March 18, 2014
Geol 105: Paleontology

Causes of the Quaternary Megafauna Extinction Event

Introduction

From approximately 50,000 years ago to 10,000 years ago, the world's climate changed as the Pleistocene gave way to the modern, warmer climates of the Holocene. During this same period, several of the world's megafauna species died, marking the only mass extinction event to have occurred while humans were on the planet (Barnosky, 2008.) Although the Quaternary Megafauna Extinction Event is the most recent in geologic history, it has proven to be quite a puzzle for paleontologists; the exact cause for the extinctions is a mystery. Several hypothesis have been developed in an attempt to find the cause for the mass extinctions, resulting in two widely accepted theories: The Overkill Hypothesis and the Climate Change Hypothesis (Haynes, 2008; Hubbe, 2013; Mann, 2013; Woodman, 2009.) The Overkill Hypothesis claims that the spread and growth of human populations and their subsequent overhunting caused the deaths of the megafauna. This theory is supported by the alignment of human arrival dates and locations with megafauna extinction dates and locations, stone tools and other artifacts used for hunting and butchering, and the prolong survival of megafaunal in areas absent of humans (Barnosky, 2008; Fillios, 2010; Turney, 2008; Veltre, 2008; White, 2013). The opposing theory – The Climate Change Hypothesis – claims that the changing climate of the Pleistocene-Holocene transition is to blame for the demise of the megafauna. This theory is supported by the dates and locations of climate swings and shifts, evidence for altered paleoecosystems and paleohabitats, and the relationship between severe climate changes and severe extinction events (Haynes, 2008;

Hubbe, 2013; Mann, 2013; Nikolskiy, 2011). In addition to these two leading hypotheses, a third hypothesis combining the climate change theory with the overkill theory is also well supported and widely accepted. This combination theory suggests that climate change and human arrival and overhunting worked in tandem to cause the Quaternary Megafauna Extinction Event (Haynes, 2008; Woodman, 2009.)

Megafauna and their Extinction Dates and Locations

Megafauna are all mammals weighing over 44 kg (Barnosky, 2008). This definition includes the typical Ice Age animals such as mammoths, saber-toothed cats, short-faced bears, and dire wolves, but it also includes animals that are not usually thought of as a megafauna – such as caribou and even humans. One hundred seventy-eight of these megafaunal species were annihilated during the Quaternary Megafaunal Extinction Event, in addition to two-thirds of the total mammalian class (Barnosky, 2008). But, the extinction of these large mammals did not occur all at once nor world-wide. The Quaternary Megafaunal Extinction Event took place over an approximately 40,000 year period and in a continent-by-continent pattern. Australia was the first to be affected; it lost 88% of their megafaunal species in a period spanning from approximately 50,000 years ago to 32,000 years ago. The next continent to be affected was Eurasia, where a lesser amount – only 35% – of the species went extinct. The Eurasian extinctions occurred in essentially two pulses, the first from approximately 48,000 to 23,000 years ago, and the second occurred from 14,000 to 10,000 years ago. Seventy-three percent of the North American megafauna went extinct, during a period that occurred concurrently with the second Eurasian extinction event, from 14,000 to 10,000 years ago. South America was the last continent to experience the extinction event; it lost 83% of their megafaunal species during a period from approximately 12,000 to 8,000 years ago, although these exact dates are still being debated (Barnosky, 2008).

The Overkill Hypothesis

The Overkill Hypothesis claims that humans killed off the megafauna as they migrated into new territories, overhunting and butchering the species to feed their growing populations (Barnosky, 2008; Fillios, 2010; Turney, 2008; White, 2013; Veltre, 2008). The dates and locations of megafaunal extinctions provide supporters of this hypothesis with their main body of evidence. In Australia, Eurasia, and North and South America, the megafauna populations began to decrease and genera-wide extinctions began to occur within a few hundred to a few thousand years after humans first arrived into each new territory. For example, the human arrival dates onto the continent of Australia is estimated to be around 50,000 years ago, which exactly matches the dates of the initial stages of the Australian megafauna extinction event (Barnosky, 2008). The megafauna extinction dates on Tasmania also supports this pattern, however, the period is significantly delayed when compared to Australia. This is because Tasmania was accessible only by a briefly, and periodically exposed land bridge that connected it to the continental mainland. Although the dates are delayed in the world-wide pattern, the extinction dates are right in line with the human arrival dates. Evidence shows that humans migrated onto Tasmania as soon as the land bridge became accessible, around 43,000 years ago and within only 2,000 years, around 41,000 years ago, Tasmanian megafauna began to go extinct (Turney, 2008). Tasmania, Australia, and all of the other continents show the same, global pattern: megafauna populations began to decrease as soon as humans arrived onto each new continent. The species of large mammals continued to dwindle as human populations grew, until humans replaced all

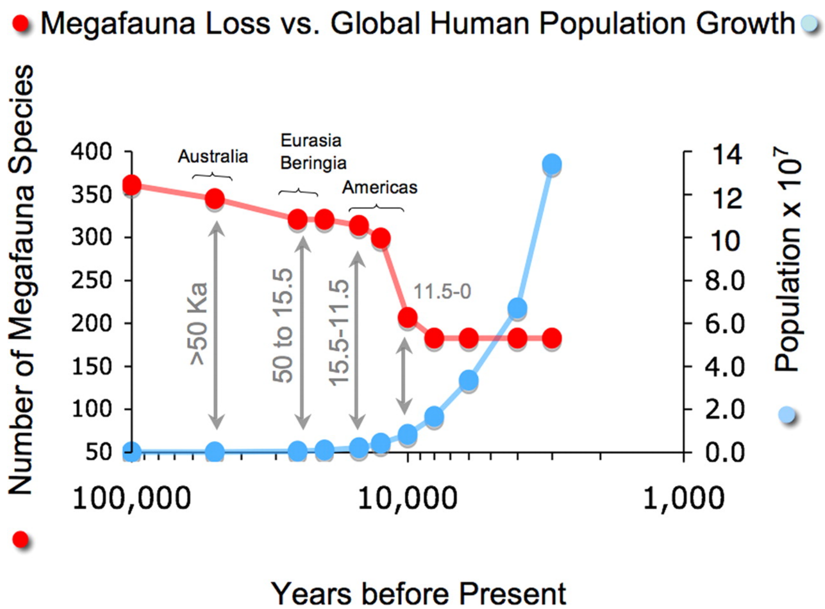

Figure 1: As humans migrated onto new continents and the human populations increased, megafauna populations decreased (Barnosky, 2008).

other megafauna, as shown in Figure 1. The Quaternary Megafaunal Extinction Event was completed shortly after humans migrated throughout and inhabited the entire world (Barnosky, 2008).

The correlating dates and locations of human arrival and megafaunal extinctions can also clarify why some continents, such as Africa and Eurasia, experienced fewer megafaunal extinctions than the other continents (Barnosky, 2008). It is widely accepted that Africa was the birthplace of modern *Homo sapiens*. Because of this, African megafauna were able to evolve with humans; these large mammals adapted their survival techniques to live successfully alongside humans instead of being completely vulnerable to them. Thus, in Africa very few species of megafauna went extinct during the global Quaternary Megafauna Extinction Event. The situation in Eurasia was similar that of Africa. Species of *Homo* (other than *Homo sapiens*) had inhabited the area for approximately 400,000 years. The Eurasian mammals had time to adapt to species of *Homo* and, therefore, suffered a much less severe extinction event when modern humans arrived. Nonetheless, Eurasia did experience some extinctions. The two pules of Eurasian extinctions are correlated to, first, the initial arrival of modern *Homo sapiens*, and, second, a dramatic increase in the human population (Barnosky, 2008).

Although the megafauna's lack of human familiarity and of adapted survival techniques played a large part in the Quaternary Megafauna Extinction Event, the skillful hunting and butchering of the animals by humans may be been even more significant in understand the Overkill Hypothesis. The megafauna of North America were perhaps the quickest to be eliminated, and this is very likely due to the advanced stone tools and big-game-hunting methods used by the Clovis Paleoindians (Woodman, 2009). A site within Australia – Cudde Springs, - offers very compelling evidence of man-made tools specialized for large-game hunting and on-site butchering. These human artifacts have been found below, above, and beside the bones of megafauna. Additionally, some of the megafaunal bones even show scars from being cut (see

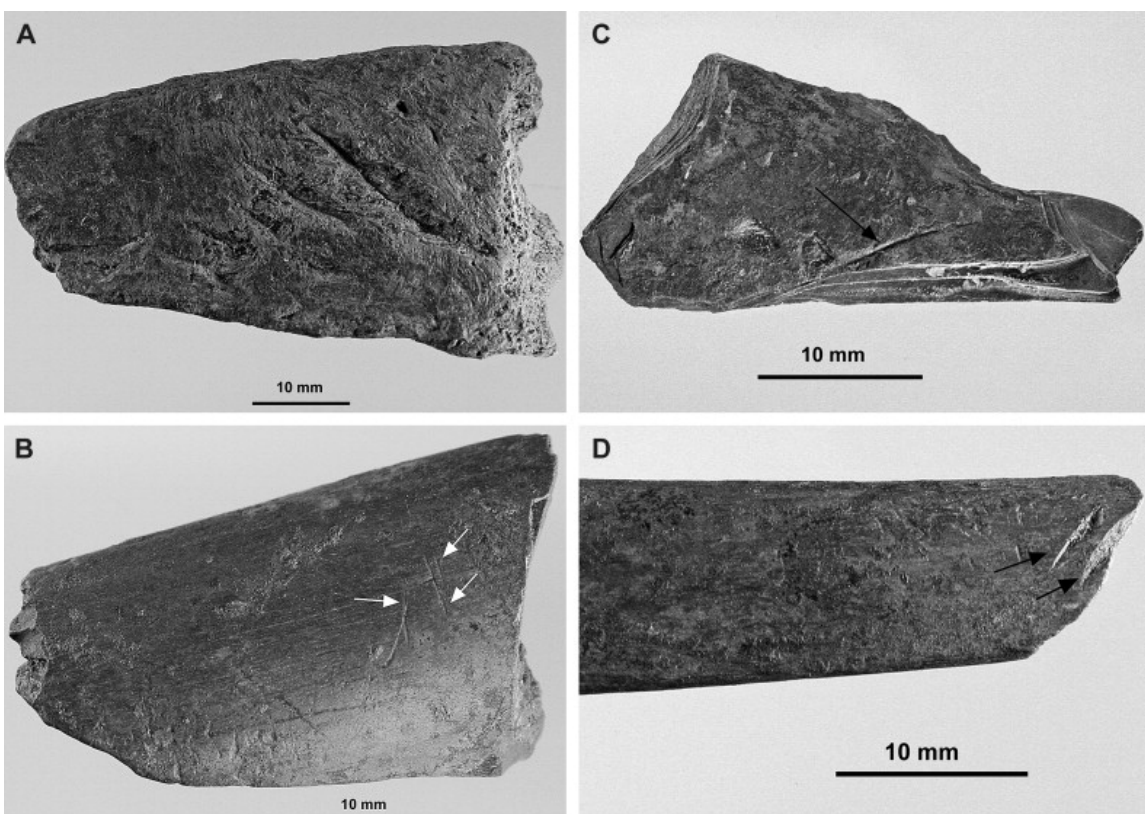

Figure 2: Kangaroo bones display cut marks from human tools (Fillios, 2010).

Figure 2). This evidence proves that, at least, humans played a role in the demise these large creatures, and thus provides powerful evidence supporting the Overkill Hypothesis (Fillios, 2010).

On an island in the Southwest Pacific, near Australia, there is more evidence of human involvement in the termination of megafaunal species; several remains of terrestrial turtles have been found within midden heaps and as the base layer of a human cemetery (White, 2013). These assortment of skeletal remains are noticeably biased toward the more fleshy parts of the turtles – the parts commonly consumed by the human inhabitants. What is more noteworthy about this site, however, is the age of these remains – they date to approximately 3,000 years ago, well into the Holocene and much later than the extinction dates for several other megafauna species. The late survival of these terrestrial turtles is another source of evidence supporting the Overkill Hypothesis. These turtles were able to survive much longer than other megafauna species because they lived on an island isolated from humans. The first people to come to the small Southwest Pacific island arrived around 3,300 years ago. The species of terrestrial turtles went extinct approximately 300 years later (White, 2013). A similar occurrence is well documented with several mammoth populations on islands surrounding North America and Siberia. On Wrangle Island, the Channel Islands, and St. Paul Island off of Alaska, mammoths were able to survive well into the Holocene – several thousands of years after the extinctions of mammoths on continental mainlands. Data shows that many of these islands were similar to the mainland in environmental and climatic conditions; however, the islands were uninhabited by humans until relatively recently. It is implied, therefore, that megafauna would have been able to survive, at least to much later dates, if humans had not migrated into their habitats and overhunted them to extinction. (Veltre, 2008).

The Climate Change Hypothesis

In opposition to the Overkill Hypothesis, the Climate Change Hypothesis claims that the Quaternary Megafauna Extinction Event was caused by shifts in world-wide climates (Mann, 2013; Nikolskiy, 2011; Woodman, 2009). It is well established that the Pleistocene had dramatically different climates and climatic patterns than are experienced today in the Holocene. The transition to and from periods of extremely different climates may have proven to be too severe for the Pleistocene megafauna, thus causing their extinctions (Mann, 2013). Like the Overkill Hypothesis, the Climate Change Hypothesis uses the dates and locations for the megafaunal extinction events as a main source of supporting evidence. The extinction dates and locations align with the dates and location of climate swings (Nikolskiy, 2011). A study done on mammoth populations in Siberia throughout the end of the Pleistocene shows that that dates of increasing and decreasing mammoth populations corresponds to the timing of Milankovitch Cycles and also smaller, millennium-scale cycles. Additionally, the period in between the first and second pulse of the Eurasian megafauna extinction event corresponds to the dates of the Last Glacial Maximum, from approximately 23,000 to 15,000 years ago. After the end of the Last Glacial Maximum, mammoth populations in Siberia dramatically decreases, eventually resulting in the extinction of the mammoth species (Nikolskiy, 2011).

Perhaps more important than the changing climates of the Pleistocene-Holocene transition was the affects that this climate change had on megafaunal habitats and ecosystems (Mann, 2013; Woodman, 2009). In Eurasia and North America, for example, environments changed from dry grasslands and tundras to wet landscapes of marshes and peatlands full of shrubs, and trees. Especially in the case of herbivores, a change to the vegetation within a species' habitat would require that species to either adapt to a new diet or relocate. An additional factor to consider is that the megafauna that were extremely large – like mammoths – require hard, strong ground to stand on. When Eurasia and North America changed to marshes or bogs, several megafauna would have found themselves sinking into the mud. These changes to the environment would have weakened the megafauna, making them vulnerable to starvation or predation, which could then very easily result in the extinction of the species (Mann, 2013).

Additional support for the Climate Change Hypothesis comes from areas or times that experienced very extreme climatic swings and shifts (Haynes, 2008; Hubbe, 2013; Woodman, 2009). São Paulo, Brazil is one such area that was characterized by severely and rapidly changing temperatures and humidity levels throughout the last 10,000 years of the Pleistocene. These Brazilian climate swings were more dramatic than the climate swings in several other localities. But, so was the megafaunal extinction rates – the Brazilian megafauna went extinct within a shorter amount of time and at a higher density than in several other places (Hubbe, 2013). Another example of a severe climate swing that affected the megafauna extinction event is the Younger Dryas – a period of intense cold primarily experienced within the northern hemisphere from approximately 11,000 to 10,000 years ago. The areas that experienced the worst of the Younger Dryas seem to have also experienced catastrophic-like extinction rates within the same time period of the Younger Dryas (Haynes, 2008; Woodman, 2009).

The Combined Climate Change and Humans Hypothesis

Both the Overkill Hypothesis and the Climate Change Hypothesis have strong lines of evidence supporting their claims, and neither of them have any real data to discredit their theories. It is for these reasons that many paleontologists have concluded that it was not one or the other of these hypotheses that is correct but both of them. The combined climate change and human-induced hypothesis for the Quaternary Megafauna Extinction Event has been gaining acceptance, and it relies on all of the data cited above (Barnosky, 2008; Haynes, 2008; Mann, 2013; Woodman, 2009). There does seem to be one more line of evidence, however, to support a combinations of these hypotheses. This evidence comes from stratigraphic layers that contains megafauna bones, human artifacts, and black organic matter characterizing the Younger Dryas. The megafauna bones within this sequence represent the latest surviving populations for several species, the human artifacts represent the earliest dates of human arrival and inhabitation, and the organic matter – called "black mats" – represents the short and specific period of the Younger Dryas. Within these stratigraphic sequences, megafauna bones and human artifacts can both be found within the Younger Dryas black mats, but there are never megafauna bones found above this layer and there are never human artifacts found below it. This shows that the extinction of the megafauna, the arrival of the humans, and the Younger Dryas occurred all at the same time – in fact, within an approximately 100 year period. Because the dates for all three of these events align, it is parsimonious to believe that it was not humans *or* climate change the caused the megafaunal extinctions, but humans *and* climate change (Haynes, 2008).

Conclusion

The Overkill Hypothesis, the Climate Change Hypothesis, and the combined climate change and human hypothesis rely on some of the same lines of evidence to support their claims, such as the alignment of the dates and locations for the first arrivals of human and the cyclic and severe climate shifts with the dates and locations of megafaunal extinctions. But, these three hypothesis also utilize several different lines of evidence, such as the suggested implications of human tools, the prolonged survival of megafauna on isolated islands, the changes to paleoenvironments and paleoecosystems, the severity of climate swings, and the overlap of stratigraphic layers. This evidence strongly supports all three of these hypothesis, and each of these theories lack the data required to discredit them. The result is that all three of these hypothesis have become widely accepted. But, in the end, none of these theories provide us with the definitive and secure data explaining what happened to the saber-toothed cats, dire wolves, ground sloths, short faced bears, terrestrial turtles, mammoths, and all of the other Pleistocene megafauna. Although we have three well supported and widely accepted hypothesis, we still do not know what, exactly, caused the Quaternary Megafauna Extinction Event.

Works Cited

Barnosky, A. D., 2008, Megafauna biomass tradeoff as a driver of Quaternary and future extinctions: Proceedings of the National Academy of Sciences of the United States of America, v. 105, no. 1, p. 11543-11548.

Fillios, M., Field, J., and Charles, B., 2010, Investigating human and megafauna co-occurrence in Australia prehistory; mode and causality in fossil accumulations at Cuddie Springs: Quaternary International, v. 211, no. 1-2, p. 123-143.

Haynes, V. C., Jr, 2008, Younger Dryas 'black mats' and the Rancholabrean termination in North America: Proceedings of the National Academy of Sciences of the United States of America, v. 105, no. 18, p. 6520-6525

Hubbe, A., Hubbe, M., Karmann, I., Cruz, F. W., and Neves, W. A., 2013, Insights into Holocene megafauna survival and extinction in southeastern Brazil from new AMS ^{14}C dates: Quaternary Research, v. 79, no. 2, p. 152-157.

Mann, D. H., Groves, P., Kunz, M. L., Reanier, R. E., and Goglioti, B. V., 2013, Ice-Age Megafauna In Arctic Alaska; Extinction, Invasion, Survival: Quaternary Science Reviews v. 70, p. 91-108.

Nikolskiy, P. A., Sulerzhitsky, L. D., and Pitulko, V. V., 2011, Last straw versus Blitzkrieg overkill: Climate-driven changes in the Arctic Siberian mammoth population and the Late Pleistocene extinction problem: Quaternary Science Reviews, v. 30, no 17-18, p 2309-2328.

Turney, C. S. M., Flannery, T. F., Roberts, R. G., Reid, C., Fifield, L. K., Higham, T. F. G., Jacobs, Z., Kemp, N., Colhoun, E. A., Kalin, R. M., and Ogle, N., 2008, Late-surviving megafauna in Tasmania, Australia, implicate human involvement in their extinction: Proceedings of the National Academy of Science of the United States of America, v. 105, no 35, p 12150-12153.

Veltre, D. W., Yesner, D. R., Crossen, K. J., Graham R. W., and Coltrain, J. B., 2008, Patterns of faunal extinction and paleoclimate change from mid-Holocene mammoth and polar bear remains, Pribilof Islands, Alaska: Quaternary Research, v. 70, no. 1, p. 40 – 50.

White, A. W., Worthy, T. H., Hawkins, S., Bedford, S., and Spriggs, M., 2013, Megafaunal meiolaniid horned turtles survived until early human settlement in Vanuatu, Southwest Pacific: National Academy of Science, v. 107, no. 35, p. 15512-15516.

Woodman, N, and Beavan Athfield, N, 2009, Post-Clovis survival of American Mastodon in the southern Great Lakes Region of North America: Quaternary Research, v. 72, no. 3, p. 359-363.