Natural Trap Cave

XIAOMING WANG AND LARRY D MARTIN

Late Pleistocene, Paleoecology and Large Mammal Taphonomy, Natural Trap Cave, Wyoming

Natural Trap Cave is one of the most important Ice Age localities in North America. We report here on its depositional environment, paleontological sampling, and vertebrate taphonomy. The taphonomical conditions and death assemblage within the cave are contrasted to those of open land sites. Bone preservation is excellent. Snow cover may be responsible for the good bone preservation during the long interval between the initial trapping of the large mammals and final burial in the sediments. Vertebrate remains inside the cave were free from disturbances by carnivorans, water currents, and surface weathering, which are commonly associated with open land sites. The accumulative curve in large mammal taxa indicates that ≤15 000 specimens were needed to adequately sample the faunal assemblage. Large carnivorans are overrepresented and are postulated to have been attracted by the carcasses.

The last 100,000 years encompass most of the events leading to modern humans and the rise of civilization. During this period the world has changed from a glacial climate to one now concerned with global warming; a mass extinction occurred with a possible human component; and a unique record of climatic and biological fluctuations piled up on the floor of Natural Trap Cave (Figures 1 & 2) in north-central Wyoming. Many of the fossil remains in this deposit are unique in their completeness, including the only complete skeletons of the American cheetah Miracinonyx trumani (Figure 3) and the extinct musk-ox Bovotherium bombifrons. More than 40,000 specimens have been recovered (31,145 of which are computer catalogued) from a serially deposited stack of roof fall, eolian sediments, and bones. The completeness of this record and the high quality of preservation provides an opportunity for detailed studies of change over a 100,000-year period. However, this record cannot be deciphered without a thorough understanding of the processes controlling the entry and recovery of fossil remains in these deposits.

Since the initial exploration of Natural Trap Cave, it has been systematically excavated in 10 separate field seasons by University of Kansas scientists and Earthwatch volunteers. It contains a well-preserved late Pleistocene (Sangamonian–Wisconsinan) to Holocene vertebrate fauna.8,10,20 The large size and depth of the cave and its enclosed nature left no possibility for non-flying vertebrates to escape. It acted as a natural sampling experiment, free of many of the biases associated with open sites. A nearly constant physical environment inside the cave considerably reduced postmortem damage and weathering. Postmortem bone modification was mostly limited to falling rocks; few animals could survive the 26-m drop, eliminating the effects of trampling and scavenging.

Our current knowledge of taphonomical processes has been mostly derived from open land sites or aquatic environments.5,7 Studies on cave deposits2,6 have shown the physical, environmental, and biological variables involved in the accumulation and preservation of bones to differ considerably from those of open land situations (Table 1). Vertebrate remains generally have a far better chance of being preserved in the more-stable cave environment. Research on taphonomical factors involved in Quaternary caves is important because of the significant contribution of Quaternary cave faunas to the broader understanding of the biological communities in the Ice Age.

The fossil sample from Natural Trap Cave was applied to a series of successively more inclusive questions concerning the quality of the sample: as
a representation of the preserved fossil assemblage, of death assemblages, and of the local community.

Although passive trapping was the main mode of bone accumulation, the unusually large number of gray wolves (*Canis lupus*) may be attributed to their attraction to animal carcasses as was also suggested for carnivores in the case of the Rancho La Brea tar pit of California and Lava Blister caves of Idaho.

### Excavations

Excavations from 1974 to 1985 followed an archaeological approach that divided the cave floor into 1.5- × 1.5-m squares with 15.24-cm stratigraphic intervals. Sketches of bone distribution and orientations were recorded for the fossiliferous levels. Excavated squares were exhaustively searched for bones with hand and shovel. All fragments of bones were collected with provenance data attached. Samples of the matrix from each square were transported outside the cave and screen washed. Since 1974, >40,000 specimens have been collected by the Museum of Natural History at the University of Kansas. All identifiable specimens and those of stratigraphic values were computer catalogued (31,145 in all). All stratigraphic information associated with the specimens was organized through the FOCUS data-base management program. A 3-dimensional cave floor reconstruction was created through the IBM mainframe SAS graphic program, using the 3-D grid routine. The results are plotted on a Hewlett-

<table>
<thead>
<tr>
<th>ECOLOGICAL AND TAPHONOMICAL FACTORS</th>
<th>NATURAL TRAP CAVE</th>
<th>OPEN SURFACE DEPOSIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>cause of death</td>
<td>fall and isolation in the cave</td>
<td>many causes</td>
</tr>
<tr>
<td>death assemblage</td>
<td>remains near death site</td>
<td></td>
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<tr>
<td>fluvial transportation</td>
<td>very limited and within the cave</td>
<td>various distances for different bones</td>
</tr>
<tr>
<td>hydraulic sorting</td>
<td>none or little</td>
<td>various degrees</td>
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<tr>
<td>carnivore transportation</td>
<td>none</td>
<td>various degrees</td>
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<tr>
<td>faunal mixing</td>
<td>none</td>
<td>distant species may be carried to site</td>
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<tr>
<td>change of temperature</td>
<td>small</td>
<td>large</td>
</tr>
<tr>
<td>change of humidity</td>
<td>small</td>
<td>large</td>
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<tr>
<td>exposure to sunlight</td>
<td>very limited</td>
<td>often complete exposure</td>
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<tr>
<td>burial of bones</td>
<td>very slow</td>
<td>variable rate</td>
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<tr>
<td>carnivore damage</td>
<td>probably none</td>
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<td>trampling</td>
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<td>rockfall damage</td>
<td>important</td>
<td>little or none</td>
</tr>
<tr>
<td>gravity movements</td>
<td>important but confined to a small area</td>
<td>usually less important</td>
</tr>
</tbody>
</table>

Some of the comparisons in the table can be derived from empirical observations; many of them still remain hypotheses to be further tested.

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In fact, it has been suggested that the superb running ability of modern pronghorn antelopes may be a result of coevolution with the Pleistocene American cheetah.\textsuperscript{9}

Figure 3.  
American cheetah Miracinonyx trumani, a nearly complete skeleton of 1 of 11 individuals recovered from Natural Trap Cave, Wyoming.  
JON BLUMB

Packard 7221A plotter. Only large mammals are analyzed in this paper, small mammals and other vertebrates are currently under study.

All of the Natural Trap Cave materials, with taxonomic identifications,\textsuperscript{1,6,9,13,19,22,27} are housed in the Division of Vertebrate Paleontology, Museum of Natural History, University of Kansas.

PHYSICAL ENVIRONMENT OF NATURAL TRAP CAVE

Natural Trap Cave (NW 1/4, SE 1/4, sec #28, T58N, R94W) lies just south of the Wyoming–Montana border and Crow Indian Reservation, northeast of Lovell, Big Horn County, Wyoming. It is a 26-m-deep karst sinkhole on the west side of the Big Horn Mountains (Figure 2). At an elevation of 1300 m on the Little Mountain plateau, the cave is currently surrounded by a short grass–sage steppe.\textsuperscript{20} It was probably situated on 1 of only 2 or 3 natural game trails leading down to the Big Horn Basin and was used during annual migrations by large grazers and their predators.\textsuperscript{13}

The 4.6-m-diameter cave entrance is hidden on top of a gentle slope. Unwary animals might not see it before falling in. Thus the cave, with its
Figure 4.
Topographic map of Natural Trap Cave with a projected Pleistocene snow cone. All squares and rectangles are areas of excavations. Sections enclosing C–D–E–F are shown in the fence diagram of Figure 5. Sections A–A' and A–B are sectioned planes in Figure 6.

Figure 5.
Details of stratigraphy of Natural Trap Cave (top 3 m) in the southwestern quarter (see Figure 4 for location of the sections). Unit 4 is a grayish silt mixed with boulders and gravel from rockfalls. In this fossiliferous zone, bones yielded radiocarbon dates of ~12 000 to 21 000 bp. The concentration of bones within unit 4 may have resulted from a permanent snow cone during the glacial maximum. Large limestone boulders are indicated at the bottom of the southwestern corner of the section. One small channel is present at the base of unit 6. For detailed stratigraphic descriptions of the various units see I. D. Martin and B. M. Gilbert.
single outlet, acted as a pit trap. Animals, having slipped through the entrance, would fall through a 26-m free-drop before hitting the ground. The cave, 30 m in maximum diameter, is surrounded by Mississippian Madison limestone, and has a basically dome-shaped profile in vertical section. The entrance is ~10 m off the apex to the south. Horizontally, it is pear-shaped with the narrow end pointing north (Figure 4).

Distinct stratigraphic layers are visible throughout most of the excavation pits (Figure 5). Radiocarbon dates from mammal bones range from 21,000 to 12,000 years BP. Three lenses of volcanic ash were found since the 1980 excavation (Figure 6). The uppermost layer of the ash has been fission-track dated at 110,000 BP. Screen washing of deposits associated with the 110,000 BP date yielded a microfauna suggesting a Sangamonian interglacial fauna. The large number of mammalian fossils throughout the stratigraphic column indicates that the cave has been trapping for the last 100,000 years.

During the most recent excavation (summer 1985), another smaller cave chamber was discovered under the floor of the main excavation (Figure 6). A complete horse skull and a mammoth femur were found on the surface, but no excavation has been attempted.

Bone Preservation and Distribution

Sedimentation Rate and Bone Preservation
The only way sediments in Natural Trap Cave could have been lost is by washing into peripheral passages. To estimate the rate of sedimentation, the entire cave floor was divided into 1.5-× 1.5-m grids along north–south and east–west directions. Topographic elevations were mea-

![Figure 6. Three-dimensional representation of part of the cave floor under the opening and the cave cross section. The position of the lower chamber and the 110,000-year-old volcanic ash are shown.](image-url)
Figure 7. (above)
Top, partially articulated lion skeleton during excavation. Bottom, skull of the same lion.
JOHN D. CHORN

Figure 8. (right)
Small bones from the Sangamonian level.
JOHN D. CHORN

asured in each grid. The total floor-surface area of the cave is 852 m² (total number of grids, 367). The maximum sediment thickness currently obtained is 4.27 m at the point 525 NW 520. Assuming a flat bottom throughout the cave, the minimal volume of total sediments can be estimated at 4740 m³ by the sum of all 1.5- x 1.5-m columns (the height of the columns is their elevations adjusted by the height at 525 NW 520). A total of 249 m³ of sediment has been excavated so far, or ~5% of the total estimated sediments in the cave.
Using the 110 000 BP fission-track date as minimal length of depositional history for the main chamber, annual sediment accumulation averages 0.043 m$^3$ (4740/110 000). The effective rate of sedimentation on the cave floor is thus ~0.05 mm/y (0.043 • 1000/850). The Holocene deposits may serve as an independent check for the above estimate. The Holocene layer ranges from 152.4 to 304.8 mm. Its sedimentation rate would thus be within the range of 0.015 to 0.30 mm/y if we assume a duration of the Holocene of ~10 000 years. The estimates of Pleistocene and Holocene sedimentation rates thus appear to be within the same order of magnitude.

Although sporadic rockfalls or volcanic ash accumulation may considerably vary the rate of bone burial, the overall depositional rate was probably extremely slow (certain parts of the ash lens are ≤30 cm, an equivalent of a 6000-year time span for the normal sedimentation rate). At the rate of deposition of 0.05 mm/y, a long bone 30 mm in diameter (the size of a bighorn sheep femur) would take 600 years to be completely covered by sediments. This would far exceed the burial time in open land sites that preserve bones of similar condition. For instance A K Behrensmeyer, who devised the system to describe bone weathering, reports 6 to 15 years to reach stage 5 disintegration in an open African savanna.

When first excavated out of the cave, the majority of bones from Natural Trap Cave are still within stage 1 weathering, i.e., superficial cracking on long bones and mosaic cracks on articular surfaces. Using the estimate of long duration of bone exposure (600 years for a long bone), weathering is obviously slow. Factors such as constant temperature, high humidity, and limited exposure to sunlight in the cave are clearly involved in the preservation of bones. However, a snow cone may have contributed even more to the protection through rapid burial and refrigeration.

**CAVE STRATIGRAPHY AND BONE DISTRIBUTION**

Distinct stratigraphic units can be recognized throughout most of Natural Trap Cave (Figure 5). Throughout the stratigraphic column are various concentrations of fallen limestones from the cave roof and walls. The Holocene lens consists of a very thin (usually <0.3 m) of loose silt with few large mammal bones. Unit 4 (zone 7 of the field stratigraphic units) is distinctly more fossiliferous than other layers and accounts for 35% of the total number of catalogued bones. Within a single stratigraphic plane, bones are clustered in small concentrations (Figure 9). With the exception (Figure 7) of 1 American lion Panthera atrox, most of the mammal bones were found disarticulated, although cases of definite associations of partial limbs are not uncommon.

The surface of the cave floor dips towards the north with the lowest elevation near 580 NW 490 and the highest elevation near 450 NW 440 (Figures 4 & 5). Between the area directly underneath the entrance and that of the lowest elevation on the floor there is a gentle south–north trench. One of the striking features is that the area directly underneath the cave entrance is ≤2 m below the highest deposits in southwestern part of the cave floor (Figure 6). To the east of the entrance, the elevation is even higher. Some large mammalian fossils excavated at the southwest quarter are also higher than the present cave floor under the entrance.

These topographic relationships demand either erosion of the surface of a former accumulation below the entrance or the existence of a snow cone. The presence of a gentle trench from below the entrance leading north may seem consistent with an erosional process but the presence of
small channels between units 5 and 6 showing no major stratigraphic disturbance (Figure 5) indicates otherwise. The presence of a permanent snow cone during the peaks of the glacial maximum, however, would not only account for the high-level distribution of bones but also explain the massive well-preserved fossiliferous layers.

The topology of a conical snowcap on the cave floor would enable the transportation of animal remains and sediments to the periphery of the snow cone some distance from the edge of any normal cone of sediments. One consequence of a year-round snow cone would be a high concentration of bones in discrete layers when the snow melts. Bones in the snow matrix would collapse into layers. This may be the case with unit 4 which produces large quantities of bones radiocarbon dated ca 12 000 to 21 000 BP.

A permanent snow cone may also help explain the exceptionally well-preserved bones in Natural Trap Cave. The long duration of exposure implied by the extremely slow sedimentation rate would seem unfavorable for bone preservation. The fact that some Holocene bones exposed on the floor surface develop deep longitudinal cracks and flakes in contrast to the better preserved Pleistocene bone samples indicates a different mode of preservation. The quick burial of animal remains by snow and thus the "refrigeration" of the bones may have contributed to this difference. The present summertime temperature in the cave is 5°C, and caves in the immediate vicinity at higher elevations still contain ice year-round. A permanent snow cone during the Pleistocene appears likely.

**Samples and Sampling**

Whereas it is logically impossible to answer fully the question of completeness of fossil records, it is nevertheless realistic to ask how complete the samples are as estimates of the total buried communities. By taking advantage of the large sample size and the enclosed nature of the cave, several levels of questions may be addressed concerning the completeness of the assemblage:

- The completeness of the excavated sample as a representation of the total preserved bone assemblage—a purely statistical question since the entire fossil bone assemblage is theoretically obtainable by exhaustion of the cave deposits;
- The completeness of the preserved fossil assemblage as a representation of all animals falling inside the cave—a problem of postmortem processes that determine which animal and what element are preserved and recovered;
- The completeness of the fallen animal assemblage as a representation of the local community—addresses possible biases introduced by the home ranges of different age groups and foraging behaviors of different species. It concerns most paleoecological investigations and is dependent on our ability to answer satisfactorily the previous 2 questions.

**THE SAMPLE AS A PRESERVED FOSSIL ASSEMBLAGE**

A complete faunal list cannot be verified without exhausting the entire deposit of a given locality. In the case of Natural Trap Cave, only an estimated 5% of the sediments has been excavated thus far, and, at the current rate, it may take another 100 years to exhaust the entire cave deposit. We use a more empirical approach to estimate of the completeness of the fossil assemblage.

The successive faunal lists augmented by each field season should intu-
itively approach a theoretically complete faunal composition in a logarithmic curve. When the accumulative numbers of taxa are plotted against the year of collection (Figure 10), the curve of accumulation levels off in successive seasons. The rate of discovery of new taxa drops off at a sample size of ~15,000. Each of the rarest large mammals—Mammuthus, Camelops, and Arctodus (Figure 12)—has a minimum number of individuals of 2 at a total sample size of 31,145 specimens. Thus, many specimens would have to be excavated to sample adequately these rare taxa.

THE SAMPLE AS A PIT-TRAP ASSEMBLAGE

Having satisfied ourselves that the Natural Trap Cave sample is adequately large, we now turn to the question of the sampling of skeletal parts—the question of bone preservation and recovery. Although it is not possible to know the sample representation of nonpreserved taxa, we may have some idea of the effects of preservation and recovery by comparing the differential recovery of osteological elements.

We assumed that all bony elements of a fallen animal remained there permanently. Except for partial carcasses dropped inside by carnivorans, any loss of bony elements would be due either to destruction or excavation bias. The fact that deposition rate in this cave is very slow and many bones are well preserved indicates stable conditions inside the cave, free of disturbances by large mammals. This makes it possible to examine with reasonable accuracy preferential preservation of bones. The relative abundance of bone elements for 4 large mammals—Canis, Miracinonyx, Ovis, and Equus—indicates that different skeletal parts are being recovered and identified for the respective genera (Figure 11).

The pattern of recovery seems to correspond to the mechanical strength of individual bones and their body size. Astragali (ankle bones) are probably the most resistant to breakage in herbivores and thus are often used in counts of minimum number of individuals (Figure 12). Larger bones do not necessarily preserve better than smaller ones. Proximal limb bones are often the largest long bones, but the recovery rates usually fall between 40 and 80%. In fact, proximal limb bones of bighorn sheep consistently preserve better than those of horses, although the former are significantly smaller. The low rates of recovery in certain small-sized bones, such as caudal vertebrae and sesamoids (bones occurring mainly in the feet, embedded in tendons or joints), are probably an artifact of difficulties in taxonomic identification.

THE SAMPLE AS A LOCAL COMMUNITY

For 2 reasons we think that Natural Trap Cave did not sample the fauna of an extensive area: The physical impossibility for carnivorans to use it as a den rules out transport by large carnivorans; and the relatively gentle topography surrounding the cave entrance prohibits large amounts of animal remains from being funneled into the cave from a distance. This limited sampling area probably prevented large-scale faunal contamination, a problem often associated with open land sites. Nevertheless, owls may have dropped some of the rodents whose fossils were found. Given the small area of sampling, the cave was remarkably successful in trapping and preserving a large quantity of mammals (Table 2). Noticeably absent are any species of Cervidae. This may indicate an open environment for the Natural Trap Cave community that may have discouraged large browsers such as deer. The open nature of the community is also evidenced by its predominantly cursorial elements of the fauna."
One of the interesting aspects of the Natural Trap Cave sample is that trapping of certain mammalian species by the cave was probably controlled by their behavioral inclinations.28 The cave sample is partially controlled by biological factors in addition to environmental factors, like the Pleistocene Rancho La Brea tar pit but unlike the Pleistocene Alaska fluvial deposits (Figure 12). Large carnivores, especially *Canis* (the vast majority of them gray wolf *C. lupus*), are clearly overrepresented in the Natural Trap Cave samples. The Pleistocene Rancho La Brea tar pit was a trap that resulted in abundant dire wolves (*C. dirus*) in the pit, lured there through sight, sound, or smell of trapped large mammals.23 Natural Trap Cave appears to be similar in this respect, i.e., the smell of carcasses may have tempted the more opportunistic wolves. The Lava Blister Cave of Idaho may be another example; here a large number of foxes were attracted to the cave.29 In comparison, the Pleistocene Alaskan sample is more balanced. Its fluvial deposition and freedom from behavioral biases are a better approximation of the relative proportion of a living large mammal community near Fairbanks, Alaska.15,16

The abundance of horses (*Equus* sp), the unusually good sample of pronghorn antelopes (*Antilocapra americana*), and the numerous specimens of the American cheetah (*Machairodus trunmani*) all point to the curatorial nature of the Natural Trap Cave fauna.13,19,20

### The Death Assemblage

Two types of death assemblages in fossil records have traditionally been recognized: catastrophic and attritional.24 A catastrophic death assemblage represents an entire local population that died instantaneously in a sudden flood, volcanic eruption, or other natural catastrophe. Every individual, healthy or not, has an equal chance of being struck. Its age distribution should closely resemble that of the living population, which, if healthy, often has a unimodal distribution, with the young adults being dominant (Figure 13, Top). In contrast to the catastrophic death assemblage, a typical attritional death assemblage should have a bimodal distribution with the very young and very old being the most vulnerable to predation and disease (Figure 13, Center).

Characteristics of a trap accumulation are unique. The Natural Trap Cave sample could not have been a catastrophic death assemblage because the animals certainly did not all die at the same time. The fossils are found throughout a stratigraphic column representing a continuous deposition of at least 110 000 years. Additionally, an estimated average rate of accumulation of 1 horse every 70 years would certainly rule out the likelihood that many animals belonged to the same population. The average number of years for 1 horse to be trapped = \( T/N \cdot V_e/V_t = 110 000/(83 \cdot 4740/249) = 69.62 \) years, where, \( N \) = minimum number of horses in collection; \( T \) = minimum duration of the Natural Trap Cave; \( V_e \) = volume of sediments excavated; \( V_t \) = volume of sediments in total. However, the Natural Trap Cave sample is also not a strictly attritional death assemblage because animals trapped inside were not results of “natural” death (age, disease, predation, etc). In other words, the sample does not necessarily contain only the weak, destined to die soon.

The age distribution of Natural Trap Cave bighorn sheep (*Ovis canadensis*) was tabulated to test the above hypothesis (Figure 13, Bottom). It
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Figure 13.
Top. Age distribution of a living population of Himalayan tahr (Hemitragus johni), sample size N = 623. This would be the distribution pattern if the population dies catastrophically. Center, Age distribution of a Dall sheep (Ovis dalli dalli) population in Mount McKinley before the year of 1941, sample size N = 655. This is an example of an attritional death assemblage. Specimens whose age could not be determined are excluded. Bottom, Age structure of bighorn sheep (Ovis canadensis) from Natural Trap Cave, sample size N = 28.
Table 2. Large Mammals from Natural Trap Cave Compared with the Composite Record of Pleistocene Wyoming

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<tr>
<th>FAMILY CARNIVORA</th>
<th>PLEISTOCENE WYOMING</th>
<th>NATURAL TRAP CAVE WISCONSINIAN²⁵</th>
<th>SANGAMONIAN¹⁰</th>
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<td>Canis dirus (dire wolf)</td>
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<td>FAMILY FELIDAE</td>
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<td>Miracinonyx trunumani (American cheetah)</td>
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<td>Alces alces (moose)</td>
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<td>Cervus elaphus (wapiti)</td>
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<tr>
<td>Odocoileus hemionus (mule deer)</td>
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<tr>
<td>FAMILY Bovidae</td>
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<td>Bison bison (buffalo)</td>
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<tr>
<td>Booratherium bombifrons (musk-ox)</td>
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<tr>
<td>Oreamnos americanus (mountain goat)</td>
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<tr>
<td>Ovis canadensis (bighorn sheep)</td>
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<tr>
<td>ORDER PROBOSCIDEA</td>
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<tr>
<td>Family Elephantidae</td>
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<tr>
<td>Mammuthus sp (woolly mammoth)</td>
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A widely accepted system to describe bone weathering was developed by A K Behrensmeyer, who divided the entire spectrum of bone decomposition into 6 stages (0 to 5). Bones in stage 0 weathering suffer no apparent damage, whereas those in stage 1 to 2 exhibit progressively deeper cracks and flaking. By stage 3 and 4, the bony surfaces begin to roughen and the weathering penetrates the inner cavities. Stage 5 represents nearly complete disintegration of bones, and external morphologies of bones become difficult to recognize. On recent mammal samples from Amboseli Basin, southern Kenya, stage 1 weathering was recorded on bones exposed in 0 to 3 years and stage 5 in 6 to 15 years. This rapid weathering in an open environment of African savanna is in sharp contrast to a much slower rate in Natural Trap Cave.

shows a predominance of young adults. Although superficially similar to a unimodal catastrophic pattern, the truncation of the Natural Trap Cave bighorn sheep age curve, at both ends of young and old ages, clearly shows that not all members of the bighorn sheep population are represented in the sample. A true catastrophic death assemblage should be a cross section of the time axis when everything was frozen “instantaneously.”

Instead, the age distribution of bighorn sheep may be an indication of behavior differences among different age groups. Not only is the bighorn age group dominated by young adults, but an estimated 85% of them are males, a subgroup that normally has the lowest mortality. V Geist¹² observed that young male bighorn sheep often venture alone or in small numbers into unfamiliar territories. This biological inclination was dutifully documented in Natural Trap Cave as long ago as the late Pleistocene.
We know that at least 5 unrecovered mammoth skeletons remain in Natural Trap Cave. That we have missed such a mass of material indicates the richness of the site and the potential for further recovery. At our present rate it would take 100 years to completely excavate the deposit, but we think that much of this work should be left to future scientists.

**Conclusions**

The following preliminary conclusions may be drawn from the taphonomy and paleoecology of Natural Trap Cave:

- Depositional environments inside Natural Trap Cave were stable throughout most of its existence. Good stratigraphic control is available for most of the vertebrate collections.

- An average rate of sedimentation is estimated to be ~0.015 to 0.05 mm/y, which is accompanied by occasional rockfalls and periods of rapid volcanic ash fall.

- A snow cone may have been present during the maximal glaciations making possible a large concentration of bone in some layers. The refrigeration of carcasses and bones inside the snow cone may have contributed to the reduction of postmortem destruction despite the slow rate of burial.

- Large numbers of bones, perhaps as many as 15,000 specimens for Natural Trap Cave, are needed to sample adequately the rare elements of the fauna. Sampling of the local paleocommunity by this cave is probably close to complete.

- The death assemblage of the Natural Trap Cave bighorn sheep is found to be uniquely different from conventional models of catastrophic or attritional assemblages. The age distribution of the bighorn may have been controlled by their home-range behavior.

**References**


24. Voorhies, M R: Taphonomy and population dynamics of an Early Pliocene vertebrate fauna, Knox County, Nebraska.

University of Wyoming Contributions to Geology Special Paper 1:1–69; 1969.

Figure 14. Authors Xiamong Wang and Larry D Martin stand with an extinct bighorn sheep, Ovis canadensis, skeleton.

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