-eating megafauna led to an overabundance of fuel for fires, natural and human induced. Only much later, in the renewed cold, do the researchers find the last known megafaunal bones. "It makes this process look like it's spread out for a thousand years," says Robinson. Knocked down, the megafauna finally went out under the weight of further hunting, the cold, the altered environment, or some other stress or stresses that would not otherwise have caused extinction, says Robinson.

The Fordham group has found the same sequence of fungal spore decline, charcoal increase, and megafaunal collapse in Madagascar. But it came during the last 2 millennia without a climate shift to warmth or cold, suggesting that climatic stress isn't even essential for the knockout punch. "That strengthens our case" against humans rather than climate, says Robinson.

New evidence in this contentious field takes time to sink in. "Their approach is a novel one that deserves some additional attention," says paleobotanist Norton Miller of the New York State Biological Survey in Albany. "My own bias is more toward climate than anything, [but] the fungal story provides some good information that would argue against climate." Perhaps more of these little things will one day settle the fate of the big things.

–RICHARD A. KERR

* Joint meeting of the Geological Society of America's Northeastern Section and the Atlantic Geoscience Society, 27 to 29 March, Halifax, Nova Scotia.

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