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A TALE OF TWO SITES: A TAPHONOMIC COMPARISON OF TWO LATE TRIASSIC (CHINLE GROUP) VERTEBRATE FOSSIL LOCALITIES FROM NEW MEXICO

KATE E. ZEIGLER, ANDREW B. HECKERT and SPENCER G. LUCAS

New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, NM 87104-1375

Abstract—New Mexico Museum of Natural History (NMMNH) localities 3379-3381 are located on the western flank of the Lucero uplift in central New Mexico and are approximately 250 Ma old. The site, which is low in the Bluewater Creek Formation of the lower Chinle Group has produced an astonishing amount of fragmentary remains of *Rutiodon*-grade phytosaurs, large indeterminate metoposaurids, *Apachesaurus* sp., and indeterminate reptiles, archosaurs and the lungfish *Arganodus*. The fossils occur over a large area and are weathering out of fine-grained overbank deposits and in some instances occur in sandbars in shallow channel deposits. None of the fossils are articulated or associated. The bones themselves display stage 3 to stage 4 weathering with splintered ends and longitudinal cracks along the bone shafts, indicating that the animals were subaerially exposed to decay and weathering for a long period of time. Elements recovered include scutes, vertebrae, limb bones, fragmentary skull bones and a large number of phytosaur teeth.

In direct contrast to L-3380 is the younger Snyder quarry (NMMNH L-3845), located in north-central New Mexico. The Snyder quarry is in the Petrified Forest Formation of the Chinle (Revueltian – Norian age) and is approximately 210 Ma old. Thousands of bones have been excavated from this quarry, including the remains of phytosaurs, aetosaurs and coelophysoid dinosaurs. The bones were deposited in a wide, shallow channel and are in excellent condition with essentially no evidence of either weathering or scavenging. The skeletal elements are associated or rarely articulated. These two localities provide an opportunity to contrast two very different taphonomic settings. The Snyder quarry represents a catastrophic event, most likely a forest fire, whereas NMMNH L-3380 represents an attritional accumulation of corpses on a floodplain.

Keywords: Taphonomy, Chinle Group, New Mexico, Triassic, tetrapod, catastrophic, attritional

INTRODUCTION

The Chinle Group of New Mexico is renowned for its rich fossil horizons, which include a number of famous bonebeds (Hunt and Lucas, 1989). Most of the well-known sites are large bonebeds dominated by a single taxon; for example, the *Coelophysis* quarry at Ghost Ranch (Colbert, 1989; Schwartz and Gillette, 1994), the phytosaur-dominated Canjilon quarry (Ballew, 1985; Hunt and Downs, 2002; Zeigler et al., 2002) and the amphibian (*Buettneria*) quarry near Lamy (Romer, 1939; Zeigler et al., 2002). There are other localities that produce just as large an amount of fossil material, but differ significantly from these bonebeds in their manner of formation. To date, taphonomic studies have only touched on a few of these localities (e.g., the *Placerias* quarry, Fiorillo et al, 2000). Here, we compare two rich Late Triassic vertebrate fossil localities in New Mexico that are significantly different in terms of their taphonomic mode.

NMMNH LOCALITIES 3379-3381 – THE LUCERO SITE

NMMNH localities 3379-3381, which occur at a single horizon, are located in the Lucero uplift, southwest of the city of Albuquerque, in central New Mexico (Fig. 1). The site is stratigraphically low in the Bluewater Creek Formation of the lower Chinle Group (Fig. 2) (Heckert et al., 1998; Heckert, 1999). Thus, the site is of Adamanian (latest Carnian) age (~228 Ma) (Lucas and Heckert, 1994).

Robert Dello-Russo discovered these localities in 1996 while surveying a right-of-way for cultural resources. These sites have produced over 240 kg of fossil material that consists mostly of

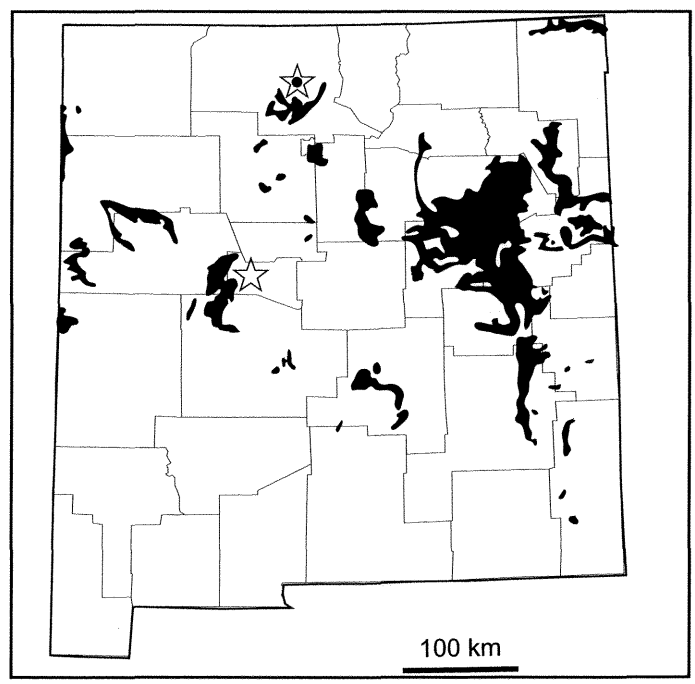

FIGURE 1. Distribution of Triassic strata in New Mexico. Open star = Lucero uplift localities, NMMNH L-3379-3381. Star with filled circle = Snyder quarry, NMMNH L-3845.

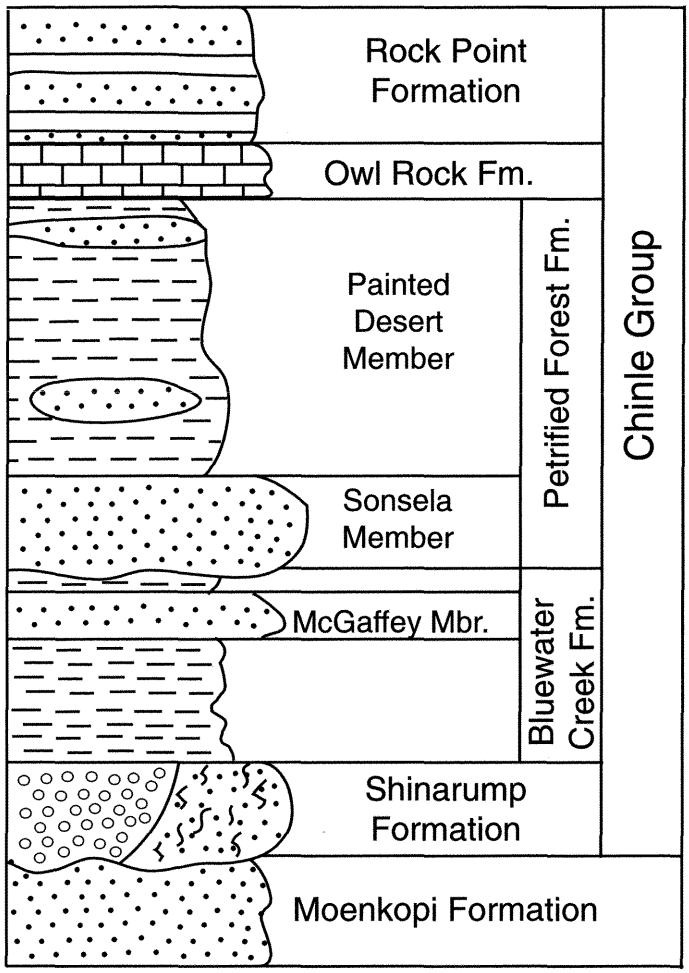

FIGURE 2. Representative stratigraphic column for the Lucero uplift localities (L-3379-3381). All thicknesses are schematic.

isolated and fragmented teeth, limb bones, vertebrae, scutes, and skull material from a moderately diverse fauna of Late Triassic reptiles, amphibians and fish. The fauna includes fragmentary remains of phytosaurs, metoposaurids, various archosaurian reptiles, and lungfish (Heckert, 1999). The phytosaurs are known mostly from more than 200 teeth and numerous vertebrae and scute fragments. Given the poor preservation of the fossils, we cannot identify the phytosaurs beyond the genus level, although strata of this age typically yield "*Rutiodon*-grade" phytosaurs. The metoposaurid fossils consist mostly of skull fragments with their distinct waffle-pattern pitting and a large, incomplete interclavicle excavated in the summer of 2000. The lungfish are known from isolated tooth plates, and the remaining archosaurian reptiles from a variety of small bones and vertebrae. This locality is also very rich in coprolites (Heckert, 1999). The fossils are unevenly distributed in patches over nearly 1000 m^2 and occur predominantly in reddish-brown silty bentonitic mudstones. Patches of fossil material also occur along the edges of buff, poorly indurated silty sandstones with lateral accretion sets.

Taphonomic Analysis

Sedimentological Data

The sediments at the Lucero locality consist of reddish-brown silty mudstones with intermittent lenses of buff sandy siltstone that contain well-developed cross-laminations and planar crossbeds. Therefore, we interpret the mudstones as floodplain sediments located near a channel that is represented by the siltstones, which we interpret as bar deposits. The majority of Chinle mudstones have been interpreted as floodplain deposits (Blakey and Gubitosa, 1984; Kraus and Middleton, 1987; Newell, 1993) and in general, the Chinle Group is considered to be predominantly fluvial in origin (Stewart et al., 1972; Dubiel, 1989).

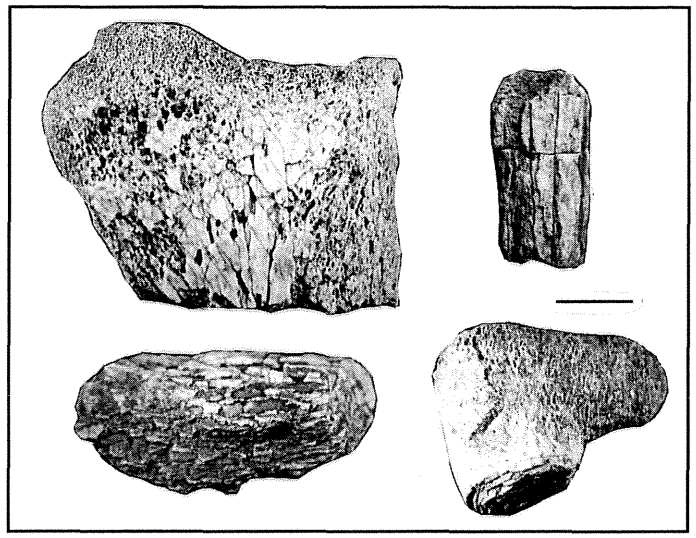

FIGURE 3. Bone material from L-3379-3381, showing Behrensmeyer's (1978) "moderately weathered" fossil weathering stage. Scale bar = 1 cm.

Though no bone orientations were measured, there is no obvious preferred orientation of long bones. Indeed, the bone material occurs in moderately dense patches over an area of nearly 1000 m^2 with no apparent pattern to the distribution. There is no hydrodynamic sorting of the material. The vast majority of material is highly fragmentary, with the pieces generally being smaller than 10 cm^2 across their largest dimension. Also, while the bones are fragmentary, there is little, if any, evidence of abrasion, as might be expected with material that had been fluvially transported (Shipman, 1981).

Biological Data

None of the bone material from the Lucero site is articulated, or even clearly associated. We have not observed scavenge marks on any of the bones. The few longer elements present, such as ribs, show post-burial fracture patterns: breaks that are perpendicular to the long axis of the bone, rather than spiraled as would be expected for breakage in a fresh bone (Shipman, 1981; Fiorillo et al., 2000).

The bone material also shows different degrees of weathering (Fig. 3), as might be expected for material that has been left to decay without protection from the elements (Behrensmeyer, 1978). Limb shaft fragments exhibit the "moderately weathered stage" described by Behrensmeyer (1978) , which corresponds to modern stage 2 to stage 4 weathering. We could not calculate minimum numbers of individuals (MNIs), nor could we construct an age or size profile for any of the taxa present; the extremely fragmentary nature of the material precludes such analyses.

NMMNH Locality 3845 – The Snyder Quarry

NMMNH locality 3845 is located in the Chama basin in north-central New Mexico (Figs. 1, 4) near Ghost Ranch (Heckert et al., 1999, 2000) and is stratigraphically equivalent to the Canjilon quarry (Hunt and Lucas, 1993). Thus far, 64 jackets of sediment and fossil material have been collected from this locality, as well as hundreds of isolated elements. Fossil material at this site con-

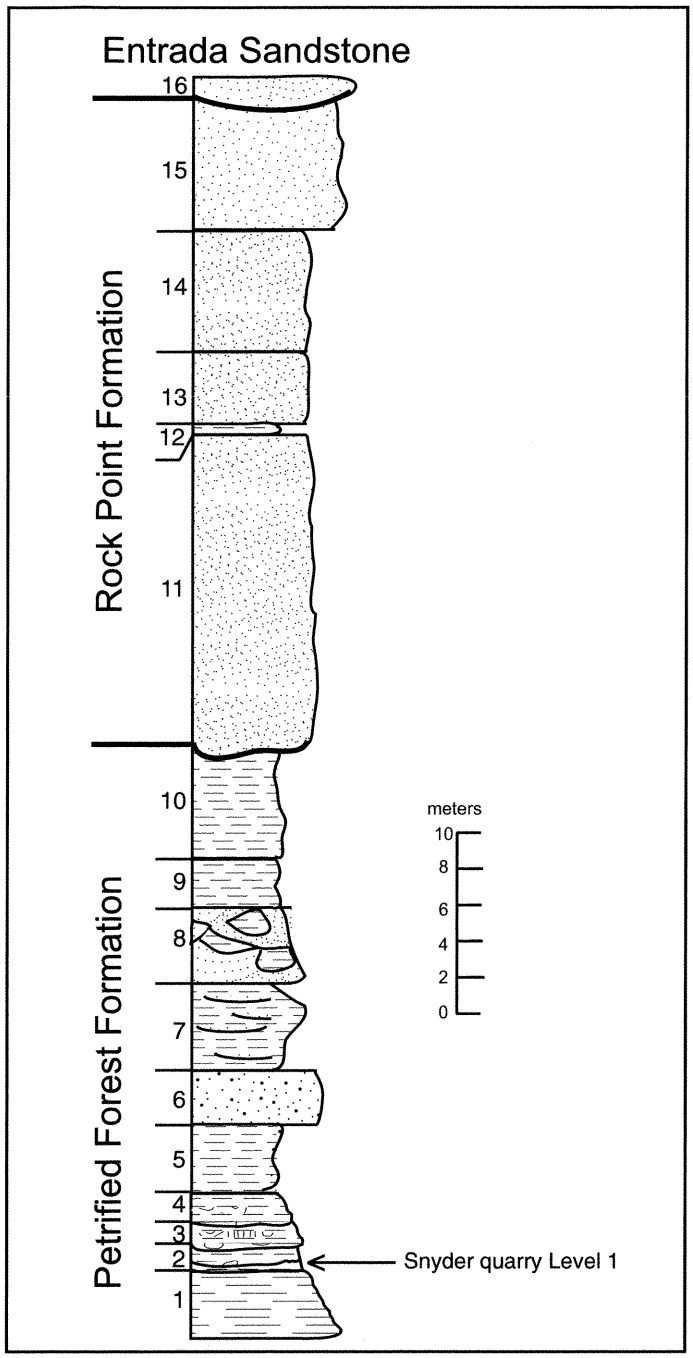

FIGURE 4. Stratigraphic column for the Snyder quarry (L-3845).

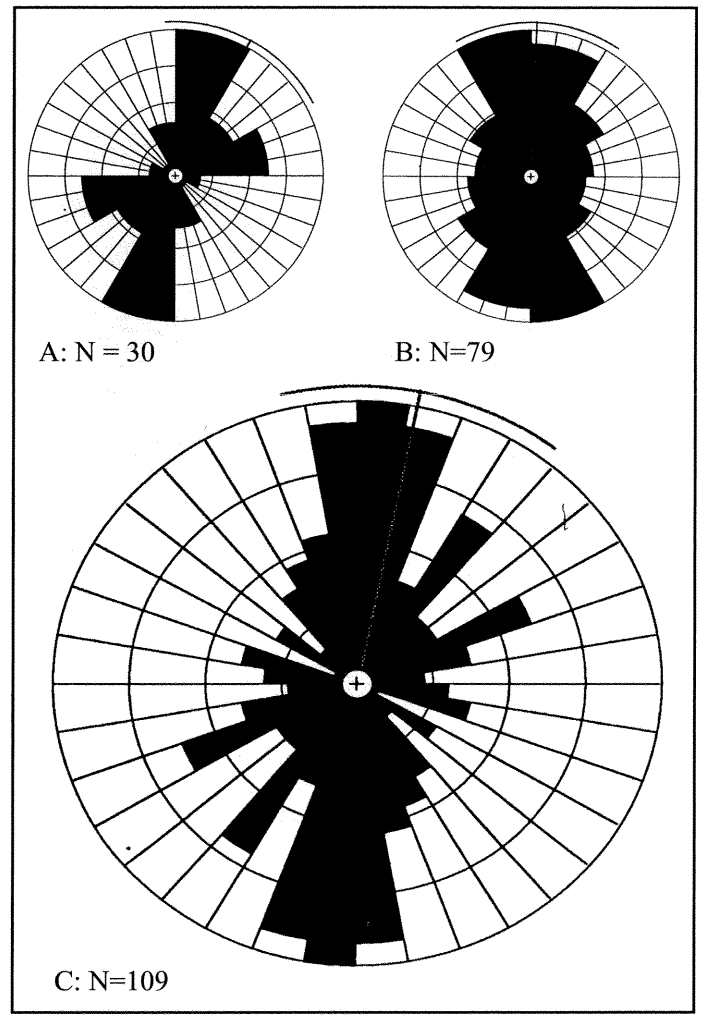

FIGURE 5. Rose diagrams indicating paleocurrent directions as measured on bone and wood material in the Snyder quarry. **A**, Wood data; **B**, Bone data; **C**, Bone and wood data combined.

sists of large numbers of scutes, limb bones, ribs, vertebrae, girdle elements, teeth, and even skulls from a variety of animals. We have identified a diverse fauna that ranges from crustaceans to phytosaurs (Heckert et al., 1999, 2000; Zeigler et al., 2000a,b). The vertebrate taxa consist of the phytosaur *Pseudopalatus*, the aetosaurs *Typothorax coccinarum* and the new species *Desmatosuchus chamaensis* (Zeigler et al., 2002b), the primitive theropod *Eucoelophysis baldwini* (Heckert et al., 2000), metoposaurs, semionotid fish, xenacanthid sharks and procolophonid reptiles. The invertebrate fauna of this quarry includes decapod crustaceans, unionid bivalves and conchostracans. There is also a significant amount of charcoalized wood and carbonized plant frond material present.

This locality is stratigraphically high in the Petrified Forest Formation of the Chinle Group (Fig. 4). It is of Revueltian (early to mid- Norian) age (~210 Ma) (Heckert et al., 1999, 2000). At L-3845, the fossil material occurs primarily as a nearly continuous thin sheet deposit over at least 50 m^2, though the site has not been fully excavated. Thousands of individual bones have been recovered from this horizon in four seasons of excavation. There are two slightly higher horizons of bone material, approximately 1.5 and 3 m above the original quarry horizon. All three horizons are intraformational conglomerates consisting of quartz granules and mud pebbles, that may represent shallow paleochannels. These channel deposits are interstratified with overbank and lacustrine deposits.

Taphonomic Analysis

Sedimentological Data

The most fossiliferous horizon of the Snyder quarry is an intraformational conglomerate containing mud rip-up clasts that are fine-grained silty mudstones from the underlying mudstone unit. We interpret this as a low sinuosity channel developed on finer-grained floodplain deposits. The conglomerate clasts are clearly cannibalized from the underlying floodplain deposits in much the same fashion as documented elsewhere in the Chinle by Kraus and Middleton (1987). The orientation of bones and wood in the main horizon reveals a very strong preferred orientation to the north-northeast (Fig. 5). This horizon has an average

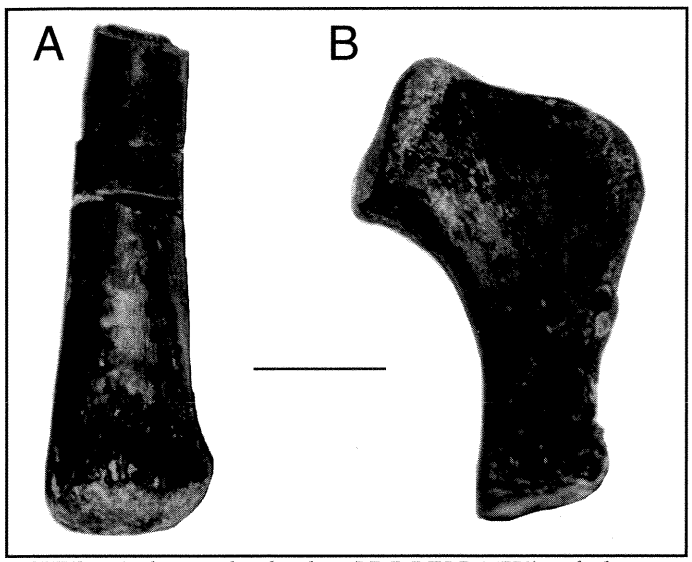

FIGURE 6. Archosaur distal radius (NMMNH P-34750) and phytosaur metatarsal V (NMMNH P-34728) from the Snyder quarry, showing weathering stage 0 (Behrensmeyer, 1978).

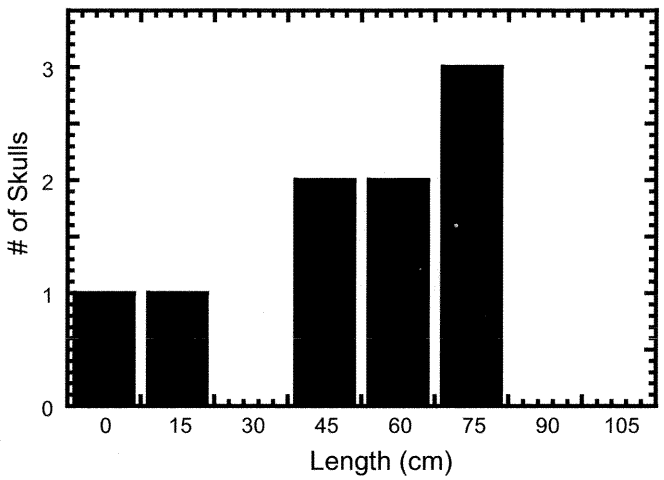

FIGURE 7. Age histogram for the Snyder quarry phytosaur sample population.

bone density of 16 bones/m^2, and a range of 1 bone/m^2 to 67 bones/m^2 (only bones with a length of greater than or equal to 5 cm were counted).

The material in the quarry is hydrodynamically sorted, with the majority of the material falling into Voorhies Group 1 (high surface area to volume ratio), indicating a moderate degree of fluvial transport by a low velocity current (Voorhies, 1969), though this is probably not indicative of the complete flow regime for the transporting current. There is no evidence of abrasion on the bones, as might be expected with a significant length of time or distance of transport (Shipman, 1981). Indeed, the presence of a significant amount of charcoal, which is buoyant, in the deposit, is evidence for a short duration of transport (Nichols et al., 2000).

Biological Data

The skeletal material in the Snyder quarry is associated, with rare instances of partial articulation, indicating that the animals were in a state of partial decay immediately prior to being transported and deposited (Munthe and McLeod, 1975; Hill, 1979). The state of preservation of the skeletal elements is excellent, and very few specimens show signs of scavenging by vertebrate predators. The bones are mostly complete, though fractured perpendicular to the long axis of the shafts, which indicates that the material was buried and fossilized prior to the breakage taking place (Shipman, 1981; Fiorillo et al., 2000). The fossil material also shows no signs of weathering, falling into the modern stage 0-1 categories (Behrensmeyer, 1978) (Fig. 6).

MNIs for the taxa were calculated, revealing the presence of at least four theropods, two *Typothorax*, a *Desmatosuchus*, 10 phytosaurs, a metoposaurid amphibian, a procolophonid reptile, three osteichthyan fish (redfieldiid, semionotid and colobodontid), a xenacanth shark, a decapod crustacean, a conchostracan, and 16 unionid bivalves. An age profile was constructed for the phytosaurs because the MNI is based on 10 skulls recovered from the quarry during four years of excavations. The age profile reveals a high percentage of subadult or young adult animals (Fig. 7), which is unusual, given that these individuals are usually the strongest members of the community (Voorhies, 1969; Holz and Barberena, 1994; Therrien and Fastovsky, 2000).

The charcoal from the quarry was examined using both scanning electron microscopy (SEM) and reflectance microscopy. The SEM images show that the internal cellular structure of the charcoal has changed dramatically in comparison to unburned wood. The middle lamellae of the cell walls have been homogenized (Fig. 8), a condition that occurs at temperatures between 280 and 320 °C (Cope, 1980; Jones and Chaloner, 1991; Scott, 2000). The reflectance data show that the reflective index is much higher than the average values for other forms of coal (Scott, 1989; Jones and Chaloner, 1991; Scott and Jones, 1991; A.C. Scott, pers. comm.), with an average reflectance value that corresponds to an approximate temperature of 400 °C (Jones et al., 1991). These two lines of evidence indicate that the wood in the quarry has been burned in a medium temperature ground fire that ranged in temperature from approximately 300 ° to 400 °C.

COMPARISON

Taphonomy is the study of all of the processes that affect an organism between the moment it dies and its discovery, as well as the processes that can remove it from the rock record (Efremov, 1940; Munthe and McLeod, 1975) . There are two taphonomic endmembers: attritional and catastrophic. An attritional fossil assemblage reflects a gradual accumulation of corpses in an area over time (Behrensmeyer, 1982; Holz and Barberena, 1994). These assemblages are often fragmentary, time-averaged, and the individuals present represent those members of a population that are more susceptible to predation or disease (Voorhies, 1969; Holz and Barberena, 1994). Thus, in an age profile, these deposits will be dominated by the very young and very old members of a given community.

In contrast to the attritional assemblage, the catastrophic assemblage is an instant snapshot of an entire population that was killed all at once (Wilson, 1988). In these deposits, all members of a population are present, including the stronger subadults and young adults. In many cases, the material is not transported very far and is in an excellent state of preservation if it has been buried quickly. However, there may still be signs of moderate weathering, some abrasion if the material was transported, as well as scavenging, depending upon the event.

NMMNH localities 3379-3381 are an example of an attritional assemblage. This site represents many animals dying for a variety of reasons over the course of months or years over a wide area on a floodplain relatively near a channel system. The

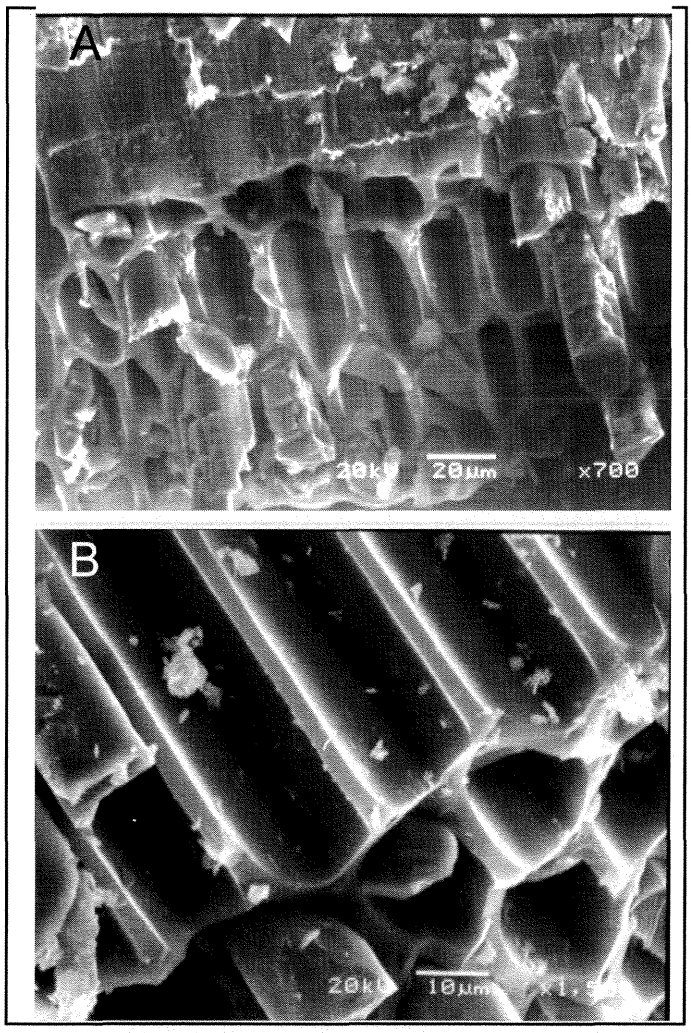

FIGURE 8. Scanning electron microphotographs of charcoal fragments from the Snyder quarry (NNMNH P-34885).

fine-grained sediments indicate a floodplain environment and because there is no orientation nor any degree of hydrodynamic sorting of the material, there was no significant degree of fluvial transport. There is no direct evidence of any particular age of animal or taxon dominating the assemblage due to the fragmentary nature of the remains. The lack of association or articulation and the advanced weathering stages seen in these fossils indicates that these animals died, began to decompose, and were probably scavenged and scattered about the floodplain prior to burial

As an example of the other taphonomic end-member, NMMNH locality 3845 represents a population of animals that were killed over a much shorter time interval, possibly all at once. The sediments are very coarse-grained and contain material scoured out from the underlying floodplain deposits, indicating a very powerful flow of water. The bones and wood are aligned and show a moderate degree of hydraulic sorting, but minimal abrasion. These data are evidence of a moderate degree of transport by a strong current. The skeletal material is associated, but with no signs of scavenging, indicating a rapid burial shortly after the corpses began to decay. The quarry population is dominated by subadult phytosaurs, the strongest members of the phytosaur population, indicating that a catastrophic mortality event took place.

The relatively unique state of preservation of the wood as charcoal indicates that a moderate temperature ground fire swept through the area. This wildfire was most likely the event that killed the animals represented by the fossil material in the quarry. In the months to years after a major fire, run-off and erosion rates in the affected watershed are substantially higher than in a normal year (Nichols et al., 2000). Thus, the evidence for a powerful current of water moving the fossil material correlates well with the data from the charcoal to suggest a wildfire as the mortality event.

CONCLUSION

These two localities serve as excellent examples of the two taphonomic end members: the attritional accumulation represented by L-3379-3381 and the catastrophic event by L-3845. The two sites share some similarities: they are close in age and they contain similar taxa. Both represent broadly similar paleoenvironments as well: a fluvial system with floodplain deposits. Yet, the two sites are exactly opposite in their taphonomic mode. The material in L-3379-3381 is derived from all of the inhabitants of a floodplain environment over an undefined interval of time. L-3845 is the result of a single catastrophic mortality event, a Late Triassic wildfire. These two localities thus provide an opportunity to examine the extremes of taphonomic processes.

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