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Abstract:

Most people, when building a fire, look for wood for their fuel source. However, wood was not available for some people in prehistory. Early arctic people of the Beringia area may have used bones as a primary fuel source. Looking at the environmental conditions of Alaska approximately 14,000 to 11,000 years ago, it could have been possible to burn bones as an alternate fuel source. Possible bone fires may have been performed at other locations around the globe, and these sites are compared to a site in central Alaska. Experiments were designed to test the feasibility of burning bones. The control for the experiment used bones that were not cooked in any way, while the variable test used boiled bones. The tests used bones from various hoofed mammals, dried grass, and pieces of lard.

Introduction

Fire is one of the greatest tools available to humans. Fire has numerous applications, which include lighting the dark, heating the cold, cooking food, and providing security from predators. Without fire, other technologies, such as ceramics and the smelting of ores, would not have been possible. There are more examples of primitive technologies, and even more examples of industrial technologies that depend on fire.

Fire is needed in all environments, from the desert to the tundra. These fires were typically built with wood. What if the environment provided little or even no wood to make fires? One possible alternative that would have been abundant was bones. Like wood, bones are organic matter that can be burned. However, could bones actually be used in place of wood as a fuel source? If possible, did the bones go through any type of cooking process, such as being boiled, before the bones were burned? Drs. Jeffery Behm and Barbara Crass have conducted bone burning experiments. Their most recent experiments were very successful and have helped to further prove that bones could have been burned for a fuel source.

For this project, three separate experiments were conducted. The first two were based off the experiments of Drs. Behm and Crass. The third experiment involved using a new element, the boiled bones. This experiment was done to see if boiled bones could have been used for building fires.

Beringia

The focus area for this experiment is in the arctic region of eastern Beringia. This section will look at the environment of this area during the time the New World was thought to be populated. Beringia is a term given to a low-lying area between Alaska and Siberia. This area, also known as the Bering Land Bridge, was last above sea level around 18,000 years ago (Fagan 2000). Beringia was a geographic separation between the Arctic Ocean and the Pacific Ocean. The most western border of Beringia reached just beyond the Lena River in Siberia, and the eastern border was just west of

the Mackenzie River in Canada (West 1996). The Bering Land Bridge began to close when the temperatures began to rise, which caused the sea levels to rise. This warming period occurred around 11,000 years ago, or at the end of the Pleistocene period and the beginning of the Holocene (Fagan 2000).

Because of this open landmass, animals were able to move between Siberia and Alaska. Some of the large mammal species that were found during this time period include: saber-toothed cats, mammoths, red deer/wapiti, steepe bison/large-horned bison, and musk-ox. According to Bjorn Kurtén, species that migrated from Siberia into Alaska included mammoth, musk-ox, caribou, moose, grizzly bear, and polar bear (West 1996). Other animal species found in Alaska include: horse, sheep, wolf, coyote, lion, camel, and mastodon. Of the herbivores found, most were predominantly grass eaters (Guthrie 1996).

If much of the animal population consisted of grass-eating herbivores, then it may be assumed that much of the plant population of the area consisted of grasses. Most research on flora remains is done through palynology: the study of pollen. Pollen studies for at least the eastern part of Beringia suggest that the area consisted of dwarf willow, birch (Colinvaux 1996), sedge, Artemesia, and grass (Anderson 1996).

Since much of the area lacked trees, humans had to find an alternative source of fuel to survive. They could have burned grass, but grass burns too quickly in order to have a long sustained fire. Only bones could have been used, but trying to burn only the bones would have been too difficult. Using both grass and bones would be a suitable mixture since both were abundant.

Archaeological Evidence of Bone Burning

Unfortunately, not a great deal of archaeological evidence for bone fires has been found in the Alaskan region. Only "possible" evidence has been discovered and most literature concerning the use of bones for fuel deals with the Old World. However, there is some evidence that suggests bone fires were used in Beringia.

Swan Point

One of the areas where possible bone burning was done is in the interior of Alaska, near Delta Junction. Swan Point (XBD-156) is a multi-component site, with the oldest period of human presence dating to around 14,000 years ago. The earliest evidence of human activity in the New World comes from Swan Point and the surrounding area. It is from the oldest levels that the evidence of bone fires comes from, and it comes in the form of small fragments of organic matter. It was not known where the fragments might have come from. Dr. Crass wanted to know where the fragments came from and brought up the theory of using bones for building fires. Working with Dr. Behm, experiments were done to test this theory. The tests showed that when bones are burned, the fat would melt and sometimes leave deposits of fat on the surface of the ground. The organic material at Swan Point may have been the remains of fat deposits that were left by burning bones.

Sibudu

Sibudu, a cave site found in KwaZulu-Natal, South Africa, that dates back to around 70,000 years ago, has shown a very high percentage of burned bone. Chester

Cain (2005) discussed the different possibilities for why the bones were burned at this site, all of which surround human behavior. These possibilities include: food preparation, disposal of part of a fresh bone into a fire, discarded bones that were burnt after a hearth was built over them, or used the bones as part of the fuel for the hearths. After Cain analyzed the bone remains and the environment of the time for this area, he believed that the bones were probably not used as fuel. Cain thought the fires were used as a way of disposing the bones, since there is much evidence suggesting that there were plenty of trees available to be used for fuel.

Pataud Rock Shelter

Another consideration of bones as fuel comes from France. The Pataud Rock Shelter, in the oldest strata, has multiple hearths filled with carbonized bone. There was very little wood charcoal present in these hearths. These observations led Théry-Parisot (2002) to suggest that the people who used this rock shelter, used bones as their fuel source. Calculations were done to see if wood was scarce near the shelter in order to determine if this was the reason why bones were burned. Unfortunately, Théry-Parisot's tests involved the use of wood. The arctic populations 11,000-15,000 would not have had wood available to them. Théry-Parisot also explains that the bone fires were probably only used for convection and radiation. Convection heat energy was used for: heating closed places, drying, and curing. Radiation heat energy was used for: heating closed places, heating a body, protection, cooking, drying, and light (Théry-Parisot 2002). Early arctic people may have needed bone fires for all of these reasons.

Even though both of the previous sites are not located in Beringia, it is important to note that the use of bones as a fuel source could possibly have taken place across the globe during different temporal stages depending on the availability of wood. Burning bone may not have been exclusive to one area; however, since it does not seem to be a highly used technique, it is hard to say whether or not the idea of burning bone for fuel spread from group to group, or if the use of it was an independent occurrence.

Bone Burning Experiments and Results

The next section of this discussion reviews a series of experiments to test whether or not bones could be used for a fuel source. Three experiments were run to test if bone fires were possible. The third test involved the use of boiled bones for the fuel source. Previous experiments done by Drs. Behm and Crass prove that bones can be used to build fires. For the first two experiments, it was predicted that the fires would be successful. Since boiled bones were never used, the prediction for the third test was that it would be unsuccessful. It was thought that it would be unsuccessful because the boiling process would affect the fat content of the bones. Each experiment was conducted differently from the previous. However, each experiment involved using the same basic materials: bones from some type of hoofed animal and grass. The three types of animals used for theresearch were White-Tail deer, North American elk, and beef cattle. The species of grasses used are unknown; however, both can be found locally in Wisconsin. Because the experiments were held outside, the weather conditions varied each day, and it is for this reason a brief description of the weather conditions are incorporated for each experiment.

Experiment One

The first experiment involved using bones from a White-Tail deer. Mostly long bones were used, and the bones varied between 17 cm to 30 cm in length. Also a scapula was used in the experiment. There were eleven bones used for this fire, and the total weight of all of the bones was 3.5 pounds. The grass used in this experiment was collected from Jefferson County. The cut and dried grass that was collected was braided into bundles. Cut up bits of lard were also used in this test. Fortunately, a lack of precipitation made it easier to try for a successful fire, but the high winds hindered it. The setup for this test was based off tests run by Drs. Behm and Crass (Crass 2005).

The fire was built inside of a metal fire pit that was filled with fine sand. A mound of braided grass was then placed on top of the sand, followed by the bones and lard. The bones were placed in a pyramid-like shape around the grass, and some of the lard chunks were placed among them. After several attempts at trying to light the fire, some of the grass started to burn. Grass was continually added to the fire in order to keep the grass burning so that the fire would become hot enough to start melting the fat from the bones. This was done for approximately30 minutes. Eventually, the grass was left to burn itself out.

The flames from this fire were never very large, and little heat was emitted. The color of the flame was an intense orange. When compared to a wood fire, the flame was much brighter. No temperatures were recorded for this half of the test. The fire from the grass charred the bones, but the bones never actually started to burn.

Since the bones had not completely burned, the test was reset for a second try. The fire pit was cleaned and the setup for this trial of the experiment was the same as before. Again, due to windy conditions, the fire was hard to light. Finally, there was success at getting a small fire started. This time, some of the bones did crack, and the rest of the long bones were cracked by hand to allow the bone marrow to be exposed to the fire. The exposed bone marrow seemed to add more fuel to the fire. As with the first trial, the same intense orange colored flame was seen. This time, a sizzling noise could be heard coming from the fire as the bone marrow came into contact with the flames. Since a sizeable fire was burning, two temperature readings were taken. The first temperature taken was about 110^{o} C. The second temperature, taken approximately 11 minutes after the first, varied between 135^{o} C and 150^{o} C. These were the only temperature readings taken for this part of the test because the fire quickly died. The total time taken to complete the entire experiment was approximately 2 hours and 30 minutes. This time included the amount of time it took to reset the fire for the second trial. All of the remains were taken out of the fire pit and were saved for later examination.

Experiment one was done to see if a bone fire could be started. Based off what happened in the experiment, it could be concluded that bone fires are not possible. Since this was the first experiment done for this research project, there were many factors that led to an unsuccessful burn. The grass used in this test never burned hot enough or even long enough to get the fat to melt. The bones that were used may not have been dry enough. Most of the fat on the outside of the bones had been cleaned away. The fire would have needed to get to a very high temperature using just the grass in order to crack the bones open. All of the fat that was needed was still inside the bone. The lard that was used in this test did not have the same effect as having fat still attached to the outside of the bone. Another factor in the unsuccessful burn was

the grass used. The grass was not as dry as it could have been. The wind on that day was also not helpful in getting a fire started. Some breeze would have been necessary to help get the fire started, but this wind was too strong. It is completely possible that if bone fires were made in the arctic, wind would have also been a factor. However, it is strongly believed that the people living in the arctic, 11,000 years ago, would have been much better at building bone fires if they did build these types of fires.

Experiment Two

The second experiment was again used to test the possibility of bone fires. However, different bones were used, and the fire was set up differently. Like the first test, wind was an issue, but there was again no precipitation. The bones used came from a White-Tail deer and from an elk. The bones from the White-Tail deer included: a complete rib cage (with vertebrae attached), long bones, and a small section of another rib cage containing five ribs. The bones that were used from the elk were two long bones and a scapula. Once again, grass from the Jefferson area was used; however, most of the grass used for the test was collected from the Green Bay region. The largest difference between the two types of grasses was the diameter of the grass stem. The diameter of the grass taken from the Green Bay region was significantly smaller than the grass taken from the area in which the tests were held. Drs. Behm and Crass used the Green Bay grass for their experiments and highly recommended using it for this experiment.

Sand was placed into the fire pit, and a greater amount was used. Instead of placing the grass directly on top of the sand, two rocks were used to make a small airshaft so that more oxygen could be let in underneath the fire. The idea for using the rocks came from a discussion with Dr. Crass at one of their recent experiments. Since the fires would often suffocate themselves, it was thought the rocks would allow even more oxygen flow. The grass braids, made with the grass from the Green Bay region, were then circled around the rocks. The complete rib cage was broken into smaller sections so that it could be placed around the grass more easily. A few of the deer leg bones were also added. No additional lard or fat was used for this fire.

Getting the fire started and keeping it burning was less difficult for this experiment. It took about 20 to 30 minutes to get an established fire started. Since the fire was very stable, the small rib cage section, the elk bones, and the remaining deer leg bones, were added to the fire. These were placed at the top of the fire, to ensure any melting fat would run down the entire length of the fire.

This fire continued to burn for about 30 minutes. Again, the very intense orange flame was observed (Figure 1). After this point, the wind picked up, which made it more difficult to keep the fire going. Since there are no natural windbreaks near the burning area, a wheelbarrow was used. It was placed on the southern part of the fire. The fire had to be reset, and the wheelbarrow did help with stopping most of the wind. After the fire was reset, it burned for another 20 minutes before completely dying out. Figure 2 shows the remains at the end of the fire. Like the first experiment, all of the remains were removed and saved. Samples were taken from the sand where the fat had accumulated.

As with the first test, the same color flame was observed. Since the fire was more stable, it was easier to get temperature readings. The first temperature was taken

Figure 1: Shows the flame from experiment two.

Figure 2: The bone remains from experiment two after the fire had died.

33 minutes after the start of the test, and was between 90° C and 100° C. The second reading, 20 minutes after the first, was at 320° C, and the third, 8 minutes after the second, was at 540° C. After the third temperature was taken, the fire had died and had to be reset. The fourth temperature reading was approximately 54 minutes after the third had been taken. This temperature was 480° C. The intensity of the heat was great enough to create calcined (decomposed carbon) bones. Even though there were some calcined bones, some of the bones did not burn.

The results from experiment two helped prove that bone fires could have been possibly sustained in the artic. A stable fire was achieved for a substantial period of time. Even though it was a partial success, there were still many things that could be changed to make the experiment more successful. The bones were much drier for this test and many of them still had plenty of fat left on the outside. More bones could have been used to make a larger, more sustainable fire. The rocks in the middle of the fire helped to allow more oxygen flow, but they also acted as a barrier, since there was a small amount of materials used. When one side of the fire was started, it was very difficult to get the other side burning. Because of this barrier, all of the materials were never burning at the same time. Next time an experiment is done similar to this one, either more bones are needed, or smaller rocks. Again, the wind was a major issue when trying to get this fire started. There are some benefits to conducting these experiments inside. For one, the weather factor is eliminated, but the weather may have been something that early arctic people would have had to also deal with, so running the tests outside puts the tests into a more realistic setting.

Experiment Three

Experiment three was to test if boiled bones could be used as a fuel source. The setup for this experiment was basically the same as experiment two. There were some elements that did change. The bones that were used were beef cattle bones. They were all leg bones that had been cut into smaller segments. Two of the pieces were fragments of long bone shafts. All of these bones were then boiled. For this test, the grass that was used was from Jefferson County, and none was taken from the Green Bay area. The weather conditions had also changed from the previous two tests. Firstly, it was considerably cooler, approximately 30^{o} F to 35^{o} F, and secondly, there was light precipitation, with snow that was accumulated on the ground and in the test pit. The wind was not an issue for this experiment.

For this experiment, the bones needed to be boiled. All of the bones were placed into the pot, and then the pot was filled with water until the bones were completely covered. The water was then heated until it was boiling. While the bones were being heated, the fat from the bones began to separate from the bone. After the bones were boiled, the fat was skimmed off the top and placed into a bowl, and the bones were placed into a different container to let the water drip off.

Before the test could be set up, snow had to be removed from the fire pit. No additional sand was added. Unlike the first two tests, the sand platform for this test was frozen and packed together. Once again, the two rocks were used to create the airshaft. Braided grass bundles were wrapped around the rocks, and the bones were placed on top of the grass (Figure 3).

The fire for this test was difficult to start and maintain. There was no success in getting the grass to burn. The grass would burn for a short time, and then die out. There was a brief moment when the fire burned strongly for at least a minute before it died. Several attempts were made to relight the fire, but it would not relight.

Experiment three was the least successful of all of the burns. In terms of what the flames did look like, the color was exactly the same as the last two tests. Since this fire was done at night, the color of the flame could be seen more noticeably. After the fire had died, the bones were collected. The next day, a second attempt was made.

Figure 3: Setup of experiment three prior to the fire being set.

There was a steady drizzle all morning, and nothing stayed dry for long. Only small, short flames were seen. Most of the bones had not burned. The fat that was still intact after the boiling process did not melt from the fire. Everything had become too wet to get a fire started.

Experiment three posed the most questions. The major question was how long the bones should be boiled. If the bones boil long enough, all the meat and fat will cook off the bones, and if the bones are cracked, the marrow may also be lost. After the boiling is over, all that may be left are bare, hollow bones. Many grass and fat scraps would have been needed to get these bones to burn. If the bones are just brought to a boil with the heat being reduced right after, like in experiment three, much of the fat remains intact with the bones, though some fat will be lost. Another question that this brings up is how should the bones be left to dry and for how long should they dry before they can be burned? The bones should be as dry as possible before an attempt to burn them since any water will hinder the fire.

Conclusions

The main question concerning bone burning, in general, is how it was done. Using dry bones and grass as the initial fuel seems to work the best in getting a good fire started. Fresh bones can then be added once the fire has enough energy. Still, how the bones were dried in the arctic 11,000 years ago is not known. One possibility is that the bones could have been left in a cache to dry. However, there is the likelihood that the group may never return to the spot in order to retrieve the bones, or the bones may be scavenged by other animals and lost. Another possibility is that the group could have taken the bones with them until they were properly dried. This could be a very dangerous scenario since they would then smell like something that a predator would eat. Boiled bones may have also worked, but some type of fire had to be established in order to boil the water. Previously boiled bones could have been used to set up the fire,

but this brings back the questions from the third test. There are more cooking processes that a bone can go through other than being boiled, but those processes also need to be tested and will generate even more questions that will need to be answered.

Until definite archaeological evidence is provided, tests will help in trying to answer all of these questions. Unfortunately, most archaeological analysis is based on the stuff that was left behind, and bones are organic matter that will decompose over time and be lost. Burnt bone, which preserves well, is mostly found with wood charcoal remains in a hearth setting. For the few sites that have possible evidence, little analysis has been done. However, through archaeological experimentation, the processes that went into to making bone fires may be discovered. In order to get the best possible understanding of how bone fires may have been used, bone fires need to be made, and then allowed to go through taphonomic stages in order to be compared to remains found at archaeological sites. Experimentation is the most promising way to understand what early arctic people may have done for fuel since many of the stories that they left behind have now vanished, and it is impossible to go back in time to see how they truly lived.

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