A NOTE ON THE TAPHONOMY OF LOWER MIOCENE FOSSIL LAND MAMMALS FROM THE MARINE CALVERT FORMATION AT THE POLLACK FARM SITE, DELAWARE[1]

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ABSTRACT

The lower shell bed (marine) of the portion of the Cheswold sands of the lower Calvert Formation exposed at the Pollack Farm Site (now covered) near Cheswold, Delaware, is unusually rich in the remains of land mammals. Two models could possibly explain the occurrence of terrestrial fossils within marine sediments: (1) post-mortem rafting of animal carcasses during floods, and (2) reworking of terrigenous bones following a marine transgression. Observations of the surface features of the mammalian bones suggest that the bones were exposed subaerially for a period of time before burial and that they were buried and permineralized prior to transport and abrasion. Carcass rafting is therefore unlikely, and reworking is the favored model of assemblage formation. Concentrations of fossil and subfossil land mammal bones in Georgia estuaries and on the Atlantic continental shelf provide possible analogs.

INTRODUCTION

Terrestrial mammals occur sporadically in Tertiary marine sediments of the Atlantic Coastal Plain in the eastern United States. Such occurrences are important from a biostratigraphic standpoint in that they form a link between terrestrial and marine biochronologies (Tedford and Hunter, 1984; Wright and Eshelman, 1987). They may also provide the only glimpses of land faunas in areas where terrestrial sediments are absent or unfossiliferous.

The exposures of the Miocene Chesapeake Group in Maryland have yielded 167 identifiable terrestrial mammal bones and teeth representing about 17 taxa in the more than 150 years that the area has been actively studied by paleontologists (Emry and Eshelman, 1998). The Pollack Farm borrow pit (now covered) near Cheswold, Delaware, was excavated in 1991–1992 and is particularly significant for the richness of the terrestrial component of its fauna. In the single year that the pit was open for collecting, it yielded over 200 identifiable specimens representing at least 26 species, making it the most diverse Tertiary land mammal assemblage in eastern North America north of Florida (Emry and Eshelman, 1998). The terrestrial mammal-bearing shelly sand at the Pollack Farm Site is interpreted on the basis of stratigraphic position and radiolarian and diatom biostratigraphy to be within the Cheswold sands (Delaware Geological Survey informal designation) of the lower Miocene Calvert Formation (Ramsey et al. 1992; Benson, 1993, 1998; Ramsey, 1998). The land mammal age assigned to the terrestrial fauna by Emry and Eshelman (1998), early Hemingfordian, is consistent with this interpretation.

Fossils come from the lower shell bed exposed at the site (see Benson, 1998, fig. 2). This unit is a medium- to coarse-grained shelly sand with densely-packed bivalve shells, interpreted to be a channel-fill deposit within an estuarine environment (Ramsey et al. 1992; Ramsey, 1998). Cross-bedding within the beds indicates a dominance of ebb-tidal currents (Ramsey, 1998). Ward (1998) interprets the molluscan assemblage as reflecting deposition in a deltaic environment where brackish-water and marine mollusks are mixed. Emry and Eshelman (1998) estimate the density of terrigenous material within the lower shell bed to be 50–60 mammal teeth per 1000 kg of matrix.

The unusual richness of the land mammal assemblage at the Pollack Farm Site inevitably raises the question of its formation. What accounts for the presence of the land mammals in marine sediments? Mixed terrestrial/marine assemblages are generally explained in one of two ways: (1) seaward transport of land animal remains (usually by rafting of carcasses during floods), and (2) reworking following a marine transgression. Horner (1979), for example, interpreted the occurrence of dinosaurs in marine sediments of the Upper Cretaceous of Montana and the Atlantic Coastal Plain to be the result of carcass rafting. Gallagher et al. (1989), on the other hand, interpreted the occurrence of fossil and subfossil land mammals on the Atlantic continental shelf to be the result of sea-level rise and reworking. Similarly, Frey et al. (1975) described mixed marine and terrestrial assemblages owing to reworking in Georgia estuaries. In a nearshore estuarine setting such as where the sediments of the Pollack Farm Site were deposited, either the carcass-rafting or reworking model is plausible.

This study is a preliminary analysis of the taphonomy of the land mammal remains at the Pollack Farm Site, with a special emphasis on resolving the question of whether the terrestrial remains were derived through carcass rafting or reworking. The two models have different implications for the relative ages of the marine and terrestrial fossils. If the terrestrial mammals were introduced into the marine environment by flotation as fresh carcasses, then they would be precisely the same age as the marine fossils. On the other hand, if they were mixed with the marine fossils by erosion and reworking of terrestrial sediments during a transgressive episode, then they would be somewhat older.

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MATERIALS AND METHODS

The fossil material from the Pollack Farm Site was collected over a period of approximately one year after the initial excavation of the pit for construction in 1991. The pit was subsequently filled and flooded, and the fossil-bearing units are no longer accessible for study. Most of the material was not collected *in situ*, but instead from spoil piles. See Emry and Eshelman (1998) for details of collection methods and personnel. The specimens available for this study consisted of approximately 50 bones and 70 teeth housed in the USNM collections. Most attention was paid to the bones, as opposed to the teeth, because they tend to show more features that were unambiguously post-mortem. The surfaces of all bones were examined under the binocular microscope (up to 50X).

RESULTS

With the exception of teeth preserved within jaw fragments, the terrigenous bone material from the Pollack Farm Site is entirely disarticulated and disassociated. The bones are primarily small, robust elements, such as metatarsals. Mandibles and long bones occur as fragments. Most bones and teeth are black, although several (e.g., USNM 475850) are brown. Black color is usually attributed to phosphatization, but the taphonomic significance of the color differences among the specimens is not known.

Nearly all bones show some evidence of abrasion. Projections and prominences on bones are rounded or chipped. Fracture surfaces and the edges of cracks on bones may also be rounded, indicating that abrasion took place after the breakage or cracking. Many abraded surfaces show a high, glossy polish.

Bone surfaces typically show fine patterns of cracks along the length of the bones, resembling Stage 1 of the bone weathering stages devised by Behrensmeyer (1978). These cracks are produced during exposure of the bones on the land surface after the removal of skin and soft tissues by scavengers and/or decay. Some bone surfaces show evidence of relatively advanced weathering. The surface of one carnivore jaw fragment (USNM 475811) is intermediate between Stages 3 and 4 (Figure 1); this represents several years of exposure on the land surface. One specimen, a scapholunar bone (USNM 475829), shows an unusual “mosaic” pattern of cracking in which fractures intersect to create an array of irregular polygons on the bone surface; it is not known what conditions lead to this pattern (Behrensmeyer, 1978).

Several bones show scratches and gouges that are interpreted here to be tooth marks (Figure 2). Most show the rounded cross section typical of mammalian carnivore tooth marks (Shipman, 1981) and may have corresponding marks on the opposite surfaces of the bone, as would be produced by occluding teeth. One bone shows sets of parallel striations that resemble gnaw marks made by rodents (Lyman, 1994).

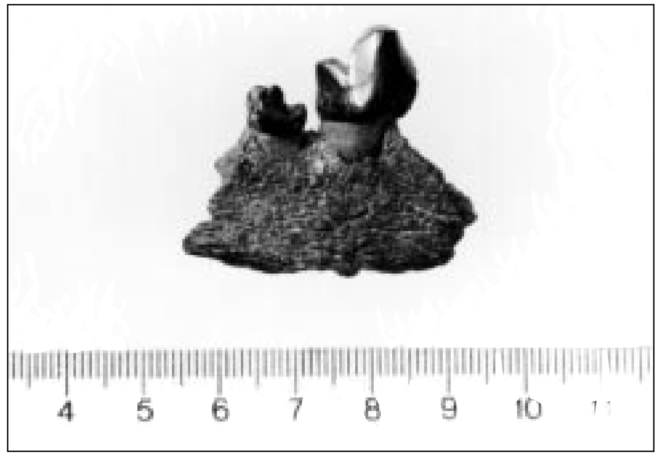

Figure 1. Weathered surface of carnivore jaw fragment (USNM 475811). Surface is intermediate between Weathering Stages 3 and 4 of Behrensmeyer (1978). Scale in mm.

Figure 2. Tooth marks on surface of a peccary calcaneum (USNM 494359). Scale in mm.

Other surface features common on the bones include patches of extremely fine dendritic etch marks visible only under the binocular microscope. The etchings were most likely produced by algal or fungal filaments that colonized exposed bone surfaces prior to burial. The etchings are primarily a surface feature, but where they are very dense they produce a pockmarked surface separated by plateaus of unetched surface. Etchings are most evident on concave surfaces and least evident on prominences. This pattern of distribution is at least partly due to removal of the etchings by abrasion. In some cases, however, etching occurs on top of abraded surfaces, so etching clearly postdates abrasion. The variable age relationships between etched and abraded surfaces suggests that episodes of etching and abrasion alternated with one another. This is reasonable given the shallow, subtidal environment of deposition: during periods of quiet water algae could grow freely on exposed surfaces, but during periods of agitation or transport algal growth would be inhibited and abrasion would predominate.

DISCUSSION

Although this analysis of the taphonomy of the Pollack Farm Site mammals is preliminary, the features observed here shed some light on the origin of the terrestrial mammal assemblage. One difference between the Pollack Farm assemblage and others interpreted to have been derived by carcass rafting (e.g., Horner, 1979) is that the remains here occur as entirely disassociated elements (with the exception of several teeth found within mandibles). Articulated or closely associated remains would argue strongly for carcass rafting, because reworked bones would lack the connective tissues necessary to hold them together. However, lack of articulation is not evidence against rafting, because rafted carcasses often shed body parts during transport (Shäfer, 1972). Also, given the high energy of the depositional environment (implied by the coarse grain size, cross-bedding, and disarticulated bivalve shells) articulation of the bones is unlikely in any case.

More informative are the surface features of the bones. The weathered and cracked surfaces and the carnivore and rodent tooth marks all imply that the bones lay exposed in a subaerial environment prior to being introduced into their final burial environment. This argues against rafting because these "naked" bones would lack the soft tissues necessary for flotation. Such a period of exposure, followed by burial, is, however, compatible with the reworking model. Evidence for a period of burial prior to abrasion is provided by the glossy polish seen on many of the abrasion surfaces. Abraded bone generally does not take on a particularly high polish unless it has been permineralized (A.K. Behrensmeyer, pers. comm., 1997). The Pollack Farm Site bones were therefore probably buried and permineralized before they were transported and abraded.

Considering all of the evidence from the bone surfaces, the following sequence of post-mortem events is implied: (1) scavenging of carcasses (indicated by tooth marks), (2) exposure of bones on land surface for up to several years (indicated by bone weathering), (3) burial and permineralization of bones (implied by gloss on abrasion surfaces), and (4) exhumation of bones followed by alternation between abrasion and algal(?) etching in an estuarine environment.

This sequence of events, involving a period of burial followed by reworking, implies that the terrigenous fossils are somewhat older than the marine fossils with which they occur. It is not possible to tell how much older they are, nor is it possible to infer at this point the geologic circumstances that led to the reworking of the bones and their admixture with the marine fossils. A geologically ephemeral coastal environment such as a barrier island may have supported a terrestrial fauna (Emry and Eshelman, 1998) but later was destroyed by erosion, leaving behind the terrigenous bones as a lag deposit. Frey et al. (1975) describe the occurrence of Pleistocene and older terrestrial bones within Holocene estuarine sediments in Georgia. They interpret these mixed deposits to be the result of erosion and reworking by estuarine channels. On the other hand, the reworking may have been caused by a sea-level rise and regional transgression. Gallagher et al. (1989) attribute the occurrence of Quaternary land mammals on the Atlantic continental shelf to coastal reworking during the post-Pleistocene sea-level rise. They recorded both glacial and interglacial terrestrial taxa from the shelf deposits off New Jersey. They also note that the bones (both terrigenous and marine) on the continental shelf tend to be spatially concentrated and mixed with estuarine to open marine invertebrates, an observation that suggests these reworked deposits may be good analogs for the rich bone-bearing beds at the Pollack Farm Site.

Gallagher et al. (1996) have also discussed the possibility that the terrestrial elements in Miocene mixed faunas of the Atlantic are reworked. They suggest that the preponderance of resistant elements suggests that the terrestrial remains were derived from upstream habitats and had experienced prolonged transport. An alternate explanation is that the abrasion occurred during marine reworking of the terrestrial deposits, and therefore did not necessarily involve significant transport. Further study of the dendritic etchings that appear to be penecontemporaneous with abrasion could shed some light on this question. If they can be attributed to marine algae that would imply that at least some of the abrasion occurred in a marine environment. This would not exclude the possibility of earlier freshwater abrasion, of course, but it would make it unnecessary to explain the condition of the bones.

The comparative condition of the marine mammal bones in the deposit are also relevant to this question because they obviously would not require transport to be incorporated in a marine deposit. Though the taphonomy of these bones has not yet been studied in detail, their abraded condition resembles that of the terrestrial mammals (D.J. Bohaska, pers. comm., 1997), suggesting that the abrasion of both assemblages was *in situ.*

CONCLUSIONS

The surface features of the terrigenous bones from the Pollack Farm Site indicate that the bones were not rafted to the estuarine environment of deposition as fresh carcasses, but rather were introduced into the estuarine deposits by reworking. Weathered bone surfaces and mammalian tooth marks on the bones both indicate that the bones were exposed for a period of time on the land surface before burial, and the high polish of some of the bone surfaces imply that they were buried and permineralized before they were abraded. The Pollack Farm bone assemblage may be analogous to the concentrations of Quaternary mammalian bones interpreted by Gallagher et al. (1989) to have been reworked by the post-Pleistocene sea level rise.

A great deal more remains to be done on the taphonomy of this rich deposit. Comparison of the taphonomy of the terrigenous mammals with that of the marine mammals, for example, should prove particularly enlightening.

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