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Justin A. Spielmann, Randy Pence, and Spencer G. Lucas
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A NEARSHORE VERTEBRATE ASSEMBLAGE FROM THE LATE CRETACEOUS (TURONIAN) ATARQUE SANDSTONE, SOCORRO COUNTY, NEW MEXICO

JUSTIN A. SPIELMANN, RANDY PENCE, AND SPENCER G. LUCAS
New Mexico Museum of Natural History and Science, 1801 Mountain Rd NW, Albuquerque, NM 87104

Abstract—We have relocated and recollected the fossil vertebrate locality in the Upper Cretaceous (Turonian) Atarque Sandstone on the Sevilleta National Wildlife Refuge first documented by Baker and Wolberg in the 1980s. The locality (now NMMNH L-5153) yields numerous teeth and bone fragments from a localized, 0.7-m-thick intrabasinal ferruginous conglomerate composed of limestone, tooth, bone, bivalve shell and chert pebbles in a section of fine-grained sandstone near the top of the Atarque Sandstone. Virtually all of the teeth and bones from this bed were broken prior to fossilization, and based on the lithology of the bonebed and fossil preservation, we interpret this fossil site as an allochthonous assemblage in a storm deposit. The following selachian taxa were previously known to be present in this assemblage: *Hybodus* sp., *Ptychodus whipplei*, *P.* cf. *P. mammillaris*, *Chiloscyllium greeni*, *Scapanorhynchus raphiodon*, *Cretodus semiplicatus*, cf. *Paranomodon* sp., *Squalicorax falcatus*, *Rhinobatos* sp., *Pseudohypolophus mcnultyi*, *Ischyrhiza schneideri* and *Ptychotrygon triangularis*. Our collection duplicates many of the selachian taxa previously known from this assemblage, and also includes numerous teleost teeth, especially of pycnodonts assigned to aff. *Coelodus* and *Micropycnodon* cf. *M. kansasensis*. Freshwater turtle shell fragments and a dromaeosaur tooth are also present, indicating a freshwater/terrestrial component to the assemblage. *Scapanorhynchus* dominates the assemblage, and the sedimentology, terrestrial taxa, assemblage diversity and rarity of *Ptychodus* suggest a nearshore association.

INTRODUCTION

Numerous marine fossil vertebrate localities are known from the Upper Cretaceous strata of New Mexico, notably concentrations of bone fragments and teeth, which were deposited in and along the margins of the Western Interior Seaway. These localities are generally selachian-dominated and contain a wide diversity of taxa. Here, we document additions to the fauna of a previously recognized locality (NMMNH [New Mexico Museum of Natural History] locality 5153) in the Atarque Sandstone, Socorro County, New Mexico, and discuss the paleoecology and depositional environment of the fossil site.

NMMNH L-5153 is in a 0.7-m-thick, localized, intrabasinal, ferruginous conglomerate of limestone, tooth, bone, bivalve shell and chert pebbles in a section of fine-grained sandstone near the top of the Atarque Sandstone (Fig. 1). The locality is on the Sevilleta National Wildlife Refuge, north of Palo Duro Canyon, Socorro County, NM. Exact locality data are stored in the NMMNH database. Specimens were collected as bulk matrix then processed chemically, using buffered acetic acid, and prepared mechanically at the NMMNH.

PREVIOUS STUDIES

Baker (1981) discovered and noted NMMNH locality 5153 in an unpublished Master's thesis. He listed a diverse shark assemblage, with additional bone fragments including "turtle carapace fragments, crocodilian teeth, fragments of dinosaur teeth and vertebrae, skate fragments, and freshwater gar-like teeth and vertebrae" (Baker, 1981, p. 24, appendix C).

Wolberg (1985a, b) first published NMMNH locality 5153, describing the extensive selachian-dominated fauna. Unfortunately, the specimens he described and illustrated have apparently been lost and thus are unavailable for restudy. Thus, the material we summarize and illustrate below are voucher specimens for this locality and are reposited in the NMMNH collection. Wolberg (1985a, b) described and illustrated the following taxa (using his original identifications): *Hybodus* sp., *Ptychodus whipplei*, *P. anonymus*, *P. polygyrus*, *Squalicorax falcatus*, *Cretolamna appendiculata*, *C. simplicatus*, *Chiloscyllium greeni*, *Scapanorhynchus raphiodon*, *Anomotodon* sp., *Odontaspis parvidens*, *O. marcota*, *Plicatolamna arcuata*, *Paranomotodon* sp., *Rhinobatos* sp., *Ischyrhiza avonicola*, *I. mira*, *Ptychotrygon triangularis* and ?*Rhombodus* sp.

Williamson et al. (1993) re-evaluated many of Wolberg's (1985a, b) identifications, based on Wolberg's illustrated specimens, and modified the list of selachian taxa accordingly, resulting in less diversity than originally reported. This list of selachian taxa from NMMNH locality 5153 of Williamson et al. (1993) was incorporated into our faunal list (Table 1).

VERTEBRATE FAUNA

All of the vertebrate specimens collected from NMMNH locality 5153 exhibit various degrees of abrasion or damage, as noted below. Indeed, complete teeth are rare from the locality (Fig. 2), and only one specimen consists of associated teeth (NMMNH P-58064, Fig. 2Z). The abrasion and damage to the specimens is likely due to the high-energy depositional environment of the fossil-bearing bed. This vertebrate fossil assemblage can be divided into three components: chondrichthyans, osteichthyans and reptiles. Each component is discussed below separately based primarily on specimens at the NMMNH.

Chondrichthyans

Chondrichthyan remains are abundant at the site, with selachian teeth comprising the vast majority of the vertebrate fossils.

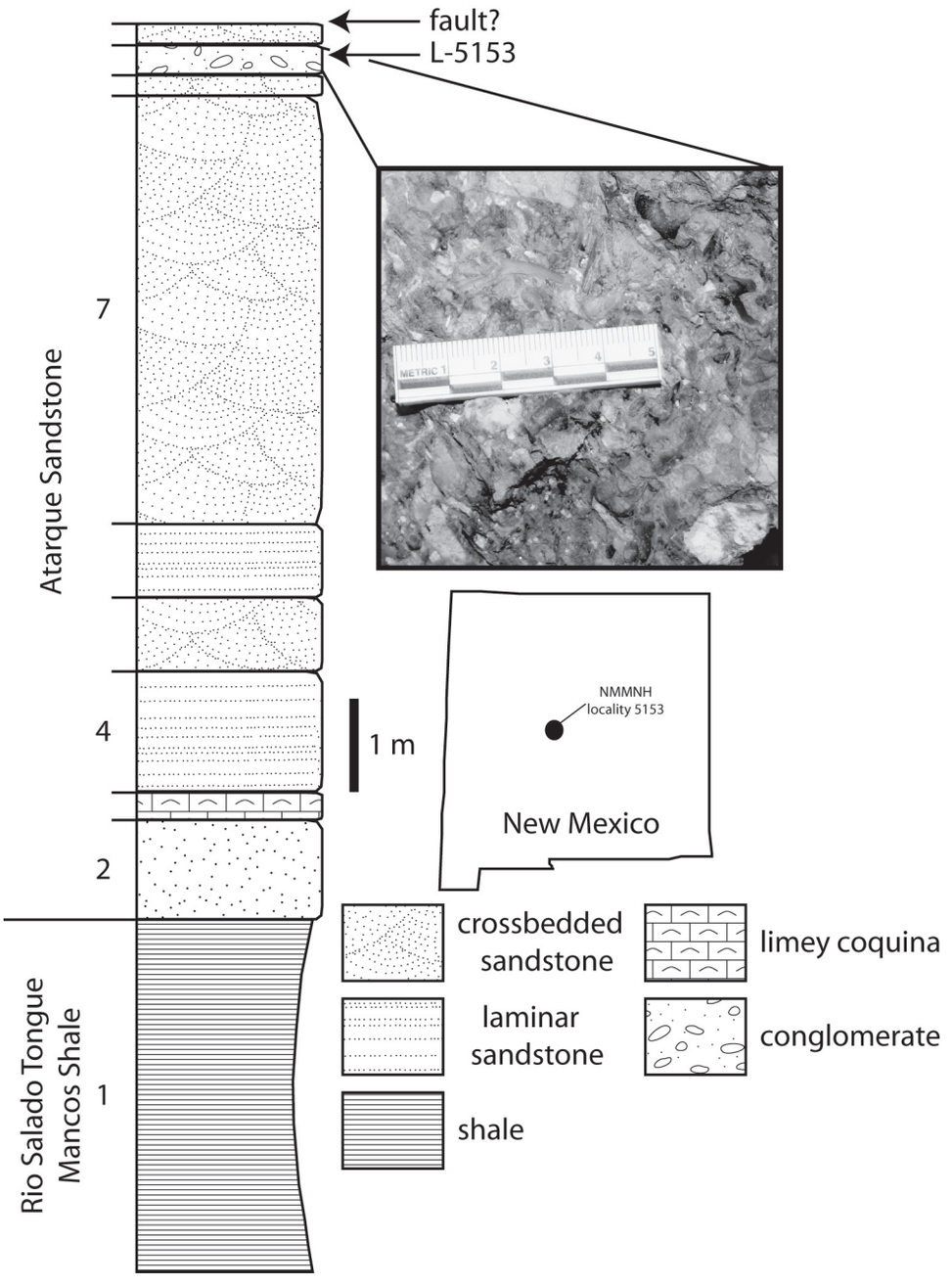

FIGURE 1. Stratigraphic section and index map showing NMMNH locality 5153 in the Atarque Sandstone of Socorro County. Inset picture of lithology of bone-bearing conglomerate at the locality; note the abundance of selachian teeth.

The following chondrichthyan taxa are now recognized from the site: Odontaspidae indet., cf. *Leptostyrax* sp., *Scapanorhynchus raphiodon*, *Cretodus semplicatus*, *Cretolamna appendiculata*, *Squalicorax falcatus*, *Ischyrhiza mira* and *Ptychotrygon triangularis*.

Indeterminate chondricthyan vertebral centra are rare from the locality, compared to the abundance of teeth (NMMNH P-58046, Fig. 2A-B). These vertebrae are elliptical, thin and are not identifiable to family-level. Their morphology is similar to that of lamniform sharks (e.g., Lucas et al., 1985; Blanco-Piñón et al., 2005).

Odontapsids are represented by incomplete teeth preserving only the main crown, without accessory cusplets (NMMNH P-58047 through P-58049, Fig. 2C-F). The presence of a lingual dental band and the sigmoid cusp profile identify these incomplete teeth as odontaspid, though the lack of cusplets and the incomplete roots prevent genus- or species-level identification. Large teeth have a crown height over 11 mm, and thus are larger than any of the odontaspid taxa reported by Welton and Farish (1993).

Teeth with triangular crowns and coarse striations, on both their labial and lingual sides, are assigned to cf. *Leptostyrax* sp.

TABLE 1. List of vertebrate taxa from NMMNH L-5153. Selachians from the list of Williamson et al. (1993, appendix, column 5). Taxa highlighted in light gray are marine taxa discussed in the text, whereas taxa highlighted in dark gray are terrestrial taxa discussed in the text.

Chondrichthyes

- Chondrichthyes indet.
- *Hybodus* sp.
- *Ptychodus* cf. *P. mammillaris*
- *P. whipplei*
- *Chiloscyllium greeni*
- Odontaspidae indet.
- cf. *Leptostyrax*
- *Scapanorhynchus raphiodon*
- *Cretodus semiplicatus*
- *Cretolamna appendiculata*
- cf. *Paranomotodon* sp.
- *Squalicorax falcatus*
- *Rhinobatos* sp.
- *Pseudohypolophus mcnultyi*
- *Ischyrhiza mira*
- *Ischyrhiza schneideri*
- *Ptychotrygon triangularis*

Osteichthyes

- Teleostei indet.
- "Teleost B"
- aff. *Coelodus*
- *Micropycnodon* cf. *M. kansasensis*

Reptilia

- Testudines indet.
- Dromaeosauridae indet.

(NMMNH P-58050, Fig. 2G-H). Given that *Leptostyrax* is diagnosed primarily by its root morphology, a definitive identification of our material is not possible. It should be noted that Williamson et al. (1993) illustrated similar teeth from roughly contemporaneous strata in northeastern Arizona as cf. *Leptostyrax* sp., though the coarse striations on the crown are more prominent in their material.

Teeth of *Scapanorhynchus raphiodon* are the most abundant (>90%) vertebrate fossils in the assemblage (NMMNH P-58051 through P-58054, Fig. 2I-L). As with many of the teeth in the assemblage, they are primarily isolated crowns (Fig. 2I-K), with specimens preserving portions of the root (Fig. 2L) being much less common. The high, narrow cusp and longitudinal striations extending almost to the apex of the crown identify the material as *Scapanorhynchus*, and the faint longitudinal striations are diagnostic of *S. raphiodon* (Welton and Farish, 1993).

Specimens of *Cretodus semiplicatus* are missing most of their crowns and preserve only their roots, cusplets and crown feet (NMMNH P-58055, Fig. 2M). Continunity of the cusplets with the root identify the specimens as *Cretodus*, and the relatively small size, strong longitudinal ridges on the crown foot and centralized lingual protuberance restrict this material to *C. semiplicatus*.

Teeth of *Cretolamna appendiculata* are incomplete, with only the crown, cusplets and small portions of the roots preserved (NMMNH P-58056 and P-58057, Fig. 2N-O). These specimens have smooth crowns and broad triangular cusplets, which identify them as *Cretolamna*, and their small size distinguishes them from *C. woodwardi*, with its distinctively more robust teeth. However, it is worth noting that the cusplets of our material are directed towards (Fig. 2N) or parallel to (Fig. 2O) the crown, which differs from all of the *Cretolamna* specimens illustrated by Welton and Farish (1993), which have cusplets directed away (either mesially or distally) from the crown. This difference in morphology may represent variability within the tooth row.

Squalicorax falcatus is represented in the assemblage by essentially complete teeth with distinctly weak serrations (NMMNH P-58058, Fig. 2P). The teeth are weakly convex, with a high crown and an anaulacorhizous root, thus identifying them as *S. falcatus*. Weakly serrated specimens of *Squalicorax* have been diagnosed by Shimada (2008) as *S. microserratodon*. However, compared to our specimens, the teeth of *S. microserratodon* are much smaller and have a backswept main cusp, with lower crown heights and a lesser angle between the distal cutting surface and root. We interpret the weak serrations of our specimens as a result of abrasion during deposition.

Rostral tooth root fragments of *Ischyrhiza mira* are present within NMMNH locality 5153 (NMMNH P-58059, Fig. 2Q-R). Root fragments identified as *I. mira* are robust with median longitudinal furrows and deeply scalloped lobes.

Ptychotrygon triangularis specimens from the locality are nearly complete (NMMNH P-58060, Fig. 2S-T). Three transverse ridges on the lingual face of the teeth in addition to the absence of smaller ridges and the higher, more pyramidal crown identify these teeth as *P. triangularis*. Additional specimens of *P. triangularis* collected from the site have had their transverse ridges abraded away, further indicating a very high-energy depositional setting.

A single microspiral heteropolar coprolite (NMMNH P-58066, Fig. 2B') is the only trace fossil collected from NMMNH locality 5351. The heteropolar morphology of this coprolite closely matches the helical anal valve of chondrichthyans (e.g., Williams, 1972).

Osteichthyans

Osteichthyans, while less common than the chondrichthyans, are a prominent part of the vertebrate fossil assemblage of NMMNH locality 5153. We recognize the following osteichthyan taxa: "Teleost B", Pycnodontidae indet., aff. *Coelodus* and *Micropycnodon* cf. *M. kansasensis*.

Indeterminate teleost fossils include an incomplete elliptical scale with concentric ridges (NMMNH P-58063, Fig. 2Y). This

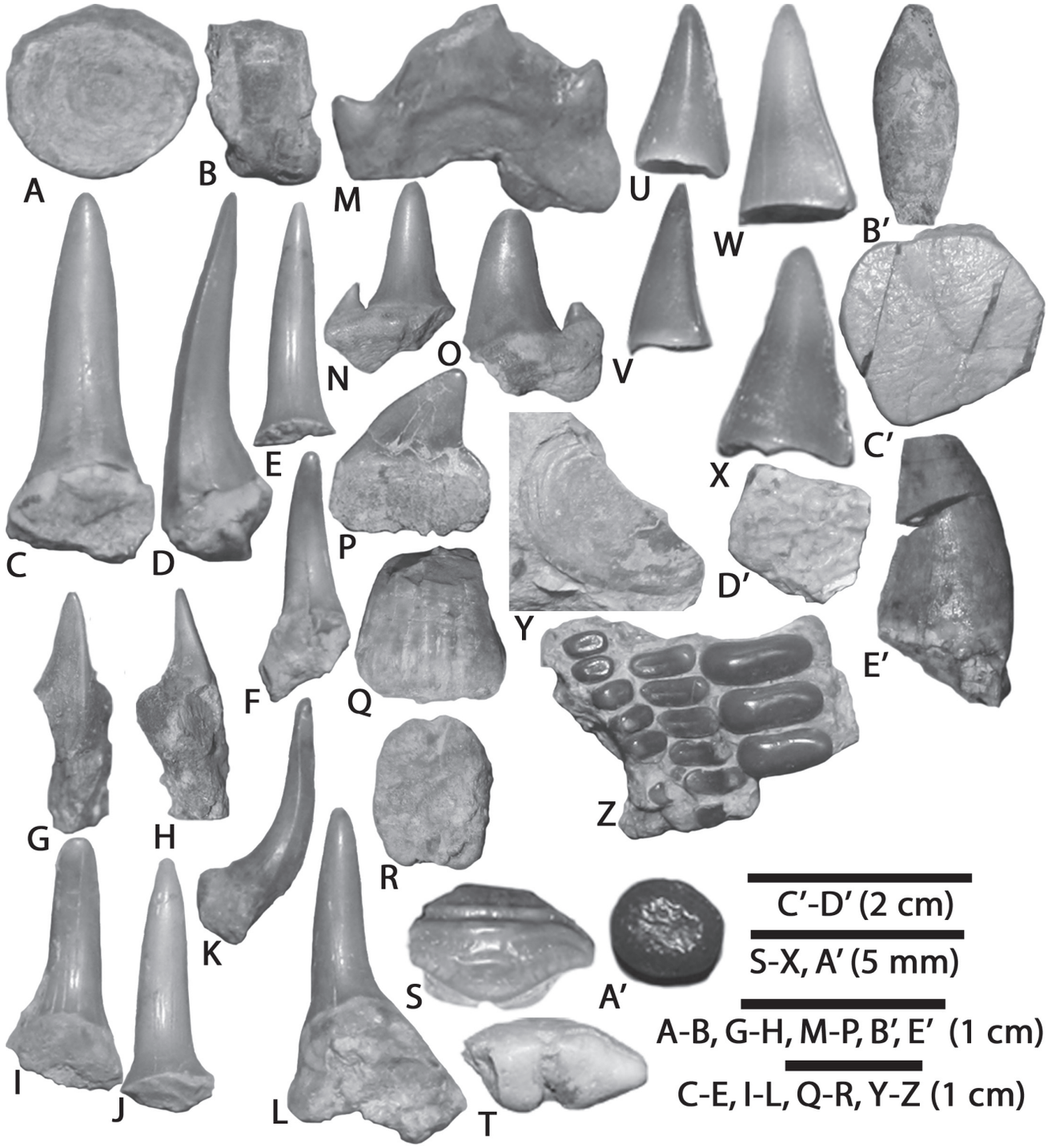

FIGURE 2. Selected fossil taxa in the NMMNH collection from locality 5153. **A-B**, Chondrichthyes indet., NMMNH P-58046, shark centrum in **A**, anterior/posterior view and **B**, lateral view. **C-F**, Odontaspidae indet., **C-D**, NMMNH P-58047, **E**, NMMNH P-58048, **F**, NMMNH P-58049, isolated teeth in **C**, **E-F**, lingual and **D**, profile views. **G-H**, cf. *Leptostyrax* sp., NMMNH P-58050, isolated tooth in **G**, labial and **H**, profile views. **I-L**, *Scapanorhynchus raphiodon*, **I**, NMMNH P-58051, **J**, NMMNH P-58052, **K**, NMMNH P-58053, **L**, NMMNH P-58054, isolated teeth in **I-J**, **L**, lingual and **K**, profile views. **M**, *Cretodus semplicatus*, NMMNH P-58055, isolated tooth in lingual view. **N-O**, *Cretolamna appendiculata*, **N**, NMMNH P-58056, O, NMMNH P-58057, isolated teeth in labial view. P, Squalicorax falcatus, NMMNH P-58058, abraded tooth in labial view. Q-R, *Ischyrhiza mira*, NMMNH P-58059, tooth root in **Q**, dorsal and **R**, basal views. **S-T**, *Ptychotrygon triangularis*, NMMNH P-58060, isolated tooth in **S**, lingual and **T**, basal views. **U-X**, "Teleost B", **U-V**, NMMNH P-58061, **W-X**, NMMN P-58062, isolated teeth in **U**, **X**, lingual and **V**, **W**, labial views. **Y**, Non-amiid teleost, NMMNH P-58063, isolated scale in lateral view. **Z**, aff. *Coelodus*, NMMNH P-58064, incomplete pavement in occlusal view. **A'**, *Micropycnodon* cf. *M. kansasensis*, NMMNH P-58065, isolated tooth in occlusal view. **B'**, Chondrichthyes indet., NMMNH P-58066, heteropolar, spiral coprolite in lateral view. **C'-D'**, Testudines indet., **C'**, NMMNH P-58067, **D'**, NMMNH P-58068, shell fragments in dorsal view. **E'**, Dromaeosauridae indet., NMMNH P-58069, isolated tooth in profile view.

scale is not similar to any amiid scales illustrated by Grande and Bemis (1998), which generally have fine, latitudinal striations and a more polygonal outline. Thus, we conclude that this scale pertains to a non-amiid teleost, but are unable to more precisely identify it.

Numerous conical, broad-crowned teeth lacking longitudinal striations (NMMNH P-58061 and P-58062, Fig. 2U-X) are identified as "Teleost B" of Shimada et al. (2006, fig. 14-13, 14-14), however, our teeth lack the transparent enameloid cap.

The most complete osteichthyan specimen from NMMNH locality 5153 is a partial dental pavement of a pycnodontid (NMMNH P-58064, Fig. 2Z). This pavement consists of three rows of teeth, with three large teeth in the most mesial row, six teeth in the middle row and six teeth in the most distal row. The three rows are from where the pavement presumably grades into numerous, smaller distal teeth. The three large teeth are elliptical, and weakly bicuspate with a round latitudinal mound against the inferred lingual edge. The middle row of teeth are also elliptical, with a low, rounded cusp on the mesial margin and a prominent latitudinal groove running from the mesial cusp to the lateral margin. The distal row of teeth are rounded squares in outline, with a latitudinal groove in the center of the occlusal surface. Based on the greater than 1:1 ratio of number of middle row teeth to mesial row teeth this specimen appears more similar to "*Coelodus browni*" than to "*C. stantoni*" (Stewart, 1900, pl. 24, fig. 12 to pl. 24, fig. 11). However, "*C. browni*" does not appear to possess the latitudinal grooves on the middle row of teeth that are present in NMMNH P-58064.

The status of North American records of *Coelodus* is unclear. Currently, *Coelodus* is known only from Europe (J. Kriwet, written commun., 2009) following the taxonomic revision of the pycnodontiform fish by Poyato-Ariza and Wenz (2002). However, this revision is of pycnodontiform taxa for which articulated material is known, and does not include the *Coelodus* "tooth taxa" of Stewart (1900). NMMNH P-58064 conforms to the diagnosis of *Coelodus* by Poyato-Ariza and Wenz (2002, p. 222) as possessing "prearticular teeth extremely elongated, up to five times longer perpendicularly to the longitudinal axis of the bone" (or to phrase it differently, prearticular teeth five times wider than long) and appears similar to the illustrated holotype of *Coelodus saturnus* (Poyato-Ariza and Wenz, 2002, fig. 22a). Given the uncertainty of the taxonomic placement of North American "*Coelodus*" we identify NMMNH P-58064 as aff. *Coelodus*.

Within the NMMNH sample there is a single tooth that we identify as *Micropycnodon* cf. *M. kansasensis* (NMMNH P-58065, Fig. 2A'). The tooth is roughly circular in occlusal outline and has a series of blunted mounds surrounding a central depression, very similar to teeth illustrated and discussed by Shimada et al. (2006, fig. 12.1). The occurrence of this taxon within the Turonian-age Atarque Sandstone is not surprising. The record reported by Shimada et al. (2006) is middle Cenomanian in age, and the holotype specimen is from a Coniacian deposit (Hibbard and Graffham, 1941), suggesting that this taxon has a stratigraphic range encompassing the lower half of the Upper Cretaceous.

Reptilia

Reptilian material in the assemblage at NMMNH L-5351 is rare, but critical to understanding the depositional environment of the locality. Only two taxa have been identified from the site in the NMMNH collection: turtles (Testudines) and theropod dinosaurs (dromaeosaurids).

The turtles at the locality are represented by isolated shell fragments (NMMNH P-58067 and NMMNH P-58068, Fig. 2C'-D'). There are two types of fragments: unornamented (Fig. 2C') and ornamented with low branching ridges (Fig. 2D'). The unornamented fragments are similar to those of baenids, whereas the ornamented fragments resemble those of dermatemyids, common freshwater/terrestrial turtles of the Late Cretaceous (cf. Gilmore, 1935). The lack of complete carapace elements prevents even family-level identification.

A single dromaeosaurid tooth has been collected from NMMNH locality 5351 (NMMNH P-58069, Fig. 2E'). The tooth is weakly recurved and serrated on both its mesial and distal surface, thus pertaining to a theropod. Based on its size we identify it as a dromaeosaurid tooth. Overall, the tooth appears similar to a tooth published by Williamson (1997) as cf. *Saurornitholestes*, but with finer, less prominent denticles, which may be due to abrasion during deposition.

DEPOSITIONAL ENVIRONMENT

The Atarque Sandstone is a Turonian-age shoreline deposit of the Western Interior Seaway. All of the vertebrate material from NMMNH locality 5153 was collected from a conglomerate containing limestone clasts, tooth, bone, bivalve shell and chert pebbles in a section of fine-grained sandstone (Fig. 1, inset). This lithology indicates a high-energy deposit (the conglomerate) with reworked deep-water clasts (the limestone pebbles) within a nearshore environment (the sandstone). The site is most likely a lag deposit from a storm event; similar Upper Cretaceous selachian-dominated, transgressive lag deposits were reported by Williamson et al. (1993, p. 448). Taphonomically, nearly all of the fossil material is incomplete and/or has been significantly abraded, further indicating a high-energy environment. The energy needed to cause this amount of damage to these fossils, especially the broken crowns on many of the selachian teeth, further suggests that NMMNH locality 5351 is a storm deposit.

The fauna is indicative of a nearshore environment. The abundance of shallow littoral taxa, *Scapanorhynchus* and *Ptychotrygon*, and the rarity of inferred deep-water taxa such as *Ptychodus* in the assemblage suggest a nearshore depositional setting (Meyer, 1974, p. 361-368). The presence of turtle material and a dromaeosaur tooth demonstrate a terrestrial influence in the deposit and thus proximity to the shoreline. Indeed, the few teeth of *Ptychodus* that Wolberg (1985) originally reported from the site may have been reworked from a farther offshore setting, much like the limestone pebbles. The Atarque vertebrate fossil assemblage thus corresponds well to the nearshore selachian association of Meyer

(1974), an observation consistent with the presence of terrestrial elements in the fossil assemblage and the sedimentology of the fossil-bearing bed.

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