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# Taphonomy of Cervids Killed by the May 18, 1980, Volcanic Eruption of Mount St. Helens, Washington, U.S.A.

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The May 18, 1980, eruption of Mount St. Helens (Washington, U.S.A.) resulted in the death of cervids occupying the blast zone. Study of a sample of the cervid remains provides insights to volcanic processes involved in the formation of a fossil record. Cervid mortality was nonselective and catastrophic. Carnivore damage to cervid bones is minimal, as many bones were buried and scavenging carnivores were also killed by the eruption. Bones of carcasses exposed to the explosive shock wave were more disarticulated and shattered than those sheltered from the force of the explosive eruption. Postmortem carcass orientation was random. The distribution of individual bones seems largely attributable to the sequence of skeletal disarticulation, gravity-related transport processes in conjunction with microtopography, exposed vegetation and forest debris, and transport by carnivores.

## INTRODUCTION

One source of interpretive models for taphonomic research involves studying modern, observable processes and events which result in the formation of a death assemblage (Gifford 1981). The May 18, 1980, eruption of Mount St. Helens, a stratovolcano in south-central Washington (46°11′ N, 122°12′ W), U.S.A., provides an opportunity for studying volcanic activity as an agent of mortality resulting in potential input to the future fossil record.

## MATERIALS AND METHODS

The May 18, 1980, Mount St. Helens eruption involved a lateral, northward explosion that triggered a massive landslide down the north-facing slope of the mountain base. Much landslide debris was deposited in canyons at the mountain. Deposition of large amounts of volcanic tephra in Pacific Northwestern North America was associated with the eruption and landslide. Creation of the "blast zone," the more than 350 $km^2$ of coniferous forest, montane, and riverine habitats to the north of the volcanic crater that were virtually totally destroyed (Findley

1981a, 1981b; Rosenfeld 1980), resulted from those three processes.

Many, but not all, animals occupying the Mount St. Helens blast zone died from suffocation, explosive shock, traumatic shock, and falling timber or pumice blocks (e.g., Anderson 1982). As part of a larger study concerning pre- and post-eruption cervid demography in the blast zone (Taber, Raedeke and Paige 1982), over two dozen sites consisting of eruption-killed cervids had been located. We examined five of these sites (Figure 1), all about 15 km away from the crater, during the late summer and autumn of 1981. Vegetation recovery was more rapid, on average, in the areas farther from the crater and precluded relocating many sites there. As a safety precaution, we were never farther than ten minutes walk from our vehicle, and we did not stay over night in the blast zone.

Collection procedures were dictated by project goals but were often limited by volcanic activity and weather conditions. Collection was directed towards recovery of complete carcasses, but when time and resource constraints precluded this, collection focused on skulls, mandibles, innominates, and fetal bones. Although most surface scatters of bones were spatially discrete and represented individual carcasses, some animals apparently died side by side and postmortem disturbance had resulted in some comingling of surface bones. Depressions approximating the size and shape of a cervid carcass within discrete patches of thick grass, generally about 2 by 2 m, denoted some carcass locations (Figures 2 and 3). Preliminary analysis of tephra samples collected near and away from carcasses suggest the association of grass with individual carcasses may be the result of increased levels of chemical residues that originated from the carcasses (Kornbacher 1982).

Portions of all carcasses were buried under 20 to 60 cm of volcanic ash (Figures 3 and 4). Excavation was employed when the primary in situ location of a carcass could be determined (Figure 5) and surface collecting failed to yield skeletal elements permitting assessment of age, sex, and/or whether or not individuals were pregnant. A sample of additional carcasses was excavated to insure no recovery bias based on surface-occurring bones would affect later analyses. All surface bones were collected. A summary catalog of collected bones is given in Table 1.

Skeletal elements of two species of cervid—elk or wapiti (*Cervus elaphus*) and black-tailed deer (*Odocoileus hemionus*)—were collected. A few bones of coyote (*Canis latrans*), hare or rabbit (*Lepus* sp. or *Sylvilagus* sp.), and an unidentified bird were also collected. Here I consider only the cervid remains.

Carcasses constituting sites 1 and 5 were in areas from which Mount St. Helens crater could not be seen,

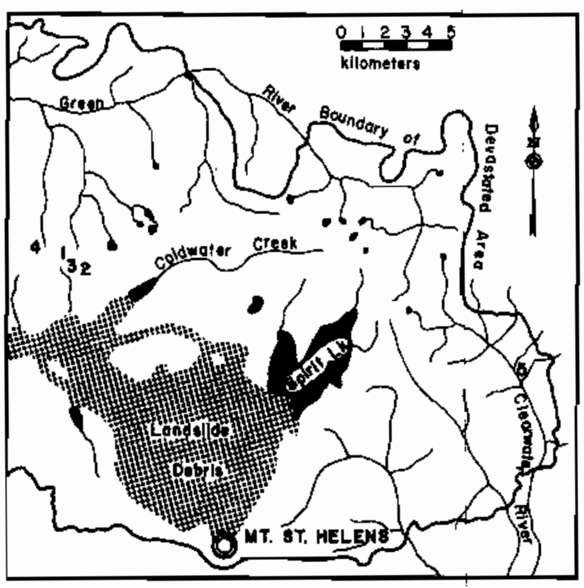


**Figure 1.** Map of area devastated by eruption (blast zone) of Mount St. Helens showing major topographic features and locations of cervis carcass collection sites (numbers 1-5).

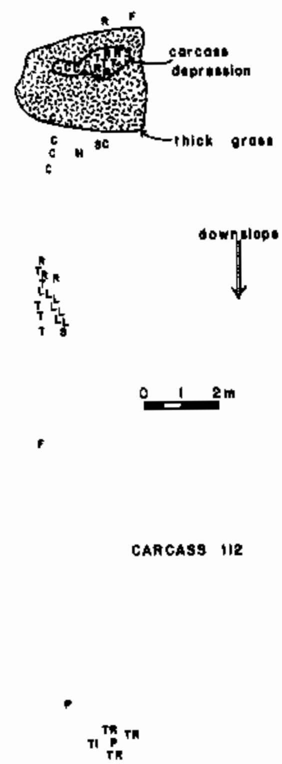


**Figure 2.** Map of carcass 112, an elk, showing carcass depression, grass patch associated with the primary carcass location, and downslope distribution of bones, C=cervical; T=thoracic; L=lumbar; S=sacrum; R=rib; SC=scapula; H=humerus; F=femur; TI=tibia; TR=tarsal; P=phalanx. Buried bones are not shown.

**Figure 3.** Carcass 503, an elk, prior to excavation. Grass has been removed and white tags have been placed over bones to enhance visibility of surface distribution. Note the muted depression between the two innominates; this is where the axial skeleton was buried. The skull shown in Figure 4 was found just above the right innominate and right humerus located just to the right and above the center of the photograph.

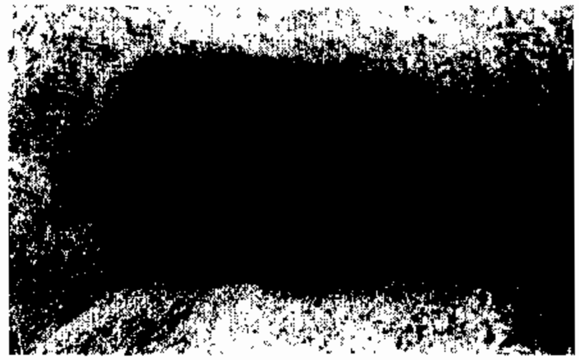

**Figure 4.** Carcass 503, showing the articulated skull, mandibles, atlas, axis, and third cervical. These parts were buried under approximately 35 cm of volcanic ash. Compare with Figures 3 and 5.

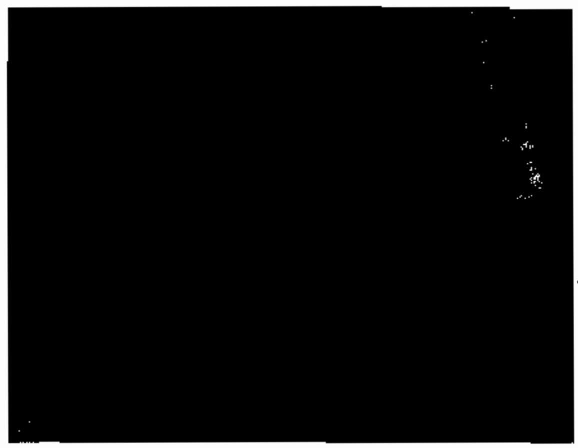

**Figure 5.** Carcass 106, an elk, partially excavated. Shown in situ are the complete right forelimb, six right ribs, and the left and right tarsals, metatarsals, and phalanges. This individual was not buried deeply, but lay under a cover of grassy sod. Trowel points to the north.

while the crater could be seen from sites 2, 3, and 4. It is supposed that individuals from sites 2, 3, and 4 were subjected to nearly the full explosive force of the eruption while individuals found at sites 1 and 5 were protected from the eruption-related shock wave by intervening ridges.

I refer below to a control sample of recent cervid carcasses. Black-tailed deer carcasses were collected from grassland and deciduous forest habitats in southwestern Oregon; elk carcasses were collected from coniferous forest habitats of southeastern Washington. These animals apparently died more or less attritionally of natural, nonvolcanic related causes. All were collected on an encounter basis during the course of various archaeological survey projects. When a carcass was found, all visible surface-occurring bones were collected. All carcasses had minimal associated soft tissues and appear to represent animals that had been dead at least 1–2 years on the basis of bone weathering (Behrensmeyer 1978).

## RESEARCH PERSPECTIVE, QUESTIONS, AND LIMITS

Cervid bones were collected with two specific research problems in mind: to assess elk demography (Taber, Raedeke and McCaughran 1982; Taber, Raedeke and Paige 1982), and to see if bone pseudotools had been created (Lyman 1984b). An additional research issue ultimately addressed was the requisite sample size for analysis of mortality patterns (Lyman 1987). These research questions were not explicitly conceived when we collected the bones, but were formulated after initial phases of lab work (cleaning, numbering, and cataloging bones). Having never dealt with an archaeological or paleontological sample like that provided by the Mount St. Helens "crispy elk" project, we were quite naive about data relevant to later analyses. We had little to guide us in the way of previous studies of analogous collections that could suggest fruitful lines of investigation. The data available are, therefore, not what might be considered *ideal* for testing taphonomic hypotheses.

Five basic issues are addressed in following pages: mortality patterns, carnivore damage, bone fracture, carcass orientation, and bone distribution. The latter four are used to assess variations in carcass depositional modes. My studies are in no sense ethnoarchaeological or neotaphonomic because no one witnessed eruption effects on the cervid carcasses. Like many studies of archaeological or paleontological collections, I follow a "pattern recognition approach" (e.g., Binford 1984), first defining patterns and then attempting to explain those patterns using ethnoarchaeological and neotaphonomic analogs. Such a procedure produces a set of inferences that should be evaluated with ethnoarchaeological research.

# RESULTS AND DISCUSSION

## Mortality Patterns

I assume that for any given site, volcanic-related mortality agents were nonselective with regards to age, sex, and taxon of cervids occupying that site. All carcasses were

**Table 1. Summary Catalog of Collected Bones.**

| | SITE 1 | | | SITE 2 | | | SITE 3 | | | SITE 4 | | SITE 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PN Deer | F Elk | PN Elk | PN Deer | F Elk | PN Elk | F Deer | PN Deer | PN Elk | F Elk | PN Elk | PN Deer | F Elk | PN Elk |
| Skull | | 3 | 11 | | | 3 | 4 | 4 | 1 | | 2 | 1 | 4 | 7 |
| Mandible | | 3 | 19 | | | 3 | 6 | 6 | | | 2 | 2 | 6 | 4 |
| Hyoid | | | 5 | | | 4 | | 3 | | | 2 | | 3 | 9 |
| Atlas | | | 12 | | | 1 | | 4 | | | 1 | 1 | | 5 |
| Axis | | | 8 | | | 1 | 2 | 3 | | | 1 | 1 | | 5 |
| Cervical | 3 | 2 | 44 | | | 15 | | 13 | | | 7 | 5 | | 26 |
| Thoracic | 6 | 3 | 109 | | 1 | 37 | 6 | 35 | | | 8 | 7 | | 67 |
| Lumbar | | 2 | 49 | | | 20 | | 21 | | | 6 | 1 | | 40 |
| Sacrum | | | 10 | | | 4 | | 3 | | | 1 | | | 7 |
| Caudal | | 1 | 6 | | | | | 4 | | | 1 | | | 7 |
| Innominate | 1 | 3 | 19 | | | 9 | 7 | 5 | | 1 | 1 | | 6 | 12 |
| Rib | 14 | 5 | 183 | | | 108 | 83 | 74 | | 1 | 8 | 16 | 56 | 136 |
| Sternabra | | | 46 | | | 22 | 2 | 14 | | | 7 | 6 | 1 | 28 |
| Costal cartil. | | | 11 | | | 31 | | 14 | | | 13 | | | 37 |
| Scapula | 1 | 3 | 19 | | 1 | 11 | 7 | 8 | | | 1 | 2 | 6 | 10 |
| Humerus | 1 | 5 | 18 | | | 8 | 8 | 5 | | | 1 | 1 | 7 | 10 |
| Radius | | 3 | 19 | | | 5 | 7 | 4 | | | 2 | | 6 | 9 |
| Ulna | | 1 | 16 | | | 5 | 7 | 4 | | | 1 | | 6 | 11 |
| Metacarpal | | 3 | 15 | | 1 | 2 | 5 | 3 | | | 1 | | 7 | 7 |
| Carpal | | | 45 | | | 7 | | 11 | 1 | | 6 | | | 30 |
| Femur | | 4 | 17 | | | 8 | 6 | 8 | | | | 1 | 7 | 9 |
| Patella | | | 3 | | | 3 | | 4 | | | | | | 6 |
| Tibia | | 4 | 18 | | 1 | 9 | 7 | 5 | 2 | | 1 | | 6 | 8 |
| Distal fibula | | | 8 | | | 1 | | 3 | | | | | | 2 |
| Astragalus | 1 | 2 | 12 | | | 2 | 1 | 3 | | | 2 | | 4 | 6 |
| Calcaneum | 1 | 2 | 10 | 1 | 1 | 3 | 2 | 3 | | | 2 | | 5 | 5 |
| Navicular | | | 12 | 1 | | | | 3 | | | 1 | | | 4 |
| Metatarsal | | 1 | 14 | 1 | | 4 | 7 | 3 | | | | | 7 | 4 |
| Phalanx 1 | | | 41 | | | 1 | 2 | 15 | | | 3 | | 14 | 10 |
| Phalanx 2 | | 1 | 39 | | | 4 | | 10 | | | 3 | | 13 | 13 |
| Phalanx 3 | | 2 | 30 | | | 5 | 1 | 10 | | | 3 | | 8 | 12 |
| Sesamoid | | | 8 | | | 4 | | 8 | | | 4 | | | 11 |

Note: The values are for the minimum number of elements in each category as defined by row and column headings. PN=post-natal; F=fetal.

partially buried by volcanic ash from the May 18, 1980, eruption, and all stratigraphically overlaid the pre-eruption ground surface. This indicates carcasses were deposited in their recovery locations while volcanic ash was being deposited. If cervid mortality was, in fact, nonselective, criteria signifying catastrophic mortality developed in ecology (Caughley 1966; Craig and Oertel 1966; Deevey 1947) and used in paleontology (Kurtén 1953; Voorhies 1969) and archaeology (Frison 1978; Klein 1982) should be apparent in the Mount St. Helens cervid data.

Nonselective, or catastrophic, mortality produces a synchronic view of a population's age structure at the time of death. Given a relatively stable population subjected to catastrophic mortality, the youngest age classes will be most abundantly represented with fewer individuals in each successively older age class. This pattern contrasts with attritional mortality which results in the death of relatively more very young and very old individuals than reproductively active adults (Klein 1982; Shipman 1981).

Elk herd population structure in May generally consists of one- to two-year-old female calves, young bulls, and late-breeding cows that have not yet secluded themselves to calve (Taber, Raedeke and Paige 1982). Female elk are generally three years of age when they drop their first calf, and the birth season generally peaks in late May and early June. Elk have a natural ecological longevity of about 15 years (Taber, Raedeke and McCaughran 1982).

Age data were derived by wildlife biologists (Taber, Raedeke and Paige 1982). Based on age criteria including epiphyseal fusion, and tooth eruption, replacement and wear (Knight 1966; Quimby and Gaab 1957), individual carcasses were assigned to an age class. Shipman (1981) and I (Lyman 1987) have suggested a minimum sample size of 30 individuals is necessary for mortality profile analysis. Site 1 contained 24 ageable elk, site 2 contained 1, site 3 had 0, site 4 had 2, and site 5 had 10. No single site meets the minimum sample size requirement, but the site 1 sample produces an age profile approximating a catastrophic mortality event (Figure 6). The age profile for the 37 total ageable elk also approximates a catastrophic mortality profile (Figure 6), suggesting cervid mortality was indeed the nonselective result of the volcanic eruption and its effects.

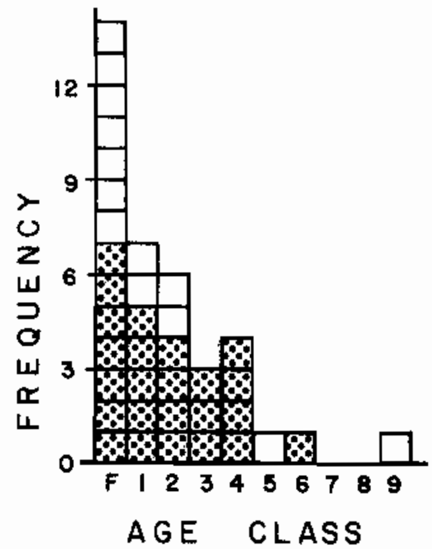


**Figure 6.** Elk mortality profile for sites 1–5. Shaded area represents site 1 sample (N=24). Total graph is all ageable elk from the five sites (N=37).

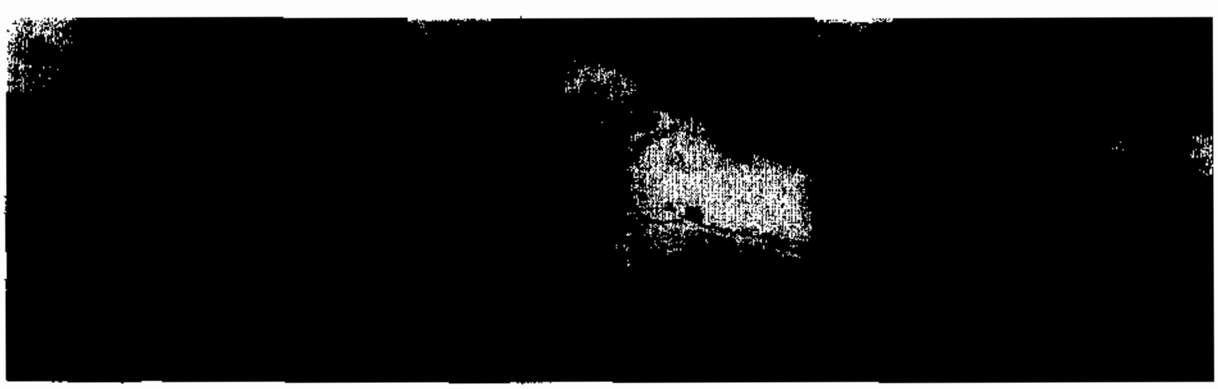

**Figure 7.** Carnivore damage types: A) punctures in a patella and ventral rib; B) furrow in a proximal femur; C) irregular damage on the greater trochanter of a proximal femur. All illustrated specimens are from elk.

**Table 2. Carnivore Damage Types, Distributions, and Frequencies.**

| CARCASS | NUMBER OF BONES RECOVERED | AGE OF INDIVIDUAL | BONE DAMAGED | TYPE AND FREQUENCY OF DAMAGE |
|---|---|---|---|---|
| 101 | 4 | F | L. metacarpal | Proximal—irregular, puncture |
| 102 | 68 | 6 | Lumbar vertebrae | 5 of 12 transverse processes—irregular, puncture |
| | | | Ribs | 3 of 18, ventral end—irregular, puncture |
| | | | Cartilage | 1 of 3—puncture |
| | | | Sternabrae | 3 of 3—irregular, puncture |
| | | | L. scapula | Superior angle—irregular |
| | | | L. humerus | Greater tuberosity—irregular |
| | | | L. ulna | Proximal—irregular, puncture |
| | | | L. femur | Distal—irregular |
| 102 (f) | 3 | F | R. humerus | Proximal—puncture |
| 103 | 3 | 4 | No visible damage | |
| 104 | 2 | 3 | No visible damage | |
| 105 | 2 | F | Radius | Proximal—irregular, puncture; distal—irregular |
| 106 | 131 | 2 | Lumbar vertebrae | 1 of 12 transverse processes—puncture, irregular |
| | | | L. ulna | Distal—irregular, puncture |
| 107 | 80 | 2 | Ribs | 1 of 21, ventral end—irregular |
| 108—not recovered | | | | |
| 109 | 10 | 3 | L. femur | Distal—irregular |
| 110 | 26 | 1 | No visible damage | |
| 111 | 29 | 4 | Sternabrae | 1 of 5—puncture |
| 112 | 65 | 4+ | Thoracic vertebrae | 8 of 12 neural spines—irregular |
| | | | Lumbar vertebrae | 3 of 14 transverse processes—irregular |
| | | | Sternabrae | 1 of 5—irregular; 1 of 5—puncture, furrow |
| | | | L. humerus | Greater tuberosity—irregular (scooped out) |
| 113 | 89 | 3 | Lumbar vertebrae | 3 of 12 transverse processes—irregular |
| | | | Ribs | 1 of 19, ventral end—irregular |
| 113 (f) | 25 | F | R. femur | Proximal—puncture |
| | | | R. tibia | Distal—irregular |
| 114 | 12 | 1 | No visible damage | |
| 115 | 33 | 1 | No visible damage | |
| 116 | 108 | 4 | Atlas | Irregular |
| | | | Lumbar vertebrae | 2 of 12 transverse processes—irregular |
| | | | Sternabrae | 1 of 6—irregular |
| | | | R. scapula | Inferior angle—irregular |
| | | | L. humerus | Greater tuberosity—irregular |
| 116 (f) | 14 | F | R. astragalus | Irregular |
| | | | L. calcaneum | Irregular |
| 117 | 17 | 1 | L. tibia | Proximal—irregular |

**Table 2. Carnivore Damage Types, Distributions, and Frequencies (continued).**

| CARCASS | NUMBER OF BONES RECOVERED | AGE OF INDIVIDUAL | BONE DAMAGED | TYPE AND FREQUENCY OF DAMAGE |
|---|---|---|---|---|
| 118 | 77 | 4+ | Atlas | Puncture, irregular |
| | | | Thoracic vertebrae | 1 of 13 neural spines—irregular |
| | | | Lumbar vertebrae | 5 of 12 transverse processes—irregular |
| | | | Sternabrae | 2 of 7—irregular; 1 of 7 puncture |
| | | | R. scapula | Inferior angle—puncture, irregular |
| | | | R. humerus | Greater tuberosity—irregular |
| | | | R. innominate | Ilium—irregular, puncture anterior aspect<br>Ischium—irregular, puncture posterior aspect |
| 118 (f) | 6 | F | No visible damage | |
| 119 | 66 | 4 | R. humerus | Greater tuberosity—irregular |
| 119 (f) | 3 | F | L. ilium | Puncture, furrow anterior aspect |
| | | | R. femur | Proximal—puncture |
| | | | L. tibia | Proximal and distal—puncture, furrow |
| 120 | 44 | 2 | No visible damage | |
| 121 | 18 | 2 | No visible damage | |
| 122 | 11 | 1 | L. lunar (carpal) | Puncture |
| 123* | 28 | i | Cervical vertebrae | 2 of 3—irregular |
| | | | Thoracic vertebrae | 3 of 6 neural spines—irregular;<br>3 of 12 transverse processes—irregular |
| | | | R. humerus | Proximal diaphysis—irregular |
| | | | Innominate | Puncture |
| 201 | 75 | i | Thoracic vertebrae | 1 of 8 centra—puncture and furrow;<br>1 of 8 neural spines—puncture and furrow |
| | | | Lumbar vertebrae | 1 of 3 neural spines—puncture;<br>1 of 3 neural arches—puncture;<br>5 of 6 transverse processes—irregular |
| | | | Sacrum | Puncture |
| | | | Ribs | 2 of 19, proximal—puncture |
| | | | Sternabrae | 1 of 5—puncture and furrow |
| | | | L. humerus | Greater and lesser tuberosity—puncture, furrow |
| | | | L. innominate | Ischium—puncture, furrow |
| 201 | 5 | F | No visible damage | |
| 202 | 94 | i | Atlas | Puncture, furrow |
| | | | Cervical vertebrae | 2 of 5 puncture, furrow |
| | | | Thoracic vertebrae | 6 of 6 transverse processes—furrow;<br>3 of 3 neural arches—puncture |
| | | | Lumbar vertebrae | 5 of 5 neural spines—irregular;<br>1 neural spine—puncture;<br>3 of 10 transverse processes—irregular |
| | | | Ribs | 2 of 26, ventral end—puncture, furrow |
| | | | Sternabrae | 2 of 7—puncture, furrow |
| | | | L. humerus | Greater tuberosity—furrow, puncture |

**Table 2. Carnivore Damage Types, Distributions, and Frequencies (continued).**

| CARCASS | NUMBER OF BONES RECOVERED | AGE OF INDIVIDUAL | BONE DAMAGED | TYPE AND FREQUENCY OF DAMAGE |
|---|---|---|---|---|
| (202 cont.) | | | R. humerus | Lesser tuberosity—puncture |
| | | | L. femur | Greater trochanter—irregular; head—puncture |
| 203* | 4 | i | No visible damage | |
| 204 | 59 | i | Thoracic vertebrae | 2 of 12 neural spines—puncture, furrow |
| | | | Sacrum | Puncture |
| | | | L. femur | Greater trochanter—puncture, irregular; head—puncture |
| | | | R. femur | Head—puncture |
| | | | L. patella | Puncture |
| 205 (two individuals are represented) | 90 | i | Cervical vertebrae | 2 of 3—puncture |
| | | | Thoracic vertebrae | 2 of 22 transverse processes—puncture |
| | | | Lumbar vertebrae | 1 of 7 neural spines—puncture |
| | | | Ribs | 7 of 25, ventral and 3 of 25, dorsal—puncture |
| | | | Cartilage | 1 of 2—puncture |
| | | | Sternabrae | 7 of 8—puncture |
| | | | R. humerus | Proximal—irregular |
| | | | L. femur | 2 of 2, proximal—puncture, furrow |
| | | | R. femur | 1 of 2, distal—furrow; 1 of 2 proximal—furrow |
| 206 | 22 | i | Thoracic vertebrae | 2 of 6 transverse processes—irregular |
| | | | Ribs | 1 dorsal and 1 ventral of 13—puncture |
| | | | Sternabrae | 1 of 2—puncture, furrow |
| 20—? | | | L. humerus | Greater and lesser tuberosity—irregular |
| | | | L. innominate | Ilium—puncture, furrow |
| 301* | 107 | 4 | Lumbar vertebrae | 3 of 7 neural spines, 5 of 14 transverse processes—irregular |
| | | | Sternabrae | 1 of 4—furrow, irregular |
| | | | L. humerus | Greater and lesser tuberosity—furrow, puncture, irregular |
| | | | L. ulna | Olecranon process—puncture, irregular |
| | | | Third phalanx | 1 of 5—puncture and irregular |
| | | | L. innominate | Ischium—puncture, furrow, irregular |
| | | | L. femur | Greatertrochanter—puncture, furrow, irregular |
| 301* (f) | 105 | F | No visible damage | |
| 302* | 27 | i | R. humerus | Diaphysis—irregular |
| 303* | 134 | 8 | No visible damage | |
| 303* (f) | 105 | F | No visible damage | |
| 304 | 4 | i | No visible damage | |
| 305* | 58 | 2 | No visible damage | |
| 401 | 94 | i | Thoracic vertebrae | 2 of 7 neural spines, 1 of 14 transverse processes—puncture, furrow |

**Table 2. Carnivore Damage Types, Distributions, and Frequencies (continued).**

| CARCASS | NUMBER OF BONES RECOVERED | AGE OF INDIVIDUAL | BONE DAMAGED | TYPE AND FREQUENCY OF DAMAGE |
|---|---|---|---|---|
| 401 (cont.) | | | Lumbar vertebrae | 12 of 12 transverse processes—irregular |
| | | | Ribs | 2 of 8, ventral end—puncture |
| | | | Cartilage | 1 of 13—puncture |
| | | | Sternabrae | 3 of 7—irregular |
| | | | R. humerus | Lesser tuberosity—irregular; head—furrow |
| 402 | 13 (2 individuals) | F | No visible damage | |
| 501 | 111 | 2 | No visible damage | |
| 502 | 82 | 2 | R. femur | Greater trochanter—puncture, furrow |
| 503 | 2 | 1 | No visible damage | |
| 504 | 88 | 1 | Thoracic vertebrae | 1 of 11 neural spines—puncture, furrow, irregular |
| 505 | 95 | 9 | Sternabrae | 2 of 4—puncture, irregular |
| | | | R. femur | Greater trochanter—puncture, irregular |
| 505a (f) | 78 | F | No visible damage | |
| 505b (f) | 58 | F | No visible damage | |
| 506 | 41 | 5 | Axis | Puncture, irregular |
| | | | Cervical vertebrae | 5 of 5 neural spines—puncture, irregular |
| | | | Lumbar vertebrae | 2 of 5 transverse processes—puncture, irregular |
| | | | Ribs | 2 of 10, ventral end—puncture, furrow, irregular |
| | | | R. ulna | Olecranon process—puncture |
| | | | L. ilium | Anterior aspect—puncture, irregular |
| | | | L. tibia | Proximal anterior crest—irregular |
| | | | R. calcaneum | Furrow, irregular |
| 506 (f) | 16 | F | Humerus | Proximal and distal—irregular |
| | | | Metacarpal | Proximal and distal—irregular |
| 507 | 127 | 4+ | Hyoid | Puncture |
| 507 (f) | 20 | F | No visible damage | |
| 508 | 15 | 4+ | L. humerus | Greater tuberosity—puncture, irregular |
| | | | L. ulna | Olecranon process—puncture |
| 509* | 44 | i | Cervical vertebrae | 1 of 5—puncture |
| | | | Ribs | 2 of 16, ventral end—puncture, furrow |
| 5—? | 7 | — | Rib | Dorsal and ventral—puncture, irregular |
| | | | L. metacarpal | Proximal and distal—puncture, furrow, irregular |

Note: Age is in years (F=fetal; i=indeterminant). *Carcasses are of deer; all other carcasses are of elk. Fetal skeletons directly associated with adults are assigned the same carcass number as the adult, and are denoted with a lower case "f" in parentheses. Several bones were recovered from sites 2 and 5 which could not confidently be assigned to a particular carcass; these have been included for sake of completeness of presentation of the carnivore damage data. Refer to Figure 5.

## Carnivore Damage to Bones

Three types of physical damage attributable to carnivores were recorded on the Mount St. Helens cervid bones (Figure 7). These damage types are well documented and described by various researchers (Binford 1981; Bonnichsen 1973, 1979; Bonnichsen and Will 1980; Brain 1981; Bunn 1981; Haynes 1980, 1982, 1983b; Miller 1969, 1975; Morlan 1980; Potts and Shipman). Damage types are defined here below:

*Puncture:* circular or oval depression with fragments of bone crushed inwards towards bottom of depression.

*Furrow:* broad groove typically rounded or U-shaped in cross section, occasionally with fragments of bone crushed inwards.

*Irregular:* amorphous fracture plane resulting from removal of cancellous body tissue, often with punctures and/or furrows associated.

A catalog of all recorded damage to the Mount St. Helens cervid bones that I attribute to carnivores is presented in Table 2.

Gifford (1977:279) notes it is too simplistic to assume the longer bones are exposed on the ground surface the greater the probability of their incurring carnivore damage, as well as noting that "damage to bones by carnivores may occur as an incidental result of meat consumption or as the effect of deliberate ingestion of bone." Variables that affect whether or not bones are chewed by carnivores include the number, size, strength, taxon, and hunger of the carnivores, number of available carcasses, and season and mode of prey animal death. For instance, wolves (*Canis lupus*) of northern North America tend to more fully exploit carcasses of prey animals that they have killed than carcasses of animals that have died from other causes during winter and which they have subsequently scavenged. Consequently, bones of prey animals in the former case tend to display a higher degree of carnivore-induced damage than those in the latter case (Haynes 1982).

Haynes (1983a) summarized apparent differences between stage of carnivore damage to large bovid femora and tibiae. The Mount St. Helens cervid femora and tibiae display very light carnivore-induced damage. Only 1 of 39 proximal tibiae and 0 of 29 recovered distal tibiae showed any evidence of carnivore damage. Two of 42 distal femora had irregular damage and 1 had a furrow; of 39 proximal femora recovered, 1 greater trochanter had a puncture and 1 had irregular damage, 3 femoral heads had punctures and 2 had furrows, and 1 proximal diaphysis had a furrow. Haynes (1983a:164) suggests that "very light damage by all taxa of carnivores might look identical" before presenting data on carnivore damage that can be used to determine the carnivore taxon that did the gnawing. The very light degree of damage to the Mount St. Helens bones does not permit inferring the responsible carnivore taxon. The degree of damage *does* suggest that carcass exploitation was not intensive. Because the degree of carnivore damage to bones relates to the number and taxon of carnivores exploiting bones (Haynes 1982, 1983b), it is relevant to consider why Mount St. Helens cervid bones are so lightly damaged.

I assume that many carnivores, as well as cervids, in the Mount St. Helens blast zone were killed by the eruption and its effects. Several months after the May 18, 1980, eruption, however, numerous coyotes were observed in the blast zone (Marvin Jones, personal communication). Coyotes are well-documented opportunistic feeders (Van Vuren and Thompson 1982). No coyotes or fresh signs of coyotes were seen and little fresh tissue remained on cervid bones at the time of collection. Therefore, it is probable that the carcasses were not being exploited by scavenging carnivores at that time, but rather that carnivore damage occurred relatively soon after cervid death.

Exposed carcasses were probably visited and exploited by scavenging carnivores during the summer and autumn of 1980. Few live prey species were in the blast zone at that time, and the stationary cervid carcasses would have presented prime targets for exploitation as they were observed to retain some portions of hide and soft tissue (Marvin Jones, personal communication). Damage to bones attributed to carnivores is not as extensive as that reported in contexts where carnivores were exploiting prey they had killed (Binford 1981) or were fed in a zoo (Haynes 1980, 1982). In these published cases, bones of prey were provided over a long time span to a relatively stable carnivore population. In contrast, in the blast zone a plethora of prey carcasses became relatively instantly available to a population of scavenging carnivores that had also been reduced by eruption related effects, and which subsequently expanded slowly in size.

Most bones showing evidence of carnivore damage were recovered from site surfaces. The few buried bones which had been gnawed were buried by alluvial processes subsequent to the May 18, 1980, eruption and generally were not articulated with other bones. The distribution of carnivore damage across bones and skeletons (Table 2) suggest only those readily accessible bones (i.e., not buried by volcanic tephra) were exploited.

Carnivore damage of one type or another is distributed across nearly all elements of non-fetal cervid skeletons. Gnawing damage most consistently occurs on the humerus greater trochanter (13 of 39, or 33% of the recovered specimens), sternabrae (26 of 166 recovered, or 22.4%), thoracic neural spines (18 of 255 specimens, or 7%), and lumbar transverse processes (46 of 272 specimens, or 17%). These elements are not very dense (Lyman 1982, 1984a), and thus are more prone to show evidence of exploitation by carnivores than other denser elements.

Comparison of frequencies of postnatal and fetal deer and elk bones damaged by carnivores to the total number of bones in each of these classes (Table 3) indicated as the total number of bones per class increases, the number displaying evidence of carnivore damage increases. Comparison of percentages of carnivore dam-

**Table 3. Sample Sizes and Relative Abundances of Four Classes of Cervid Bones: Postnatal Elk, Postnatal Deer, Fetal Elk, and Fetal Deer.**

| | TOTAL SAMPLE SIZE | NUMBER CHEWED BY CARNIVORES | % OF TOTAL CHEWED BY CARNIVORES |
|---|---|---|---|
| **Postnatal** | | | |
| Elk | 1895 | 167 | 8.8 |
| Deer | 402 | 36 | 9.0 |
| **Fetal** | | | |
| Elk | 247 | 13 | 5.3 |
| Deer | 210 | 0 | 0.0 |

Note: The average size of bones in each class decreases in this order. See text for discussion of carnivore damaged bones, and see Table 2 for additional details.

aged bones in each class suggest, however, that postnatal deer bones were more regularly gnawed than postnatal elk bones. Two factors may account for this. First, as ordered in Table 3, bones increase in average size over the classes. The largest bones (those of postnatal elk and deer) were probably less prone to burial as a consequence of their greater size; these larger bones would have had a greater chance of being exposed and accessible to scavenging carnivores than would fetal elk and deer bones. Second, bigger carnivores can more effectively exploit large bones than smaller carnivores (Morlan 1980). If coyotes were the major carnivore exploiting the Mount St. Helens cervid carcasses, perhaps postnatal elk bones are too near the upper size limit whereas postnatal deer bones are well below the maximum size limit of bones that coyotes can efficiently exploit (see also "Bone Fracture," below).

The Mount St. Helens cervid data suggest that not only is accessibility to carcasses an important factor controlling whether or not fossil bones will display gnawing damage, but that numbers of exploitable carcasses and carcass-exploiting scavengers, and carcass condition (presence/absence of soft tissue on bones) are also important variables. The distribution of bones around carcass locations and bone fracture data tend to corroborate conclusions derived from carnivore damage data.

## Bone Fracture

Patterns of bone fracture or lack thereof provide important information on taphonomic processes that have affected fossil assemblages (Behrensmeyer 1978; Bonnichsen and Will 1980; Stanford et al. 1981). For example, spiral (or radial) fractures have long been argued to result only from human intervention (Dart 1957) and, despite convincing evidence to the contrary (Binford 1981; Bonnichsen 1973; Haynes 1980, 1983a; Lyman 1984b; Morlan 1983; Myers et al. 1980), are still used to infer human presence (Bonnichsen 1979; Morlan 1980). More general fracture patterns have also been used to infer human intervention (Shipman et al. 1981), but these too met with some debate (Binford and Todd 1982; Shipman et al. 1982).

Two kinds of fractures were recorded for the Mount St. Helens cervid long bones (Figure 8). These are defined below.

*Spiral/radial:* fractures diagonal to bone long axis, cutting across natural bone structure or grain.
*Transverse:* fracture at more or less right angle to bone long axis.

Linear fractures (parallel to the long axis of the bone) were not found. Many specimens did, however, display longitudinal "split line cracks" characteristic of weathered

**Figure 8.** Bone fracture types: both are tibiae of black-tailed deer. Top, spiral/radial fracture; bottom, transverse fracture.

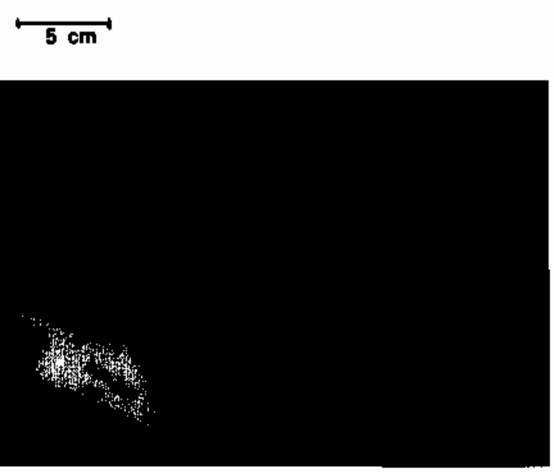


**Figure 9.** Typical fragments of elk bone: **A)** rib; **B)** glenoid fossa of a scapula; **C)** ischium portion of an acetabulum; **D)** ilium portion of acetabulum. All specimens are from site 2.

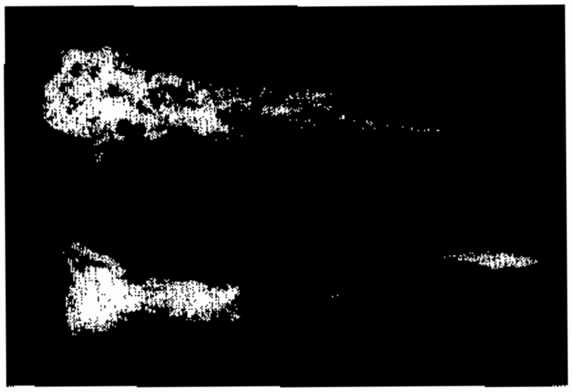

**Figure 10.** Mid-diaphysis spiral/radial fractures of elk bones. Top, left distal tibia; bottom, left distal radius.

**Figure 11.** Mid-diaphysis fragments showing spiral/radial fracture patterns. All specimens are of elk.

bone (Behrensmeyer 1978; Miller 1975). Cervid long bones from sites 1 and 5 are not broken, but bones from sites 2, 3 and 4 are fractured (Figure 9). Only 2 transverse fractures were recorded, 1 each for deer (tibia) and elk (femur). Seven of 32 (22%) deer long bones (1 femur, 1 metacarpal, 2 tibiae, 3 metatarsals) and 16 out of 191 (8.4%) elk long bones (1 humerus, 2 femora, 2 metatarsals, 3 radii, 3 metacarpals, 5 tibiae) are spirally fractured. Six elk bones (1 humerus, 1 femur, 2 metacarpals, 2 radii) display 2 spiral fractures and 1 deer bone (metatarsal) display 2 spiral fractures. There are two probable agents of fracture: scavenging carnivores, and the eruption and its effect.

No visible carnivore damage is in direct association with the fractures, suggesting on the basis of negative evidence that carnivores were not the fracture agent. Studies on carnivore damage indicate carnivore-induced spiral fractures originate at long bone ends. Many of the Mount St. Helens spiral fractures are mid-diaphysis breaks (Figure 8, 10 and 11). Finally, most researchers agree that there is an upper size limit of bone that can be spirally fractured by a particular carnivore taxon (Morlan 1980, 1983).

Spiral fractures are common in the sample of deer bones representing 7 carcasses collected from southwest Oregon. Seventeen of 33 collected long bones display spiral fractures. Eight fracture margins display evidence of carnivore gnawing, and all 8 fractures originate at the long bone ends. Gnawing damage to femora and tibiae closely matches that reported by Haynes (1983b) for wolves, but the local dominant scavenging carnivore is the coyote. These data indicate that coyotes can regularly fracture bones of black-tailed deer-sized animals. Spiral fractures are *not* represented in the sample of three elk carcasses collected from southeast Washington. The elk bones display gnawing damage similar to that attributed to wolves by Haynes (1983a), but again the most abundant local scavenging carnivore is the coyote; there are no wolves in the area, but there are a few feral dogs (*C. familiaris*) and black bear (*Ursus americanus*). These data, while certainly not conclusive, suggest elk bones are too large for fracture by coyotes. The implication of these data is that carnivores did not fracture the Mount St. Helens cervid bones.

The explosive eruption has been estimated as approximately equivalent to 35 megatons (Donn and Balachandran 1981). Effects of this eruption that are relevant to our consideration of cervid bone fractures are summarized by Rosenfeld as follows:

> The lateral blast was probably a combination of steam and explosive gas releases mixed with pulverized rock material from the mountain's north flank, formed into a dense high-speed cloud and heated to about 500° C. Near the northern flank of the mountain nearly every exposed slope within a 10 km radius was completely denuded of all vegetation and covered by up to 2 m of ash and rock debris. Beyond this (at about 15 km radius), trees were snapped off at their bases and completely stripped of their branches. . .trees on the leeward sides of the slopes were singed but left standing [1980:501].

Similarly, Snellgrove et al. report the following observations on trees in the blast zone:

> Destruction in some places close to the volcano was severe, with most of the timber gone or buried. Amount of breakage in other areas appeared to be controlled as much by steepness of slope and shielding afforded by the terrain as by distance from the crater. Typically, trees were uprooted and generally oriented in the direction of drainages leading away from the crater. In protected areas, such as behind ridges, trees were often snapped off but not uprooted, while uprooted trees sometimes pointed toward the volcano, suggesting an eddy effect [1983:369].

Our observations while in the blast zone tend to conform to those cited above.

If elk were standing on the leeward slopes, they were not subjected to the full force of the dense, high-speed ash cloud, in which there were rocks, pumice blocks and probably cervid carcasses! Sites 1 and 5 are located on the leeward slopes or in valleys that were not directly facing the volcanic crater and the oncoming ash cloud. Sites 2 and 3 were also on leeward slopes, but several carcasses were in locations that were relatively more exposed to the ash cloud. Site 4, in fact, consisted of a single elk carcass on a crater-facing slope. Bones of carcasses at sites 2 and 4, in particular, were much more shattered and scattered than bones of carcasses at sites 1 and 5. Bones of carcasses at the former two sites were located in much denser tangles of brush and debris that appear to have been deposited from the ash cloud. Bones of carcasses at sites 2, 3, and 4 were not selectively fractured; that is, it seems every bone of a carcass had an equal chance of being broken, as bones of all types were. As well, there are specimens of all skeletal elements that are not broken. Patterned fracture of bones, such as ribs, or just long bones, would suggest that some selective fracture agent had broken the bones. Observed fractures thus suggest a nonselective fracture agent.

I suspect bones of carcasses at sites 2 and 4 particularly, and probably site 3, were broken as carcasses were engulfed in the ash cloud, picked up, tossed about with trees, rocks, and pumice blocks, and hurled to their recovery locations. Impact of carcasses as they were deposited may also have broken bones; if so, this has implications for broken bones recovered from archaeological kill sites that are jumps. Bones of carcasses at sites 1 and 5, in contrast, are not broken because these bones were located in protected areas relative to the dense and turbulent ash cloud.

## Carcass Orientation

Carcass orientation was recorded by measuring the compass bearing of the axial skeleton. Because the vertebral column was generally disarticulated and dispersed at other sites, only orientation of carcasses at sites 1 and 5 could be determined. Postmortem orientation of these cervids seems to be unrelated to the location of the volcano responsible for their deaths, as exemplified by site 1 carcasses shown in Figure 12. Trees blown down by the explosive shock wave and/or ash cloud were not present on site 1; all trees there were standing. Nearby trees that had been blown down show a patterned orientation that does not correlate with carcass orientation nor with the location of the volcanic crater, suggesting the "eddy effect" postulated by Snellgrove et al. (1983). Nearly equal numbers of individual animals lay on their left and right sides, indicating further that eruption effects did not control postmortem orientation or location of skeletons at sites 1 and 5. These carcasses occurred both away from and among tangles of brush and timber blown onto the sites by the shock wave and/or ash cloud. Bones are unbroken and often articulated, indicating eruption effects

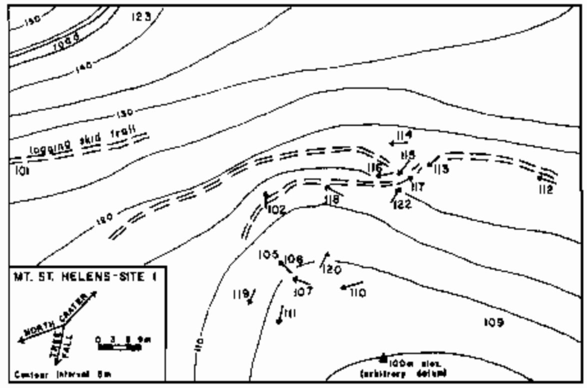


**Figure 12.** Map of site 1 showing topography and carcass location and orientation. Arrow points from rear towards head of animal. If no arrow is associated with a carcass number, orientation could not be determined.

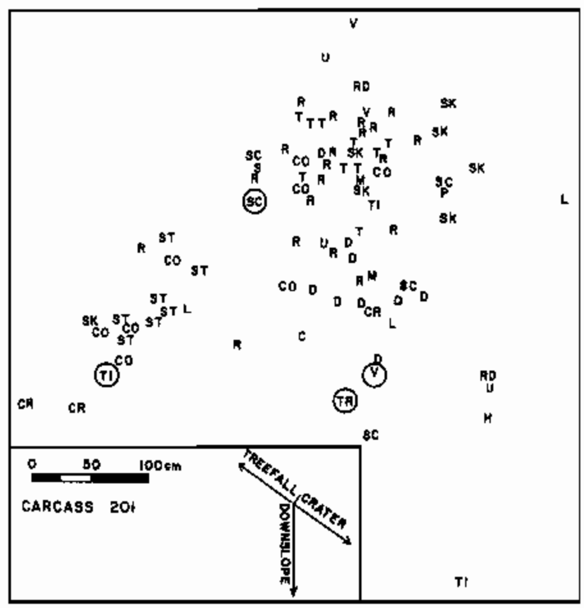


**Figure 13.** Map of carcass 201. Compare to Figure 2. An adult female and a fetal elk are represented. Circled symbols denote fetal bones; all others are adult. C=cervical; CO=costal; CR=carpal; D=diaphysis fragment of long bone; H=humerus; L=lumbar; M=metapodial; P=phalanx; R=rib; RD=radius; S=sacrum; SC=scapula fragment; SK=skull fragment; ST=sternabra; T=thoracic; TI=tibia; TR=tarsal; U=ulna; V=indeterminant vertebra fragment. Buried bones are not shown.

did not control carcass positioning. Apparently, animals at sites 1 and 5 died where they stood.

Carcass orientation at sites 2, 3, and 4 was impossible to ascertain because bones were highly fragmented, disarticulated, and dispersed (Figure 13). Animals at these sites were probably exposed to the explosive shock wave and speeding ash cloud, and were hurled to their recovery locations. This interpretation is corroborated by the immense amount of tangled and fragmented forest debris deposited with these carcasses. Deterioration of soft tissues was no doubt enhanced by the same force that caused bone fragmentation. Bones of carcasses at sites 2, 3, and 4, when first deposited, were probably articulated to lesser degrees and were more fragmented than bones of carcasses at sites 1 and 5.

Additional evidence of differences in depositional modes of carcasses at sites 1 and 5 and carcasses at sites 2, 3, and 4 is found in the proportion of complete ribs in proper anatomical position. On one hand, of 309 ribs recovered from sites 1 and 5, 290 (94%) are complete and 260 (84%) were in proper anatomical position, or nearly so (Figure 5). On the other hand, the minimum number of 116 ribs recovered from sites 2 and 4 are represented by 180 fragments, and virtually none of these were in proper anatomical position (Figure 13).

## Postmortem Dispersal of Cervid Bones

Virtually all buried bones were articulated to some degree. Often, some surface bones were more widely dispersed, usually downslope of the primary carcass location (Figure 2) as a result of gravity-related transport. No spatial patterning similar to that described by Behrensmeyer (1975), Hanson (1980), and Hill (1979), or Voorhies (1969) could be detected in the surface distribution of elk bones. Most of these researchers defined patterns in experimentally generated distributions of disarticulated mammal bones subjected to fluvial transport across a uniform bed. The Mount St. Helens elk bone data indicate that these experimentally generated patterns may be a rare occurrence when a nonuniform bed (e.g., extreme variations in microtopography and vegetation patchiness) and articulated bones are involved. For example, if a carcass lay on its left side, generally only the right limbs moved downslope; in this case left limb bones tended to be buried by tephra.

The distribution of surface occurring bones of nine elk carcasses at site 1 was mapped in detail (e.g., Figure 2). Hill's (1979) model of large artiodactyl skeleton disarticulation indicates forelimbs will disarticulate from carcasses before hindlimbs, and the thoracic-lumbar region will disarticulate last. This model can be compared to the elk bone distributional data for mapped carcasses. All vertebral columns were articulated when collected, but one (carcass 112, Figure 2) was about 6 m downslope of the original carcass location. Irregular damage to several lumbar transverse processes suggest carnivores moved the vertebral column out of the carcass 112 depression; gravity-related transport may then have carried the column downslope. Forelimbs and hindlimbs of carcasses 113 and 116 were both 2 to 4 m downslope of the carcass. Hindlimb elements of carcass 102 were strewn 6 to 12 m downslope of the carcass while forelimb elements clustered 14 m downslope. This fits Hill's (1979) model of disarticulation *if* it is assumed the first element to disarticulate has greater time to be dispersed, and thus will be dispersed farther. The hindlimb of carcass 112 was, however, 19 m downslope of the carcass while the forelimb was only 2 m downslope (Figure 2). The disarticulation of carcass 112 limb bones thus contradicts either the assumption expressed regarding carcass 102, or Hill's (1979) disarticulation model, or both. Alternatively, both Hill's (1979) model and the assumption are correct and some other factors or set of factors accounts for the observed distribution. Given that Hill's (1979) model has tended to hold up under additional testing (e.g., Hill 1983 and references therein), and given that the assumption seems realistic (e.g., Behrensmeyer 1983; Crader 1983), I suspect factors such as microtopographic variation and density and patchiness of post-eruption emergent vegetation (Means et al. 1982; Moral 1983) have tended to convolute the pattern of bone movement downslope that Hill's (1979) model and the assumption suggest. The other five mapped carcasses (106, 107, 109, 110, 120) all tended to be on relatively level ground and most bones were articulated (Figure 12).

Carcasses 113 and 116 were pregnant female elk. Associated fetal bones for both of these carcasses formed distinct clusters of elements 3 and 5 m downslope of the adult female's carcass, respectively. This suggests as soft tissues of cow elk deteriorated, the still articulated fetus "disarticulated" from the cow, moved downslope as a unit, and subsequently disarticulated. This observation has significance for showing how Hill's (1979) model might be elaborated to include fetal carcasses.

Evidence for dispersal of bones by carnivores is 1) carnivore damage to bones, and 2) upslope locations of bones relative to the primary carcass location. Carnivores apparently chewed many bones adjacent to carcass locations because few gnawed bones had upslope of carcass locations. In two cases, however, clear evidence of carnivore dispersal was apparent. Carcass 508 (elk), consisting of a complete left forelimb (minus the scapula), was approximately 40 m upslope of all other bones at site 5. This limb had undoubtedly been moved by carnivores; the proximal humerus and proximal ulna display punctures. In the second case, the left hindlimb of carcass 301 (deer) was approximately 20 m upslope of the remainder of the skeleton. The greater trochanter of the femur displays punctures, furrows and irregular damage. The left forelimb of 301 was approximately 40 m away from the carcass, and the humerus and ulna display punctures and irregular damage. This forelimb was, however, downslope of the carcass. This forelimb and the primary carcass were in the bottom of a small canyon. The type and chronological order of taphonomic mechanisms responsible for dispersal of many skeletal elements, as in the case of the 301 left forelimb, are unclear.

## SUMMARY AND CONCLUSION

Study of Mount St. Helens eruption-killed cervids has produced several implications for analysis and interpretation of broken bones recovered from paleontological and archaeological sites. Analyses of patterns of bone distribution, damage and fragmentation described above (see also Lyman 1984b) suggest the explosive force of the eruption and its attendant ash cloud were major taphonomic agents, affecting both the condition and distribution of *some* bones and carcasses. Other carcasses were in what appear to be undisturbed death poses (sites 1 and 5) very similar to those seen in Voorhies' (1981) Miocene site in Nebraska. Carnivore disturbance of carcasses was minimal, no doubt because of the relative paucity of scavengers in the blast zone immediately after the eruption and because of the abundance of potentially scavengable carcasses. This, too, tends to closely match Voorhies' (1981) observations on much older bones. Finally, it seems clear that a single volcanic eruption acting as an agent of mortality will produce much variability in the resulting (future) fossil record. This variability originates with the manner in which mortality is induced (e.g., suffocation versus explosive shock wave and ash cloud) and tends to be enhanced by variation in surficial exposure of bones, carnivore activity, and microtopography and vegetation.

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