THE CATASTROPHIC DEEP-FREEZE OF THE BERESOVKA MAMMOTH

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It is commonly held in historical geology that Pleistocene extinctions were a gradual process lasting over thousands or millions of years. However, frozen mammoth carcasses found buried in the tundra muck give evidence leading to a different conclusion. Of particular interest is the carcass of the Beresovka Mammoth (1901). An analysis is presented of the temperature drop necessary at the time of its death to leave the mammoth in the state of preservation in which it was found. By using thermodynamic models of the mammoth, it is demonstrated that the animal must have frozen to death in mid-summer by being suddenly overcome by an outside temperature below − 150 ° F.

The opening remarks of Aleksandr Solzhenitsyn in his now famous *Gulag Archipelago* remind all students of natural history of one of the most perplexing mysteries of the northern tundras: the existence of thousands of frozen animal remains.

> In 1949 some friends and I came upon a noteworthy news item in *Nature*, a magazine of the Academy of Science. It reported in tiny type that in the course of excavations on the Kolyma River a subterranean ice lens had been discovered which was actually a frozen stream—and in it were found frozen specimens of prehistoric fauna some tens of thousands of years old. Whether fish or salamander, these were preserved in so fresh a state, the scientific correspondent reported, that those present immediately broke open the ice encasing the specimens and devoured them with relish on the spot.[1]

There is perhaps no inquiry in the whole range of Natural history more fascinating than the study of these frozen remains. Of particular interest are the mammoth carcasses found in Siberia and Alaska. Imaginations of both children and scientists are stirred when they read how barren are the inhospitable wastes of Northern Siberia. There, neither tree nor shrub will grow, and the land for hundreds of miles is covered with a damp moss barely sprinkled for two months with a few gay flowers and for the rest of the year is locked in ice and snow. There only white fox and polar bear can now survive. There, are found below the ground huge hoards of bones of elephants and other beasts whose appetites needed corresponding supplies of food.

But one's interest rises to the highest pitch when it is observed that this vast cemetery not only teems with fresh bones and beautiful tusks of ivory, but with the carcasses and mummies of these great animals. So well preserved are they in the perpetually frozen soil that the bear and wolves and even, it has been reported, men in some cases, can feed upon them. As recently as February 1976, it was reported that Russian fox trappers have frequently used mammoth meat as bait in their fox traps.[2] This usage has long been reported by other writers.[3] Lydekker has observed:

> In many instances, as is well known, entire carcasses of the mammoth have been found thus buried, with the hair, skin and flesh as fresh as in frozen New Zealand sheep in the hold of a steamer. And sleigh dogs, as well as Yakuts themselves, have often made a hearty meal on mammoth flesh thousands of years old.[4]

The Beresovka Mammoth

One of the most intriguing finds was that of the Beresovka mammoth on the Beresovka River in 1901. At this site, a perfectly preserved whole carcass was excavated 60 miles within the Arctic Circle and 2,000 miles north of the present range of living elephants.[5]

The expedition which excavated the mammoth was led by Dr. Otto F. Hertz, a zoologist on the staff of the Academy's museum, M. E. V. Pfizenmayer, a zoological preparator of the Academy's museum, and M. D. P. Sevastianov, a geological expert of Yurievsk University. The Beresovka mammoth was found frozen into a cliff of the River Beresovka, a right tributary of the River Kolym, 200 miles northeast of Srednekolymsk and 800 miles west of Behring Strait. The mammoth was located in the midst of a landslide and thus, was not found in the location where it met its death.

The excavation began on September 24th.[6] By the time the scientists got there, the head had been exposed for over two years. Thus, much of it had been eaten by wolves and local carnivors. The mammoth originally was exposed during spring thaws when the cliff in which it was frozen began to thaw as it was washed away by spring floods. Some of it therefore, rotted and refroze during the two summers before it was examined by scientists. Well-preserved food fragments were found in the mouth and between the teeth of the mammal.[7] This could only mean that the animal met with a sudden death and did not even have time to swallow the last meal!

The scientists built a house over the mammoth and began to thaw it out. The stench was so bad from the rotten parts that initially it was unbearable.[8] Further indication of sudden death was found in blood which was collected in great masses due to a hemorrhage. It was found to be in such a good state of preservation that it could be examined about as easily as the blood of recent animals. It was even possible to establish the relationship of the blood to the Indian Elephant.[9]

Much decayed food was found in the stomach and the walls of the stomach were badly decayed.[10] Decay of the stomach wall appeared to be due to the fact that the mammoth's back had been torn open by wild animals and the vital organs had been eaten. Thus, it had lain exposed almost to the stomach for two summers before the scientists arrived. One afternoon, the left shoulder was severed from the body and under it a startling discovery was made.

> The flesh under the shoulder, fibrous and marbled with fat, is dark red and looks as fresh as well-frozen beef or horsemeat. It looked so appetising

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> that we wondered for some time whether we would not taste it. But no one would venture to take it into his mouth, and horseflesh was given the preference. The dogs ate whatever mammoth meat we threw to them.[11]

Apparently while some parts of the Beresovka mammoth had rotted away during exposure to the sun, other parts not so exposed, remained as fresh as when the animals had originally died. The meat in Hertz' own words looked fresh enough to eat! Pfizenmayer added, "As soon as it thawed, however, it entirely changed its appearance. It became flabby and grey, and gave off a repulsive ammoniacal stench that pervaded everything."[12]

The flesh and fat of the right leg was also well preserved.[13] Bits of frozen blood were found which, when heated, turned into dirty, dark red spots indicating that the oxygen content of the blood had not been fully extracted. This condition frequently indicates a sudden death. Another interesting and unexpected feature was an erect male genital.[14] This condition is normally explained by a death by suffocation such as by drowning.[15]

As the stomach was cut open, the most amazing discovery of all was made. Inside, 24 pounds of vegetation were removed in an excellently preserved state.[16] Many plants of the same type still grow in Siberia today in the summer. Others are found only far to the south, proving that the climate must have been much warmer when the mammoth lived. For example, common buttercups were found. In fact, the remains were so well preserved that it was actually possible to distinguish between species. This suggest that the stomach temperature was lowered in a relatively short time!

The animal is exhibited in the Zoological Museum of the Academy in Leningrad as a stuffed animal with the skeleton exhibited separately.[17] The frozen skin has been cleaned, softened, and prepared and the animal has been actually stuffed like a modern quadruped and placed in the attitude in which it originally died. The skin of the head and ears is artificial and a model of the base of the proboscis has also been added.

Lessons to be learned from the animal are striking. At first glance it appears that a large animal was peacefully grazing on buttercup flowers and was suddenly overtaken by a deep-freeze in the middle of summer! The plant remains in the stomach of the Beresovka mammoth indicate that the animal died in late July or early August. Furthermore, the animal froze quickly enough to leave these stomach contents in a well-preserved state and for at least some of the meat on the carcass to be edible by dogs!

The fact that it was frozen in muck is generally accepted. What is not believed by contemporary geologists is that this freezing of the mammoth was a sudden affair that was accompanied by a general sudden climatic reversal. As the writer hopes to show, one of the most direct lines of evidence of this sudden freeze is the stomach contents. The Russian scientist, V. N. Sukachev, who examined these remains, was able to identify many different species of plants, some of which no longer grow that far north, and others which grow both in Siberia today and also in Mexico!

Circumstantial Evidence of Sudden Climate Change

There is evidence which indicated that many of the mammoths, not just the Beresovka, were frozen rapidly. For example, there are extensive reports going all the way back to ancient China of men eating mammoth meat.[18] Joseph Barnes, a former correspondent with the New York Herald Tribune, testified to having been served mammoth steak at the Russian Academy of Sciences in Moscow in the 1930's.[19] It is well known that ivory, to be useful for carving, must be fresh. Surprisingly, 25 percent of the mammoth ivory brought back from the tundras is as fresh as new, indicating it froze quickly.[20] Ezra and Cook, after a histological analysis of a mammoth bone found in Alaska, concluded that it had all the characteristics of fresh bone.[21]

Of the 39 mammoth carcasses actually examined by scientists, all were found inside the Arctic Circle, buried in the hard permafrost. The fact that these carcasses are buried in the permafrost indicates that at the time of burial, the climate must have been warm in order for the permafrost to be soft and yielding. Today permafrost only thaws down two feet in the summer.[22] Yet, since the mammoths were frozen and preserved, the permafrost must have quickly frozen after the mammoths were entombed or they would have completely dissolved and rotted. Thus, their very burial in this manner testifies to a sudden temperature reversal that was also *permanent.*[23]

Of great interest in this regard was the state of preservation of the stomach contents of the Beresovka mammoth (1901).

Identification of Stomach Contents

The following list of stomach contents and comments is compiled from the report by the Russian scientist Sukachev, who first examined them;[24] an extensive compilation of the remains by William Farrand;[25] a list given by Osborn,[26] with comments by Botanist A. A. Case of the University of Missouri.[27]

Trees and shrubs

Abies (sibirica?)
Alnus hirsuta
Betula alba
B. nana
Betula sp.
Larix (sibirica?)
Picea (obovata?)
P. sibirica
Salix polaris
Salix sp.
Vaccinium vitis idaea

Herbs, grasses, and mosses

Caryophyllaceae
    Cerastium sp.
    Dianthus sp.
    Melandrium sp.
    S. (nodosa?)
Chenopodiaceae
    Atriplex (patulum?)
Compositae
    Artemisia dracunculus
    Artemisia sacrorum

Artemia vulgaris
Aster sp.
Gnaphalium uliginosum
Lactuca (Mulgedium) sibiricum
Tanacetum vulgare
Sp. indeterminate

Cruciferae
Sp. indeterminate

Cyperaceae
Carex glareosa
Carex incurva

Carex lagopina (lachenalii?)—The remains of this sedge are numerous in the contents of the stomach. The specimens exactly resemble varieties growing today. The measurements show no reduction in size. Its range extends to the shores of the Arctic Ocean. It is found in mountainous regions, including the Carpathians, Alps, and Pyrenees. It is also found in the peat bogs of Western Prussia, in Siberia as far south as Transbaikalia and the southern island of New Zealand.[28]

Sp. indeterminate (N-2)

Gentianaceae
Gentiana sp.

Gramineae

Agropyron cristatum—The remains of this plant are very numerous in the contents of the stomach. They are so well preserved that there is no doubt as to the exact species. The individual specimens are slightly smaller than those of the typical more southern variety growing today, but this could be a result of some reduction of size because of pressure in the stomach, which is noted in other cases. The finding of these plants is of very great interest. Not only are they scarcely known anywhere in the Arctic regions, they are even, so far as I have been able to discover, very rare also in the Yakutsk district. . . . Generally speaking the *Agropyrum cristatum* L. Bess is a plant of the plains (steppes) and is widespread in the plains of Dauria. . . . The general range of this plant includes southern Europe (in European Russia it is adapted to the plains belt), southern Siberia, Turkestan, Djungaria, Tian-Shan, and Mongolia. Nevertheless, the variety found in the stomach differs slightly from both the European and Oriental-Siberian varieties found today.[29] It is similar to the crested wheatgrass of the Great Plains and High Plains of North America.[30] This hardy speaks well for the thesis

This hardy speaks well for the thesis that the climate then was similar as today's.

Agrostis borealis

Alopecurus alpinus—The remains of this grass are numerous in the contents of the stomach. A significant portion of them consists of stems, with occasional remnants of leaves, usually mixed in with other vegetable remains. . . . All these remains are so little destroyed that one is able to establish with exactitude to what species they belong.[31]

Beckmannia cruciformis—This is common American slough grass that grows in Missouri.[32] The florets of this plant are numerous in the contents of the stomach and usually are excellently preserved. The detailed description of the remains, with precise measurements in millimeters shows the species to be of the same as that of the present day, only smaller. At the present time the species is widely prevalent in Siberia and in the Arctic generally. It grows in flooded meadows or marshes.[33]

Bromus sibiricus
Elymus sp.
Hordeum jubatum

Hordeum violaccum Boiss. et. Huet—This plant is found in dry grassy areas. It is not found in the Arctic regions. In Siberia this is a meadow plant.[34] It is a variety of barley.[35]

Phragmites communis
Puccinellia (Atropis?) distans
Sp. indeterminate (N-8)

Labiatae
Thymus serpyllum

Leguminosae
Caragana jubata
Oxytropis campestris

Oxytropis sordida—In the contents of the stomach were found several fragments of these beans. . . . In the fragments taken from the teeth there were found eight whole bean pods in a very good state of preservation; they even in places retained five beans. . . . The plant is now found in the Arctic and sub-Arctic regions, but also in the northern forests. It grows in rather dry places.[36] This plant is commonly known as locoweed.[37]

Papaveraceae
Papaver alpinum

Plantaginaceae
Plantogo media

Polygonaceae
Oxyia digyna?
Rumex acetosella

Ranunculaceae
Caltha palustris

Ranunculus acris L.—This plant is known as the common tall buttercup. Some kind of buttercup may be found form the tundra in the North to near Cape Horn. Case says he has seen them in bloom under the edge of the receding snow at over 12,000 feet altitude in the Colorado Rockies in June and July.[38] The plant grows in rather dry places. It is not at present found growing together with the *Beckmannia Cruciformis* although both are found in the stomach of the mammoth.[39]

Rosaceae
Potentilla sp.
Rosa sp.
Sanguisorba officinalis

Umbelliferae
    Aegopodium podagraria?
    Angelica (decurrens?)
Polypodiacead
    sp. indeterminate (N-2)
Bryophytes
    Aulacomnium turgidum
    Cladonia ragiferina
    Drepanocladus (Hypnum) fluitans

Several general conclusions may be drawn from these data.

(1) The presence of so many varieties that generally grow much to the south, indicates that the climate of the region was milder than that of today.

(2) The discovery of the ripe fruits of sedges, grasses, and other plants, suggests that "the mammoth died during the second half of July or the beginning of August."[40]

(3) The Beresovka mammoth apparently did not feed primarily on coniferous vegetation, but mainly on meadow grasses.

(4) The mammoth must have been suddenly overwhelmed with a rapid deep freeze and instant death. The sudden death is proved by the fact that unchewed bean pods still containing the beans were found between the teeth, and the deep freeze is proven by the well-preserved state of the stomach contents.

State of Preservation of Stomach Contents

When the above list of stomach remains was presented to professional botanists, Dr. Mahler and Barney Lipscomb at the Southern Methodist University Herbarium, their reaction was one of amazement. It seemed incredible to them that the remains could have been so well preserved that different species could be distinguished. The reason for their amazement was the presence of digestive juices which quickly act to break down the vegetable material of the delicate parts of the plants which are necessary for identification. Since the elephant is not a ruminant[41] (i.e., multi-chambered stomach), acid deterioration and enzyme activity would be major factors in breaking down the "cement" which holds the cellulose together in the plant fiber. Since mechanical action of the stomach would break up all vegetable matter within one half hour, the animal must have died within one half hour of swallowing this food.[42]

According to the Dallas Coroner, acid and enzyme action would completely dissolve the delicate parts of these plants within a matter of hours. He said he would be "shocked" to see them in recognizable form a day after the death of the animal. Dr. C. W. Foley, a Veterinary Physiologist with the University of Missouri Medical School, was asked how long the buttercups might last in the stomach of the mammoth after death, and he responded, "I wouldn't think they would last more than a couple (2-3) hours, maybe more in a ruminant."[43]

As a final check on these estimates, an experiment was conducted with the aid of Dr. Larry Bruce, a gastro-intestinal physiologist with the University of Texas Health Science Center at Dallas. First, a solution of stomach acid was prepared by mixing 70 micromoles of swine pepsin with a 0.1 normal solution of HCl with a PH of 1 (250 mg of pepsin per 100 ml HCl). To this solution a small amount of NaCl (0.9%) was added as a catalyst. This solution was then poured into four different beakers, each at a different temperature: 4 °C, 17 °C, 27 °C, and 37 °C. After the temperatures had been established, some gladiolas and carnations were compacted into the beakers so that the surface level of the solution corresponded to the top of the flower compaction. The stems, leaves, and flowers were all included.

On the assumption that it was necessary to have delicate parts of these plants in order to identify them at the species level, these four solutions were left to act on the flowers until the flowers were in each case beyond recognition. Although the observation of this process proved to be highly subjective, four categories of decay were oberved:

A = first appearance of dye from the flowers in the solution;

B = the beginning of a loss of flower structure;

C = structural support completely gone, flower petal dissolved beyond recognition; and

D = leaching of flower petal pigment.

Results are reported in Table 1.

It would appear that the gladiola could not have lasted more than five hours in the stomach of a mammoth, even if the initial temperature of the mammoth was 4 °C (40 °F). The gladiola and the buttercup are both considered very delicate plants, and thus, the buttercup's longevity in a mammoth's stomach is severly limited! The carnations, however, lasted considerably longer. At the end of 10 hours in the 4 °C beaker, the carnations had hardly been touched, whereas they were beyond recognition in the 17 °C beaker in 25 hours.

Since it is not known for sure what the resistance to attack by acid and enzymens may have been in ancient buttercups, it is risky to draw precise conclusions. However, the above experiment certainly suggests some limits of perhaps 10 hours for flower longevity if the stomach temperature was initially at 37 °C.

If the buttercup had the resistance of a carnation, the stomach temperature would have had to have been lowered to 40 °F within 10 hours to have left anything in recognizable form. This is probably a maximum because the above experiment did not take into effect the chewing of the food by the mammoth, nor did it account for the continued mechanical activity of the stomach which persisted for up to ½ hour after death.[44] Both of these factors would have acted on the stems and leaves, and with great effect on the flower petals.

In view of the uncertainties involved and the omission of chewing and mechanical action after death, it seems that a reduction of the stomach temperature to 40 °F within 10 hours would be the outside limit of buttercup longevity. This would correlate fairly well also with the requirements for finding any edible meat on a mammoth which apparently has, in some cases, happened.

The only way there could have been any recognizable remains in the stomach of the mammoth would be through cessation of the digestive activity. The only mechanism that will do this is cooling. The reduction in enzyme activity follows van't Hoff's rule which says

Table 1. Progressive decay of gladiolia flower petals in a solution of stomach juice at various temperatures. See the text for the significance of A, B, C, and D.

	4°C	17°C	27°C	37°C
A	3	1½	1	1
B	4	3	3	2
C	5	3½	3½	3
D	—	25	10	10

that for every 10 °C decrease in temperature, enzyme activity is reduced by 50%. When a professor of veterinary physiology, Dr. C. W. Foley, was asked, "Is there any other way than a sudden freezing that these buttercups could have survived in such a well-preserved form?", he replied, "I can't think of any other way." Botanist A. A. Case, after examing the list of the remains concluded,

> If the mammoths and other animals were "quick frozen" in their tracks by minus 100-degree C type of climatic upheaval as suggested by some, the things found today would be logical.[45]

The acute nature of this problem has been overlooked consistently by the theorists of mammoth extinction. The plants in the stomach only blossom when the weather is warm (buttercups will not even grow unless the temperature is well above 40 °F.), and yet, shortly after ingestion, the temperature must have dropped sufficiently to reduce the stomach temperature of the mammoth to at least 40 °F within 10 hours! Clearly a drastic climatic upheavel is required and there appears to be no escape from this conclusion!

The necessity of this sudden temperature drop is seen to be inescapable when the precise state of preservation of these remains is considered. While some parts of plants are especially resistant to acidic and enzyme decay, the parts necessary to draw distinctions between species are quite soft and sensitive. For example, Sukachev drew distinctions between different species of Carex. Yet,

> In order to be certain of one's identification in this group, the largest genus encountered in Missouri, it is necessary to have fully mature pistillate flowers with well-developed achenes, and a complete specimen with roots and all.[46]

The flowers are, of course, very delicate, and would be dissolved quickly by acidic action and enzyme activity. The achene is the fruit of the plant. It is surrounded by the perigynium or "sack". The presence or absence of this delicate sack is one factor in distinguishing between various species of Carex.[47] The achene is only 0.3 to 0.6 mm long. Yet this very small part of the plant with its delicate covering was preserved through the acid bath in the stomach of a dead mammoth.

In the case of the buttercups, a similar situation exists. The achenes alone are not sufficient to identify which species of buttercup are present, because many of them are about the same size. The particular genus of buttercup is determined by the color of the leaves, dark blue or purple.[48] Thus, the buttercup flowers were preserved in the stomach of the mammoth and in such a state that it was possible to distinguish between two such similar colors as dark blue and purple! To determine the species of buttercup, i.e., *Ranunculus acris*, an examination of the fleshly parts, the sepals (a modified leaf of a flower), and the color of the petals is necessary.[49] All of this requires that the stomach temperature of the mammoth was dropped very quickly, or there would be none of these delicate parts in identifiable form.

Sudden Deep Freeze of Beresovka Mammoth

It should be evident from the above discussion that one is faced with a situation most foreign to uniformitarian geology. The stomach contents indicate that it was mid-summer when the mammoth died, and yet, the state of preservation of the stomach remains require that shortly after death, the stomach temperature must have been lowered to temperatures in the 30's F. in order to stop the activity of the digestive juices. The question now is: what degree of outside temperature drop is necessary to reduce the stomach temperature to around 40 °F. in ten hours? In consultation with Dr. Roger Simpson of the Department of Civil and Mechanical Engineering at Southern Methodist University, two thermodynamic models of the mammoth were constructed.

The Thermophysical Properties of Mammoth Meat

In order to set up a physical model from which the above question may be answered, certain assumptions must be made concerning thermophysical properties of the mammoth. Since this specific information is impossible to obtain, it will be assumed that these thermodynamic properties were similar to those of contemporary elephants and that the thermal properties of the meat are not much different from those in beef, which are fairly well known.

For the calculations below, four properties must first be determined: (1) thermal conductivity of beef, (2) specific heat of meat (3) density of the mammoth, and (4) film conductance of the mammoth.

(1) Thermal conductivity of beef. This quantity, k, is a measure of the time rate of transfer of heat by conduction, through a unit of thickness, across unit area for unit difference of temperature.[50] The dimensional units are BTU per hour per foot per F° in the British Engineering System, which is used here. This property of the meat would vary with the temperature of the animal. A value of 0.257 BTU/hr-ft.-°F. for a temperature range of 100 °F. to 32 °F. will be assumed.[51]

(2) Specific heat of beef. This quantity, c, is a measure of the amount of heat necessary to raise the temperature of a unit mass of a substance one degree F. The dimensional units are BTU per pound per degree F. Like thermal conductivity, specific heat varies with temperature. In the temperature range of 100 °F. to 32 °F. a value of $C = 0.84$ BTU/lb-°F. is used.[52]

(3) Density of beef. It will be assumed that the density of the mammoth, i.e., the mean or average density, is about the same as that of a human being or a cow today. The mean density of a cow has been computed to be 66.14 lb/cu. ft.[53]

(4) The film conductance of the mammoth. This quantity, h, is the coefficient of heat transfer between a surface and its surroundings. It is a measure of the energy dissipated from a unit area of a surface per unit

time for unit difference of temperature between the surface in question and surrounding bodies. The units are BTU per hour per ft.^{2} per °F. For forced convection heat transfer produced by a cold wind, this coefficient is dependent upon the geometry of the freezing specimen and other factors including the kinematic viscosity and the wind velocity. For modeling purposes, the mammoth will first be approximated by a cylinder. The formula for the film conductance for flow over a cylinder is then,[54] $h = (C)\ (Re)^m (k/d)$ where $C = 0.024$ and $m = 0.8$, (constants for a cylinder).[55] The diameter, d, of the mammoth will be assumed to be 5 ft. This value was suggested to the Birds Eye engineers by a curator of the American Museum of Natural History.[56] The thermal conductivity, k, of air is 0.015 BTU/ft-hr-°F. (at 0 degress C).[57] The equation for the Reynolds number, Re, is given by[58] Re = *(wind velocity)(diameter)/(kinematic viscosity)*. The kinematic viscosity is the ratio of the dynamic viscosity (1.11×10^{-5}lb/ft-sec. for air at 0 °C), to the density (0.086 lb/ft.^{3} for air at 0 °C) or 1.25×10^{-4}ft.^{2}/sec.[59] If the cold wind that overcame the mammoths moved across the tundras at 100 mph (147 ft./sec.), the Reynolds number would then be 5.68×10^6. This gives a value of h = 18.24 BTU/hr.-ft.^{2}- °F.

In 1961 Birds Eye, experienced with frozen meat, was asked to check the credibility of an article on the mammoths to be published by *Reader's Digest*. The Birds Eye engineer, Ivor Morgan, who did the calculations, assumed a wind velocity of 40 mph and a temperature of − 50 °F. and a value of h = 10.5 BTU/hr-ft.^{2} -F. In the calculations below, a value of 18.24 will be assumed.[60]

With these approximate assumptions, it is possible to predict with fair certainty the magnitude of the outside (ambient) temperature necessary to have left the Beresovka mammoth in the state of preservation it was found. Two different geometries will be used for a physical model of the mammoth: an infinite cylinder, and an equivalent sphere.

Model #1: An Infinite Cylinder

The Birds Eye engineers originally modeled the mammoth as an infinite cylinder. Luikov has presented graphical solutions for the problem of the rate of cooling of an infinite cylinder that render tremendously complex calculations relatively simple.[61]

Figure 1 shows $\theta = (T - Ta)/(Ti - Ta)$ as a function of Fourier number. T is the temperature of a certain point in the cylinder, in this case 40°F. at six inches into the mammoth. It is assumed that if the temperature of a point six inches into the mammoth has been brought to 40 °F., that digestive action will have been sufficiently retarded so that the mammoth could freeze over the next few weeks without significant further digestive damage to the stomach contents. Needless to say, this is a very generous assumption. The stomach begins at about six inches into the mammoth.[62] Ta is the ambient temperature of the surrounding air; a value of − 50 °F. (a more moderate value consistent with today's observations) and values − 100 to − 250 will be used (radical values beyond present day experience). Ti is the initial temperature of the mammoth. It will be assumed that the mammoth was suddenly overcome by intense cold so that he immediately stopped whatever he was doing (including chewing), and began slowly to freeze to death. Death will occur at 74 °F. in a mammal.[63] Thus, at − 50 °F., $(1 - \theta) = 0.274$ and at − 175 °F., $(1 - \theta) = 0.137$; and at − 200 °F., $(1 - \theta) = 0.124$.

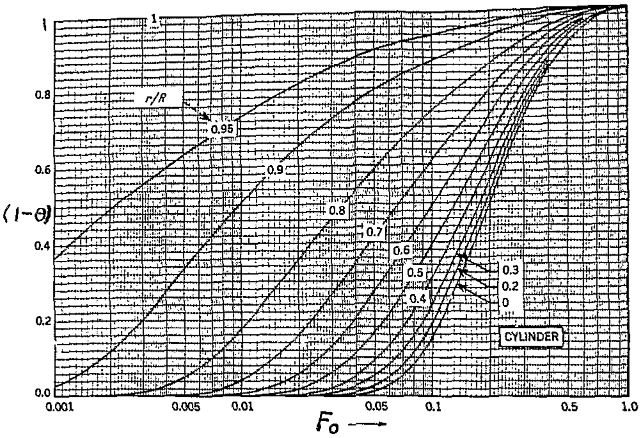

Figure 1. This is a plot of the dimensionless excess temperature $(1 - \theta)$ vs. the Fourier number for various values of the coordinate for a cylinder.

The ratio, r/R is the ratio of the distance a point r'' is from the center of the mammoth to the radius of the mammoth. In this problem a value for $r = (30'' - 6'') = 24''$ is assumed. Thus $r/R = 0.8$.

The dimensionless Fourier number is given by, $Fo = at/R^2$ where $a = k/(den)(c)$. From the above discussion of the thermophysical properties of mammoth meat, a value of k = 0.257 BTU/hr-ft.^{2}-°F., $den.$ = 66.14 lb/ft.^{3}, and c = 0.84 produce a = 0.00462 ft.^{2}/hr. In the above, t = time in hours, and R = the radius of the mammoth in feet = 2.5.

By reference to Figure 1 it can be seen, therefore, that when Ta = − 50 °F., that the Fourier number is 0.274 and t = 19.6 hours. If Ta = − 175 °F., then the Fourier number is 0.137 and t = 10.8 hours. Due to the fact that the outer few inches of the mammoth will plunge way below freezing in the first few minutes, the rate of heat removal will be somewhat faster than the above calculations allow for. This is because the thermal conductivity of the outer shell will increase threefold with the sudden freezing of the outer shell while the specific heat will drop by nearly 30%. Thus, it may be safely concluded that if the outside temperature is dropped suddenly to − 175 °F., that a point six inches into the mammoth would be brought down to 40 °F within 10 hours.

Assuming the above parameters, the time necessary to bring a point six inches into the cylinder down to 40 °F. is displayed in the Table 2 (graphical solution). If the temperature was similar to observed temperatures today, (i.e., − 50 °F.), the digestive bath would have nearly 19 hours to dissolve the stomach contents and there would be nothing left well enough preserved to distinguish the species. This calculation indicates that the mammoth must have been overcome suddenly by temperatures approaching − 175 °F.!

Table 2. Time in hours to bring the temperature of the contents of the stomach down to 40 °F, for various external temperatures of the air.

	Computer Solution (Spherical geometry)				Graphical Solution (Cylindrical geometry)
Air temp. Ta, °F.	Time, hr., to bring mean temp. of mammoth to 40 °F.		Time, hr. to bring a point 7.27″ in to 40 °F.		Time, hr., to bring a pt. 6″ in to 40 °F.
	Ti = 100	Ti = 74	Ti = 100	Ti = 74	Ti = 74 °F.
−50	45.0	25.0	33.0	25.0	19.6
−100	20.0	12.8	20.0	15.0	14.2
−129	16.3	11.0	17.5	13.3	13.5
−150	13.0	9.5	15.2	12.0	11.9
−175	11.6	7.6	14.2	10.1	10.8
−200	10.0	6.5	12.8	9.0	10.4
−225	8.3	6.5	11.4	8.8	9.9
−250	7.8	5.3	10.8	7.8	9.6

Model #2: An Equivalent Sphere

In order to validate the above equation, an inquiry was directed to the Birds Eye Frozen Food Corporation in New York. In a popular science article it had been reported that:

> Birds Eye frozen food experts, in examining the mammoth tissue, have deduced that they were "thrown into the cooler" suddenly, into temperatures below − 150 °F.[64]

The writer contacted the Birds Eye engineer, Ivor Morgan, who did the calculations on the mammoth in February of 1960. Apparently, Birds Eye had been asked by *Reader's Digest* to check the credibility of an article they were proposing to publish in 1960 on the catastrophic deep freeze of mammoths. They did not, as was erroneously reported, "examine mammoth tissue."[65]

However, Mr. Morgan supplied the writer with a computer program which he designed for Birds Eye to determine freezing rates in spheres of different diameters.[66] This program was quite rigorous and took into consideration the precise variation of specific heat and thermal conductivity with temperature, and also considered the effects of freezing and the extraction of the latent heat of fusion. In order to adapt the program specifically to the mammoth question, a computer programmer, Bert Dollahite, who works with the U.S. Army in Washington, D.C., was consulted.

The program assumed the mammoth to be composed of ten concentric spheres. It is really an approximate solution of the Fourier heat conduction equation for small increments of time and small finite increments of spherical radius. Heat flow into each of the ten concentric spheres, less heat flow out, equals the residual heat which manifests itself as a change of state and temperature. The program has the ability to compute the mean or average temperature of the mammoth at any given time as a function of the outside temperature. Mr. Morgan who designed the program and Mr. Dollahite who adapted it, said that the mean temperature would give an accurate representation of the temperature of the stomach contents of the mammoth at any given time.

In order to determine the equivalent volume of the sphere, an approximation of the size of the main body of the mammoth was made. Based on the suggestion made to Birds Eye by a curator of the American Museum of Natural History, the radius of the mammoth was set at 2.5 ft. The length of the main body was estimated to be about eight feet.[67] Thus, the mammoth's torso is modeled as a cylinder, eight feet long and five feet in diameter. The volume of such a cylinder is 271,296 cubic inches; and the radius of a sphere of the same volume is 40 inches. Thus, in the program, a sphere with a radius of 40 inches is equivalent to the mammoth carcass. The assumed film conductance is the same as that of the cylinder, 18.24, and the density is 66.14 lb/ft.^{3}. With these parameters, the Birds Eye program yields the data for the time necessary to bring the mean temperature of the mammoth to 40 °F., as a function of the ambient temperature, given in Table. 2.

From Table 2 it can be seen that the Birds Eye program and the Luikov graphical solution for a cylinder show general agreement for somewhat different assumptions on the geometry. It is obvious from Table 2 that temperatures well below − 150 °F are necessary in order to bring the temperature of the stomach contents down to the required 40 °F. within the 10-hour limit specified by the botanists and gastro-intestinal physiologists consulted.

It is interesting to note that this temperature (− 150 °F) was the same as that reported by Ivan Sanderson. Referring to a report that indicated the cells of the mammoth had not burst, Sanderson argued[68] that frozen food experts concluded that the mammoth under examination had been frozen at temperatures below − 150 °f. Thus, the same figure was determined from two entirely different approaches!

To say that 10 hours is the limit and 40 °F. the required temperature is probably a conservative estimate. It is more likely that the temperature had to be brought to 35 °F. within six or seven hours. Furthermore, if the Beresovka mammoth was killed instantly, as the evidence could indicate, then *Ti* = 100 °F., and air tempertures of below − 200 °F. would have been necessary. The value of *Ti* = 74 °F. assumes that the animal gradually froze to death.

In the computer solution, the reason that the mean temperature closely approximates the temperature of a point 7.27 inches into the mammoth is that about 42.6% of the volume of the mammoth is outside of a point 7.27 inches from the surface. The temperature outside that point is much lower, and almost half of the volume of the mammoth is located there.

It should be emphasized that the above calculations are based on the premise that rapid cooling was necessary to preserve the plant remains. However, even if it were possible to have identified these plants without reference to their vegetable parts, the fact that edible meat has been carved off of mammoth carcasses requires a similar temperature drop to 40 °F. within ten hours to have left meat edible.

Conclusion

It is clear that for the Beresovka mammoth, some violent climatic upheaval is the only explanation for these remains. The animal was peacefully grazing on summer buttercups in late July and within one half hour of ingestion of his last lunch, he was overcome by temperatures in excess of − 150 °F. He was killed soon after and frozen to death in the middle of the summer. Furthermore, he never completely thawed out *until* he fell out of a riverbank in 1901. Thus, whatever climatic upheaval caught him, permanently changed the climatic conditions of the tundra. Certainly, here is clear evidence of the sudden deep-freeze posited by so many students of the mammoth question for the past two centuries.

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[60] Using the Handbook of Chemistry and Physics value of k = 0.0138 BTU/ft-hr-°F (at 0 °C); air density = 0.08 lb/ft^3; and air viscosity = 1.15×10^{-5} lb/ft-sec (from the TPRC Data Series), a value of h = 15.42 results. Using this value instead of the above value of 18.24, yields a negligible difference in the outcome of both the graphical and computer solutions. Thus, 18.24 is maintained.

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RAPID GROWTH OF DRIPSTONE OBSERVED

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Evolutionists generally assume that dripstone deposits, such as stalactites and stalagmites, form slowly, while creationists would maintain that rapid rates of formation must be possible. Here factors affecting the rate of formation of dripstone are discussed. Hypothetical environmental conditions immediately following the Genesis flood would be expected to produce rapid formation of dripstone. Actual observations of rapid formation are reported. Therefore, the creationist position is supported by theoretical as well as experimental data relating to the rate of formation of dripstone.

Introduction

Creationists assume that limestone caverns were formed several thousand years ago, during or immediately following the Genesis flood. The generally accepted phreatic (below the water table) theory of cave formation[1-5] is in agreement with the Genesis account of a world-wide flood and therefore supports this assumption. Caves may have formed rapidly during the flood (after the major sedimentary deposits had been laid down) or immediately following the flood. As the continents were raised, declining water tables would have drained the caves and produced conditions suitable for growth of dripstone. The present existence of large stalactites and stalagmites would therefore demand recent environmental conditions suitable for *rapid* formation of dripstone.

Evolutionists, on the other hand, generally assume that dripstone has always formed *extremely slowly* under the environmental conditions found in caves.[6] Consequently, large stalactites and stalagmites, and the caves containing them, are often considered to be hundreds of thousands to millions of years old.[7]

Data concerning the actual growth rates of stalactites and stalagmites under various environmental conditions should be of interest therefore, to creationists and evolutionists alike.

Since this type of research project was suggested[8] in 1970, several brief articles have appeared in the creationist literature which suggest that stalactite growth can and does occur rapidly.[5,9-11] It is the purpose of this communication to discuss the factors which may have affected the rate of stalactite and stalagmite growth since the Genesis flood, and to report actual observations of rapid dripstone deposition.

Factors Affecting Stalactite and Stalagmite Growth

Water containing carbon dioxide is weakly acidic and reacts with calcium carbonate (calcite) in limestone to produce soluble calcium bicarbonate (reaction a) as it percolates into the ground. When the water reaches the ceiling of a cavern, evaporation and loss of carbon dioxide may reverse the reaction and cause precipitation of calcium carbonate in the form of a stalactite or stalagmite (reaction b).

$$CaCO_3 + H_2O + CO_2 \underset{b}{\overset{a}{\rightleftharpoons}} Ca^{++} + 2HCO_3^-$$

Several factors have been identified which affect the rate and manner of deposition of calcium carbonate as stalactites and stalagmites. These include: 1) the concentration of calcium bicarbonate in the solution 2) the drip rate and 3) the rate of evaporation (including loss of carbon dioxide) which is controlled by the air circulation, temperature, and humidity.[12]

Thus, a high calcium bicarbonate concentration (over 50 percent), slow drip rate (less than 1 drip per second), and rapid evaporation favor rapid vertical growth of a small diameter stalactite (Table I, A). Similar concentration and drip rate but with slow evaporation results in slow formation of a large diameter stalactite (Table I, B). High calcium bicarbonate concentration, rapid drip rate, and rapid evaporation favor rapid vertical growth of a small diameter stalagmite (Table I, C). Similar concentration and drip rate combined with slow evaporation, produces slow formation of a large diameter stalagmite (Table I, D). Finally, lower concentrations of calcium bicarbonate result in slower vertical growth rates for both stalactites and stalagmites, the effect being more pronounced for stalactites.[13]

Of these factors, the rate of deposition of calcium carbonate is usually determined by the *rate of evaporation* and the *concentration* of calcium bicarbonate. (Drip rate determines primarily whether a stalactite or stalagmite will be formed.) Since the rate of evaporation is controlled by three variables (air circulation,

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