Chapter 17
Analyzing Multi-Agent Assemblages

The topics covered in this and the following chapters shift from the relatively straightforward identification of effectors and actors summarized in Part IV to inferring past behavioral, social, and ecological contexts in which such evidence was produced (Fig. 3.2). How animal remains can shed light on the place of humans in regional ecosystems, on human social relations, on commodity production and exchange, or on ritual life encompasses most zooarchaeological researchers' ultimate interests. However, such questions present much greater inferential challenges and are more subject to debate among practicing zooarchaeologists, as the chapters of this section will outline. As noted in earlier chapters, the most commonly used faunal evidence for addressing these issues is the *aggregate patterning* of bone modifications and element frequencies, as interpreted in the context of other archaeological evidence as well as geomorphic and geological context.

Moving toward such levels of interpretation rests on the assumption that human actors produced the aggregate evidence. However, one seldom encounters vertebrate archaeofaunas accumulated and affected by only one actor or process. Even with relatively recent historical samples, scavenging birds and mammals, gnawing rodents, trampling, weathering, and other post-discard processes can influence element frequencies and overprint human bone surface modifications. Zooarchaeologists face the challenge of teasing out the dominant agents involved in "multi-agent accumulations," the sequence of their effects on a sample, and those effects on various properties of the remaining assemblage. They are not alone. Paleontological taphonomy emerged in response to parallel challenges in the use of data from fossil deposits to infer species paleobiology and paleoecological relations of multiple species in deep time. For zooarchaeologists working with samples where multiple agents appear to be involved, vertebrate taphonomists' analytic approaches are valuable resources that will be discussed at the end of this chapter.

When evidence suggests that assemblage formation involves multiple actors, one must consider what constitutes relevant and credible evidence for the action of any one of these. Referring to early sites with sparse archaeological evidence, Binford (1981) and Brain (1976, 1981) argued that spatial association of human

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artifacts with vertebrate remains is not a sufficient basis for inferring that hominins were the principal actors responsible for creating a faunal accumulation, nor is non-random patterning in fracture and bone surface modification. These insights hold true for much later sites as well, where nonhuman actors and processes can introduce or restructure archaeofaunal materials. Part IV recapitulated four decades' actualistic research aimed at specifying the distinctive effects of various actors and effectors.

In determining which actors and processes could have created assemblage structure, a prudent first step is to consider the range of such agents possibly involved, and then to narrow this range, excluding actors and processes that would most likely *not* have been involved in creating the assemblage. This is facilitated by distinguishing which of these potential agents could be both bone accumulators and bone modifiers, which modifiers were not accumulators, and whether any accumulators would not have been modifiers. Certain actors and processes can be excluded from one of these options, simply based upon a priori knowledge of their capabilities. If, for example, in a cave site excavation yielding many bison elements that display heavy gnawing by rat-sized rodents, one would be unlikely to attribute the *accumulation* of the bison bones to those rodents. One would instead seek biological actors or geological forces powerful enough to have accumulated these large and heavy objects. Cave geomorphology and sedimentology could be evaluated to assess whether the cave may have been a natural trap into which bison fell without any human intervention (e.g. Oliver 1989), or whether, given the placement of the cave mouth, the bones could have washed into it with heavy precipitation. If these options appeared unlikely, one could turn to bone surface modifications that testify to action of humans or larger carnivores – or both – capable of carrying bison parts to the cave. This process thus involves arguing from first principles in a kind of dialogue between the analyst and the assemblage, using available evidence and a background knowledge of causal relations like those covered in Sect. IV to discern modifying actors and processes and to assess what kinds of effects each could have on the sample.

The approaches outlined in Chaps. 19, 20 and 21 involve using criteria derived from actualistic research to distinguish the effects of different actors and processes on vertebrate remains. After identifying the most probably implicated actors or processes, it is useful to specify which among these could produce equifinal outcomes in one line of evidence – such as element frequencies – while leaving other, more distinctive, traces, such as tool, tooth, or trampling marks as bone surface modifications. Explicitly stipulating actors or processes that produce equifinal outcomes in one line of evidence permits one to identify other, independent lines of evidence to evaluate the likelihoods of their actions on the sample under analysis. The goal of these steps is not necessarily to "prove" the action of a given actor, but rather to stipulate which are the most and the least likely to have produced the patterns in the observed archaeofaunal evidence. This may seem a simple-minded, "paint-by-numbers" exercise, but considering and eliminating the obvious can be a useful exercise: specifying why an agent is being eliminated from consideration sometimes forces a reexamination one's base assumptions. Despite such approaches, the dominant agent or agents responsible for an archaeofaunal sample's constitution may be ambiguous. Nonetheless, getting to that conclusion systematically enables one to assess how – and even if – the sample can be used to draw inferences about human behavior. The issue of whether some assemblages are better than others at doing so will be addressed in the Egeland et al. (2004) example presented below.

The following sections present some cases that illustrate how zooarchaeologists have worked through identification of the dominant actors and processes in multi-agent deposits, all using multiple, independent lines of evidence and actualistically derived knowledge of hominin and nonhuman actors' and processes' effects. These case studies are not an exhaustive list, but they illustrate how the actualistic research outlined in Part IV is mobilized to explicate the effects of more than one actor or accumulating process. As might be anticipated from prior chapters, several cases are from palaeolithic zooarchaeology. and one derives from the Americas, employing an approach pioneered in paleontological taphonomy that may be applicable to other zooarchaeological cases. In doing this, my interest is not so much whether the authors are "right" in their broader inferences about hominin behavior as in *how they used zooarchaeological knowledge* to work through the questions they faced.

17.1 Working to Identify Actors and Contexts: Some Pleistocene Cases

Actualistic research by paleoanthropological zooarchaeologists has contributed to methods for clarifying the origins of multi-agent assemblages, regardless of their antiquity. Plio-Pleistocene vertebrate archaeofaunas often present scant and ambiguous evidence for hominin agency. Some research has focused on defining distinctive signatures of "hominin first" or "carnivore first" processing of medium- to large-sized ungulate elements, especially long bones, which preserve carnivore tooth marks and marks of human cutting and percussion. To recapitulate, hominins use percussion on diaphyses to open long bone marrow cavities, leaving epiphyses largely untouched. By contrast, carnivores attack epiphyses, regardless of whether or not they have first access to the elements or are scavenging human discards. In cases where marrow was still enclosed in diaphyses, carnivores will gnaw and compress the shafts, seeking to collapse them and in the process leaving tooth marks on diaphyseal surfaces. However, experiments suggested that, when marrow had previously been removed, carnivores did not gnaw diaphyses or shaft fragments. Given the ubiquity of carnivore species, including bone-consumers, in contemporary and paleontologically documented African ecosystems, zooarchaeological researchers believed it most prudent to focus their analytical attention on diaphyseal fragments, because these are the most likely parts of the postcranial skeleton not only to preserve but also to display the presence or absence of "overprinting."

17.1.1 What Created the Assemblage? Disentangling some African Early Stone Age Palimpsests

Building upon these actualistically derived understandings, a group of researchers who have worked on Early Stone Age (ESA) deposits in southern and eastern Africa Egeland, Pickering, Domínguez-Rodrigo, and Brain (2004) undertook a comparative assessment of mammal bone assemblages known to incorporate some carnivore and hominin modifications. Their goal was to distinguish "the level of functional independence of the hominin- and carnivore-derived portions from several important Plio-Pleistocene archaeofaunas" (Egeland et al. 2004:343). They used experimentally derived understandings of bone surface modifications to assess whether hominins and carnivores had left marks of their intervention on the same specimen and, by extension, whether these actors had interacted with components of a single carcass. Such a co-occurrence implies a close temporal association of the respective species' nutrient-seeking behaviors.

Rather than focus a priori on the *sequence* in which carcass parts were handled by the potential consumers, they chose to characterize the formation of an assemblage in terms of the *degree of overlap* of different consumers' bone surface modifications in each sample. In doing so, they aimed to develop a replicable method for sorting highly independent from highly interdependent assemblages, with the ultimate goal of defining assemblages in which the majority of elements appear to have been modified by one dominant actor, especially hominins. This in turn would enable a warranted set of inferences about hominin carcass processing. In other words, the authors aimed to construct a reliable approach to assessing what proportion of an assemblage reflected the operational chains exclusive to one or another set of actors (Chap. 15). They focused on marks typifying the "carcass or bone modification phase" of assemblage formation and chose mid-shaft, diaphyseal specimens as those most likely to preserve signatures of the original processors. "We argue that the frequency of limb bone specimens that preserve evidence of both hominin (cutmarks, percussion marks) and carnivore (tooth marks) involvement can serve as an estimate of hominin-carnivore overlap in assemblage modification" (Egeland et al. 2004:346).

Egeland et al. used actualistic documentation to create statistical expectations, expressed as a simple % average with 95% confidence intervals, for tooth and cut marks on the same element, for tooth and percussion marks on the same element, and for, tooth marks plus cut- and/or percussion marks. They applied this to their own research data plus published zooarchaeological information for FLK 22 *Zinjanthropus* ("FLK *Zinj*") from Bed I, Olduvai Gorge, Tanzania (see references in Egeland et al. (2004), also Chaps. 14–16), Monahan's (1996) Olduvai Bed II faunas from BK, MNK Main, and HWK East Levels 1–2, the ST Site Complex at Peninj, also in Tanzania, Swartkrans Member 3 (see references in Egeland et al. 2004). Details of what constituted a comparable selection of diaphyses for each site assemblage may be read in their article. They then tabulated the percentage of NISP in these assemblages that displayed at least one tooth mark and at least one cut mark, or at least one tooth mark and at least one percussion mark.

The results indicate that the percentages of both tooth and cut marks on specimens from Olduvai Bed II, Peninj, and Swartkrans Member 3 were "below those expected if their hominid- and carnivore derived components were modified under a high degree of interdependence" (Egeland et al. 2004:349). By contrast, the much-discussed FLK *Zinj* sample was within the range or above the mean for actualistically derived assemblages with both carnivore and hominin involvement. The authors remark that the Swartkrans Member 3 assemblage is especially interesting because, although carnivore-modified diaphyses outnumber those with hominin modifications three-to-one, these are generally independent of each other. As they put it, "The Swartkrans Member 3 fauna thus promises to be an extremely useful datum for understanding hominin carcass foraging in a relatively 'uncomplicated' taphonomic context… considered separately from the carnivore-modified component" (Egeland et al. 2004:349). Similar conclusions were drawn regarding the aggregate of Peninj "mini-sites" and the Bed II faunal samples from Olduvai. Thus, the method appears to efficiently identify assemblages best suited for studying early hominin carcass processing, and one can imagine permutations of it could be applicable to other contexts and cases.

17.1.2 What Created the Assemblage? Die Kelders 1 and the Middle Stone Age

Marean and coworkers (2000) published an extensive analysis using context, species and element representation, and bone surface modifications to sort out the dominant accumulating actors and processes at Die Kelders 1, a coastal South African cave containing extensive Middle Stone Age artifact assemblages, especially in Levels 10 and 11. Using Capaldo's (1997) distinction between the "nutritive" and "non-nutritive" phases of the taphonomic histories of vertebrate remains, they argued that post-nutritive processes can displace, weaken, break, or destroy skeletal elements originally accumulated in a deposit, thereby affecting the collection's potential for elucidating about hominin or other creatures' nutritive behavior. They stated their ultimate goal as, "identifying the impact and consequence of non-nutritive processes, so that we can evaluate the integrity of the DK1 fauna for investigating hominin behavior and identify those aspects of the assemblage likely to be sensitive to hominin behavior" (2000:207). This is of special interest to paleoanthropologists because the South African MSA is associated with very early modern humans.

To assess the usefulness of the Die Kelders 1 faunas for studying hominin behavior, Marean et al. first sought to identify the dominant accumulator(s) of the deposits using previously published data on the vertebrate assemblages as well as reasoning from actualistic datasets. In much the same process of elimination advocated earlier in this chapter, the authors begin by stipulating the range of possible bone accumulators and their signatures. These included African porcupines, large raptorial birds, carnivores, especially the brown hyena, and hominins. They excluded porcupines and smaller rodents as accumulators because of the very low rates of gnawing in the aggregate assemblages, given documented high rates of distinctive gnawing in rodent-accumulated samples. With regard to large avian raptors, they concluded that these had a significant effect on accumulating both molerats and very small bovids. The avian scenario is supported by the spatial distribution of gastric-etched bones fragments, which cluster toward the front of the cave near where solution holes tend to develop. These, the authors argue from modern analogy, would have provided roosts for raptors. The authors used the degree of gastric acid etching on the bone specimens of these two taxonomic groups as an index of non-hominin involvement during the nutritive phase, further excluding the likelihood of involvement of larger carnivores such as jackals and hyenas because of the lack of gastric etching on bones of larger-bodied taxa. Hyenas, for example, would have been as likely to swallow – and later vomit up – bones and bone fragments of the larger sizes of bovids as the very smallest.

Larger mammal carnivore tooth marks were common on Layers 10 and 11 specimens. However, so are percussion-marked diaphyses typical of hominin marrow processing. The authors worked through this confounding set of "signals" as follows. Percussion-marked diaphyses are precisely the types of shaft fragments in which carnivores are not interested, so their abundance reflects hominin accumulative activity at Die Kelders 1. Marean et al. examined tooth marks rates on diaphysis fragments of different-sized bovids, showing that these increase with size class. Returning to the actualistic data recapitulated at the outset of this section, Marean et al. (2000: 214) noted that the relatively low incidence of carnivore tooth marks on mid-shafts "closely resemble[s] a situation where 100% of long bones were hammer-stone broken, discarded by hominins, and then ravaged by carnivores." They further noted that comparisons of MNE estimates for different long bone segments supports this scenario because epiphyses are much less abundant than are diaphyses.

However, the authors noted that the percentage of long bone fragments with *both* percussion and tooth marks in Layers 10 and 11 is 1–2%. Citing these data, they state that,

> ...a portion of the toothmarked fragments probably were contributed by carnivores without prior processing by hominids. However, given the low overall frequency of tooth marked long bone fragments… we can confidently state that only a small percentage of long bone fragments could have been accumulated by carnivores (Marean, et al. 2000:216).

Turning to post-nutritive taphonomy, Marean et al. developed an argument based on their elaboration of Villa and Mahieu's (1991) break-edge angle/break-surface analysis (Chap. 12). They note that specimens displaying weathering in Layers 10 and 11 are rare, thus eliminating subaerial weathering as a contributing factor in assemblage fragmentation rates. Many specimens are burned and display differentially more right angle and transverse breaks. If burned specimens are deleted from tabulations, Layers 10 and 11 have few dry-bone breaks, relative to fresh breaks. Given these combined lines of taphonomic evidence, the authors argued they can use Layers 10 and 11 as a basis for studying humans' selective transport of different-sized ungulates' body segments.

17.1.3 Actualistic Notes on Human Habitations as Scavenger Magnets: Overprinting Likely

Marean and coworkers' scenario for intensive carnivore consumption of hominin bone debris may seem only likely in the remote past, when humans foraged in ecosystems full of large carnivores. However, researchers working with modern and relatively recent settlements in Africa, Southwest Asia, and South Asia have documented the persistence of scavenging carnivores, and their impacts on human refuse and burials, augmented by feral domestic dogs (Horwitz and Smith 1988; Lotan 2000; Monchot and Mashkour 2010) (Chap. 12). In regions where large, bone-crunching carnivores persist, the likelihood of carnivore "overprinting" is confined neither to forager sites nor to the remote past.

Site 105, the Dassanetch settlement mentioned in Chap. 15, was a relatively large defensive encampment created during a drought in 1973 and abandoned after about 6 weeks (Gifford-Gonzalez 1989). About a month later, I documented the site and collected about 2800 faunal specimens of cattle, sheep, and goats, fishes, crocodiles, and turtles, and at least three common zebra (*Equus quagga burchelli*) for further analysis. The dominant agent accumulating the Site 105 fauna was never in question. To my surprise, however, I found the rate of carnivore gnawing on Site 105 mammal specimens was five times higher than that documented for carcasses of 48 wild zebra, topi (*Damaliscus lunatus*), and oryx (*Oryx gazella*) that I had been monitoring from the time of their deaths, over the same time span and in the same area. Carnivore tooth marks were found on 5.5% of 105's mammal specimens, one month after the site was abandoned, versus on 1% of the aggregate sample of natural ungulate death specimens within the first month postmortem. It was possible to infer the sequence of bone processors by noting the location of human-generated damage (cuts, chops, impact fractures, thermal alteration) in relation to where carnivore gnawing occurred. The overall inference is the same as that drawn by Marean et al. for Die Kelders 1 Layers 10 and 11: carnivore impacts occurred *after* human processing. Few domestic dogs were left in the region in 1973 after a state-sponsored rabies eradication program. Specimens bore tooth marks of large carnivores, and some clearly of hyena-sized teeth (Fig. 12.5). Spotted hyenas were in evidence, although sparsely, in the region during this time.

Human sites may serve as "magnets" for carnivores scouting scavenging opportunities. These are more concentrated and certainly more spatially predictable food sources than are chance encounters with single animal deaths or small prey in semi-arid environments. Such a "magnet effect" could lead to higher intensities of carnivore modification in these assemblages than on bones dispersed throughout the landscape. Domestic animals are generally fattier than wild ones, although cooking removes fats and other nutrients from bone (Lupo 1995). The "magnet effect" documented by Marean et al. and myself for very different times and adaptations highlights the complexities of site formation and the effects of successive bone modifiers, even in modern human situations and merits further study in other contexts. Mobile foragers, such as those who created Layers 10 and 11 at Die Kelders 1 or mobile pastoralist-foragers who set up Site 105 create scavenging opportunities upon leaving a locality. This point was also made by Mondini (2002) with reference to South American rockshelters (see below). These results influence how I interpret the taphonomic histories of early pastoralist archaeofaunas in East Africa that are only a few thousand years old but were deposited when and where multiple bone-modifying wild carnivores, as well as domestic dogs, existed. More permanent human settlements may be part of regional scavenger ecology, as they are today in parts of Africa and the Near East, and researchers should consider how to detect the possibility and nature of their effects on archaeofaunas.

17.1.4 What Created the Assemblage: Yarimburgaz Cave, Turkey

Stiner, Arsebük, and Howell (1996) explored the roles of several actors, including bears, other carnivores, and hominins, in forming a cave accumulation. Yarimburgaz Cave is a limestone cave with stratified deposits containing numerous remains of the Pleistocene cave bear, *Ursus deningeri,* an earlier cave bear species than the better-known *U. spelaeus*. These were associated with sparser remains of ungulates and other carnivores, as well as over 1600 Middle Paleolithic artifacts. Over 90% of the 4180 macromammal specimens recovered were attributed to *U. deningeri*, and the remainder derived from a variety of hoofed herbivore species (NISP=151), lion and possibly leopard, two species of small cats, spotted hyena, wolf, fox, jackal, possibly a dhole (a Eurasian wild canid), and a small mustelid (total carnivore NISP=109).

In assessing accumulating actors and processes, the authors first used cave geomorphology to eliminate flowing water as a possible bone transporting mechanism during the span the cave accumulated bones. Biological actors are more likely, and, unlike carnivore taxa discussed in earlier examples, bears are likely to "self-accumulate" through their hibernation habits. Stiner et al. reviewed wildlife literature on living bear species, to identify physiological and behavioral features that can be assumed to hold for Pleistocene members of the Ursidae. With the exception of the polar bear, ursids are omnivorous and do not collect food in their hibernation dens, though they may amass piles of vegetation for bedding. They are extremely vulnerable during hibernation, and dens where they sleep are usually hidden, in terms of their visibility and the lack of olfactory clues to their location.

Stiner and colleagues explored the spatial effects of denning bears on materials in caves, skeletal element profiles, bone surface modifications, and the age structures that one might expect from hibernation deaths. In documented contemporary bears, these deaths result from starvation and peak toward the end of the winter, although bears that deplete their reserves may wake and attempt to forage. Bear deaths in dens contribute entire skeletons to a cave floor, but, as Stiner et al. (1996:291) succinctly put it, "Whereas hibernating bears are nearly odorless, a dead bear is not and therefore is likely to attract scavengers once the carcass is abloom" A redolent carcass would attract large and small scavengers, including other hungry bears, contributing to scattering and destruction of skeletal parts, as well as bone surface modifications by consumers. Today, wolves and male bears are the most common consumers of dead or hibernating bears. Age classes most affected by hibernation are immatures, which may die soon after birth or during their first or second winters due to lack of adequate foraging and fat deposition, and old adults. This creates a classic “attritional,” or U-shaped, age structure, low in representation of older juveniles and adults (Chap. 22).

From these contemporary facts, the authors framed expectations about an assemblage produced primarily by hibernation deaths, through starvation or predation and/or scavenging. They proposed that the representation of ungulate skeletal elements would differ from that of bears because the ungulates were likely to have been accumulated by non-ursid carnivores temporarily using the cave. The Yarimburgaz bear sample’s spatial organization, skeletal element representation, and bone surface modifications are examined to assess whether they matched each of these expectations.

To explore how much bears’ skeletal element representation reflected *in situ* destruction, Stiner et al. compared MNI calculated from skull landmarks with MNI estimated from teeth, reasoning that both were initially present as components of the cranium or mandible, and that nutritive-phase transport would therefore affect both equally. They argued that the divergence of the respective MNI statistics could enable assessment of the extent of *in situ* destruction, as these two components of cranial units have different durabilities. In all but one sample, tooth-based bear MNI estimates is twice as great as MNI estimates from cranial bone landmarks. A very similar ratio of tooth to bone is also seen in a comparison of MNE and MNI derived from small dense bones (e.g. carpals, tarsals, patella), limb bones, and cheek teeth (Stiner, et al.1996:296).

Carnivore tooth marks on bear skeletal elements occurred at a different rate (10%) than it did on the rarer ungulate remains (19.7%) or even on those of carnivores (18%), suggesting that remains of these three mammal groups had followed divergent postmortem taphonomic pathways (Stiner, et al. 1996:302). The authors reported that tooth marks reflect larger-bodied carnivores, and that some tooth marks in trabecular bone (see Chap. 12) are clearly from wolf-sized canids. However, four young bear bones show even larger marks, possibly reflecting ursid-on-ursid cannibalism. Acid etching on both infant bear remains and those of other species, including hares, which were recovered in spatial association, most likely are fecal deposits from large canids, rather than hyenas, which do not pass such bone fragments through their digestive tracts. The authors argued that, because modern carnivores accumulate and gnaw remains of ungulates and of their ambushed carnivore competitors, the higher incidence of tooth marks on these elements implies that such carnivores as wolves and, possibly, hyenas used Yarimburgaz Cave as a den or resting locality.

Rodent-gnawed bone specimens show the inverse pattern, with bear metapodials and phalanges being more frequently and intensively gnawed by vole-sized animals than are those of other taxa. Stiner et al. noted that weathering is little advanced on any mammal bone elements, as expectable in a protected cave environment, and that disparate sample sizes confounded assessment of whether weathering rates for bear elements actually diverge from those of other species.

The age structures of the Yarimburgaz cave bears were assessed on the P^4, M^1, M^2, M_1, M_2, and M_3, using Stiner's ternary plot format, with frequencies of Juveniles, Prime Adults, and Old Adults plotted at each point (Chap. 22). Overall, these reflect a U-shaped mortality pattern, "entirely consistent with the hibernation scenario" (Stiner, et al. 1996:313).

Hominin-modified ungulate bones are very rare, but a few cut marks were documented. No burning was represented, nor can the sizes of the loading point notches unequivocally eliminate carnivore' static loading. The spatial distributions of ursid, ungulate, and non-ursid carnivore bones, plus stone artifacts, appeared to display no preferential clustering by class, which the authors attributed to a combination of very slow sedimentation rates and, probably, bear bedding behavior as a source of mixing (Stiner, et al. 1996:305). This impression was assessed using a Pearson's (r) correlation matrix. This showed no discernable difference in the samples with bear and lithic abundances above zero, in the association of bear remains with those of ungulates and carnivores, reflecting the general impressions of excavators. However, this statistical exploration produced an unexpected, mutually exclusive relationship between ungulate remains and lithics, provoking speculation that hominins using Yarimburgaz Cave were not necessarily exploiting large animal resources.

In sum, Stiner et al. used multiple lines of evidence to infer that the dominant process of assemblage accumulation and formation at Yarimburgaz involved hibernation deaths over many cohorts of cave bears, with intermittent predation and scavenging on them, as well as considerable bone attrition in place over time. Rodents gnawed bear remains in preference to elements from other species. Carnivores, probably wolves, used the cave occasionally as a shelter, carrying in parts of ungulate carcasses and those of other carnivores. Hominins, perhaps Neandertals, visited the cave and left stone artifacts, but the mammal bones do not testify to their intensive involvement with carcass acquisition.

17.1.5 What Created the Assemblage: Late Pleistocene and Early South American Caves

South America has seen its share of controversies over the meaning of cave deposits with human artifacts and animal bones, beginning with the early finds of now-extinct Pleistocene fauna associated with Paleoindian projectile points in Tierra del Fuego and Patagonia (Bird 1938). These debates only intensified with the advent of radiocarbon dating, which showed these sites to be 10,000–13,000 years old (Borrero and McEwan 1997). Since many of the earliest sites were in caves and rock shelters where carnivores and even giant sloths took refuge from the cold climate of the late Pleistocene and early Holocene in the puna and Patagonia, the same questions of behavioral association as arose with much earlier deposits in Africa and Eurasia emerged.

Zooarchaeological bone surface modification analysis has done much to reduce the ambiguities of some deposits. For example, cut marks have been discerned on the bones of the giant sloth *Mylodon* as well as on those of extinct horses at Fell's Cave and the cave site of Tres Arroyos, Tierra del Fuego (Mengoni Goñalons 1987). The bone-accumulating and crunching effects of a lion-sized jaguar, *Panthera onca mesembrina,* up to 30% larger than modern jaguars, are seen on large mammal bones from several Pleistocene caves that the species evidently used for dens (Martín 2008), including the famous Mílodon Cave, Chile.

However, in cases where caves contain evidence of both carnivores and humans, the problem remains of how to distinguish their respective influences in bone accumulation and modification, as well as how to compare sites. Mondini (2005) took an interesting approach to comparing two early Holocene cave sites in the dry Puna, or Altiplano, immediately east of the Andes. Paralleling the actualistic research of zooarchaeologists in Africa, researchers documented the behavior of living carnivores in their interactions with prey species, both as primary predators and as scavengers, and the outcomes of those interactions in terms of bone refuse accumulations and modifications (e.g. Borrero et al. 2005; Mondini 1995; Mondini and Muñoz 2008). In the drier zones of Holocene South America, the main carnivores are the puma, small cats, fox species of the genus *Pseudalopex,* and two mustelids that occasionally hunt small prey. Mondini notes that the archaeological record of the Puna seems to testify to more intensive human use of caves and rock shelters from the latest Pleistocene to early Holocene. Given its dry climate and relatively low productivity, both early immigrant humans and nonhuman carnivores in the Puna are expected to have existed in relatively low population levels, but caves and shelters would have been zones of spatial overlap in their activities. Today, foxes have become commensal with humans throughout the region, scavenging domestic camelids and caprines. However, Mondini stresses that, during these initial phases of Puna occupation by hunter-gatherers, one must explore, rather than assume, the relationships among humans and carnivores.

Mondini analyzed two excavated archaeofaunas dating to the early Holocene. Inca Cueva—cueva 4 (ICc4), is a cave in a gorge complex in the so-called Dry Puna of Jujuy Province, Argentina, which four radiocarbon dates place in the tenth-to-eleventh millennia BP. Pollen evidence from the deposits reflects a somewhat cooler, wetter climate than today's. Quebrada Seca 3 (QS3) is a rock shelter in a gorge in the Salt Puna of Catamarca Province, Argentina, with radiocarbon dates in the eighth-to-ninth millennia BP. Mondini restudied a QS3 faunal sample from a level dating eighth-to-ninth millennia BP. It is assumed from regional environmental evidence that a drying trend characterized this time span in the Puna.

Given that Puna carnivores differ in size and habits from those documented in the African and Eurasian actualistic literature, Mondini constructed expectations for carnivore-only assemblages from actualistic observations and analysis of five modern Puna carnivore shelter deposits where humans were not involved. She adapted Behrensmeyer's (1991) "taphogram" approach to codify and organize these data and to compare these with ICc4 and QS3. Behrensmeyer's approach calibrated various lines of evidence using a numeric scale of incidence (e.g. 0–25, 0–100) and with

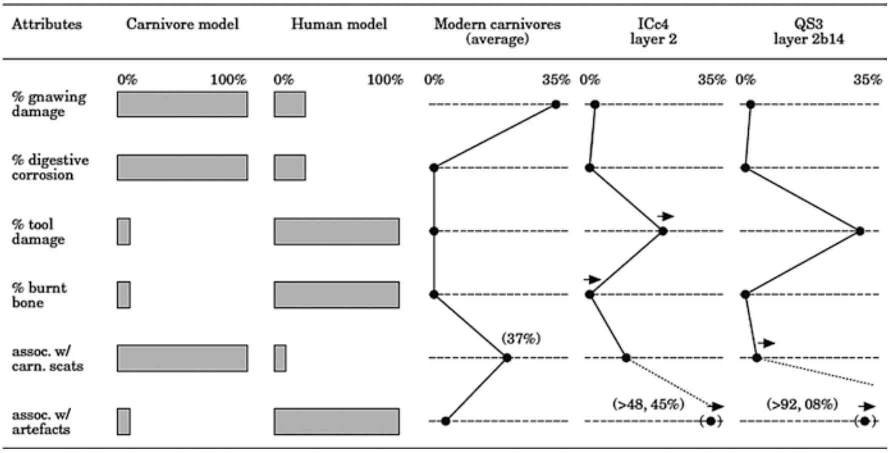

Fig. 17.1 Mondini's (2002:798, Fig. 2) adaptation of the Behrensmeyer "taphogram" approach to fossil deposits, showing average modern Puna carnivore bone deposits compared with ICc4 and QS3 cave and rock shelter archaeofaunas. (Used with permission of the N. M. Mondini and Elsevier)

ordinal rankings (e.g. "unabraded" through "highly abraded"). The multivariate values for a specific assemblage are then plotted along horizontal scales to describe the patterning of evidence in a given fossil assemblage and to compare that pattern with those of other assemblages.

Mondini used this method to make a simple, multivariate visual comparison of the average carnivore cave pattern versus those displayed by ICc4 and QS3 (Fig. 17.1). Clearly, the ancient assemblages differ from the average of carnivore assemblages. She then explored whether some of this difference could be attributed to post-discard, bone mineral density mediated attrition, as one might expect in archaeological deposits. Using Spearman's rank-order correlation coefficient, she determined that the frequencies of camelid bones in both archaeofaunas do not correlate significantly with their durabilities, a topic to be discussed in detail in Chap. 21. One of the most impressive outcomes of the analysis is how low the incidence of carnivore gnawing was in both the ICc4 and QS3 assemblages, especially given the scavenging of human trash she documented for modern carnivores in the Puna. Camelid bones in modern carnivore dens are heavily gnawed. From this, Mondini concluded that, while carnivores might have had a minor role in forming the archaeological deposits, "their incidence has not significantly affected the zooarchaeological record in terms of integrity – neither through modification and attrition, nor through addition" (Mondini 2005:799).

Finally, Mondini uses the two early Holocene deposits to comment on the possibility that these reflect a span during which local nonhuman carnivores were as yet adjusting to the entry of humans into their predator guild of the Puna. She suggests that, over the time since then, foxes especially have become more adept commensals, exploiting human habitations for their own benefit. While this speculation needs to be assessed with further archaeofaunal evidence associated with the Holocene, it provides an interesting contrast with Africa, from where so much actualistic information has been derived – and often generalized as "universal" – but where hyenas, canids, and humans had been coevolving over several millions of years.

17.2 Methods: Taking Effects of Prior Probabilities into Account

In the cases presented in this chapter, researchers have employed a number of statistical approaches to determine differences between and among samples in their own research. These investigations have compared diagnostic diaphysis breakage patterns, as did Marean et al. (2000, see also Fig. 11.9), assessed patterns of spatial association of bone modifications, taxa, and artifacts, as did Stiner et al., and checked how well bone durability predicted the frequencies of different skeletal elements and, by extension, how likely was post-discard attrition, as Mondini did. In each case, the use of statistical tests was straightforward, aimed at comparing datasets – either actualistic to archaeofaunal or among archaeofaunal samples.

None of these approaches used statistical analysis to characterize and compare assemblages as a whole. Behrensmeyer's 1991 taphogram approach took a step in that direction by employing a graphical method to describe paleontological assemblages using units of comparison with quantitative bases. This approach was also employed by Stiner (1992) with ordinal scale variables, such as abundances of various classes of prey, in a discussion that considered the effects of scales of time averaging on different faunal samples. More numerate readers may have realized that taphograms presented here could readily be converted into multivariate statistical analyses, although the analytic categories differ, some being interval and others ordinal (Chap. 18).

Not long after the taphogram approach was published in *Taphonomy: Releasing the Data Locked in the Fossil Record* (Allison and Briggs 1991), researchers in paleoecology and paleobiology began to engage in such multivariate statistical assemblage characterization studies. Behrensmeyer et al. (2000) summarized some earlier approaches in this area. Paleontological taphonomists take into account the critical question of how much time, and how much differential attrition based on size- and body part-durability that a fossil deposit encompasses ("time-averaging"). Zooarchaeologists, especially paleoanthropological researchers, may benefit from exploring paleontological assessments of the relationships among time scales in varied paleontological deposits, the "fidelity" of such deposits to the ecosystems from which they were derived, and, as a result, the appropriately scaled paleobiological research questions to ask. Their approaches include actualistically based, "forward modeling" of outcomes, with stipulated processes and ranges of outcomes.

Zooarchaeologists might also profitably explore the application of Bayesian statistical approaches to characterizing and comparing multi-agent accumulations. This approach was raised as an approach to the variability intrinsic to age estimation based upon developmental markers. Archaeologists are probably familiar with the application of Bayesian statistics to estimating the most likely age range from multiple radiocarbon dates. It is a widely used method in ecological studies, where it is deemed better able to assess outcomes of statistically operating causal processes in ecosystems (see Chap. 3). As noted in Chap. 7, Bayesian statistics differs from the probabilist statistics more familiar to most of us in its base assumptions and in its incorporation of "prior probabilities" of specific outcomes. Many variables studied by multi-agent accumulation analysts are statistically linked to an actor or a causal process. For example, the notches made by carnivores' static loading on diaphyses fall within a specific range of dimensions, while those produced by hominins' dynamic, hammerstone-aided loading fall in another, with an area of overlap (Chap. 12). This renders the inference of agency solely on the basis of notch size less than totally assured; however, some size ranges of notches are more or less likely to be linked to carnivore teeth versus hammerstones. Such "prior probabilities" of an identified causal effector can be assigned, and, taken together with other, actualistically derived probabilities, can point to the likelihood of specific actors being involved.

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