

# THE MICROFAUNA OF THE UPPER TRIASSIC OJO HUELOS MEMBER, SAN PEDRO ARROYO FORMATION, CENTRAL NEW MEXICO

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**Abstract**—Three fossiliferous horizons at the type section of the Upper Triassic Ojo Huelos Member of the San Pedro Arroyo Formation yield a microfauna of ostracodes, “spirorbids,” sharks, bony fish, and tetrapods. These fossils represent a rare lacustrine microfossil assemblage near the base of the Upper Triassic Chinle Group. The fossiliferous interval consists primarily of pisolitic limestone and sandy mudstone. The fauna includes the ostracodes *Darwinula* sp., and *Gerdalia* sp., “spirorbid polychaetes,” the hybodont shark *Lissodus humblei*, several morphotypes of actinopterygian fish, including redfieldiids and semionotids, fragmentary labyrinthodont amphibians, and indeterminate reptiles. *Darwinula* is the most common fossil. Numerically, *Lissodus*, known from dozens of teeth, dominates the vertebrate fauna, followed by actinopterygians. The smallest teeth of *Lissodus* from this locality are the smallest teeth known for the genus. This assemblage is consistent with an early Late Triassic (Carnian) age, and lithostratigraphic position suggests that this fauna is probably of Adamanian (latest Carnian) age. Carbonates of definitive lacustrine origin are rare in the Chinle, and this fauna documents the first discovery of microvertebrate tetrapods in lacustrine limestones of the Chinle Group. Because this microvertebrate fauna is clearly from an aquatic environment, this favors an aquatic (not scatologic) origin for similar fish-dominated microvertebrate faunas in the Chinle.

**Keywords:** ostracodes, microvertebrates, *Lissodus*, Actinopterygii, Adamanian

## INTRODUCTION

Three fossiliferous horizons at the type section of the Upper Triassic Ojo Huelos Member of the San Pedro Arroyo Formation yield a microfauna of ostracodes, “spirorbids,” selachians, bony fish, and tetrapods (Fig. 1). These fossils, from New Mexico Museum of Natural History and Science (NMMNH) locality 354, represent a rare lacustrine microfossil assemblage near the base of the Upper Triassic Chinle Group. Lucas (1991) first reported a small microfossil and microvertebrate fauna collected by K. Kietzke; we re-examined the collection, sorted additional material to identify the microvertebrate fauna described here, and published a preliminary abstract last year (Heckert et al., 2001). Because the original intent of this project was to sample for invertebrate calcareous microfossils, this collection was based on a relatively small sample of matrix (10s of kg) and washed through very fine (100-230 mesh) screens. However, this collection merits its own discussion as, in addition to the calcareous microfossils, it includes a diverse microvertebrate fauna from an unusual lithofacies. Here we describe both the calcareous microfossils and the microvertebrates and discuss their significance. Throughout this paper, NMMNH = New Mexico Museum of Natural History and Science

**Anatomical abbreviations:** TCH = total crown height, measured from crown-root break to apex (total tooth measurement in actinopterygians); TCL = total crown length, measured antero-posteriorly (=mesio-distally).

## STRATIGRAPHY AND AGE

The Ojo Huelos Member of the San Pedro Arroyo Formation is stratigraphically low in the Chinle Group (Lucas, 1991; Heckert and Lucas, 1997). The localities sampled here range from approximately 2 to 8 m above the base of the “mottled strata,” a pedogenically modified horizon that, with the Shinarump Formation, marks the base of the Chinle Group regionally (Lucas, 1991, 1993, 1997). To date, the most diagnostic vertebrate fossils from the San Pedro Arroyo Formation are isolated bones and teeth

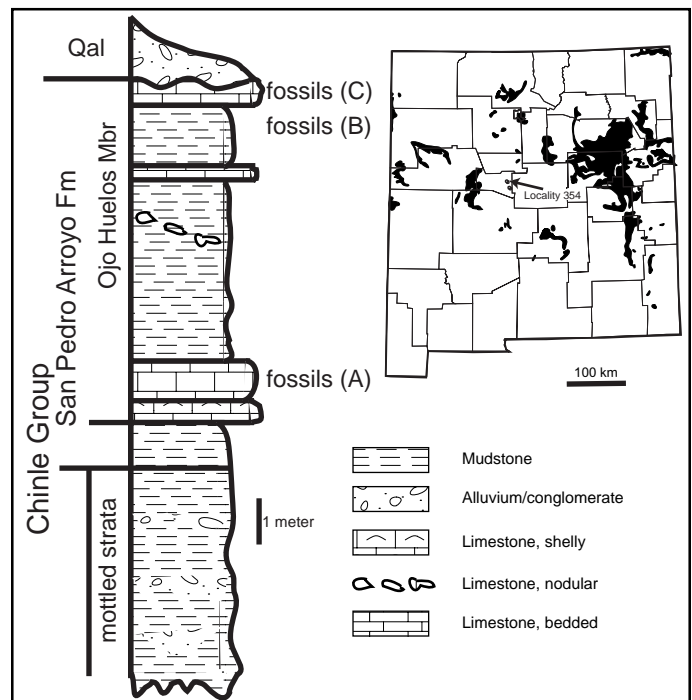


FIGURE 1. Index map and stratigraphic sections showing the location and stratigraphic position of NMMNH locality 354 in the type section of the Ojo Huelos Member of the San Pedro Arroyo Formation (Lucas, 1991). Three distinct levels yielded microfossils. Qal = Quaternary alluvium that overlies the section locally.

of phytosaurs, metoposaurs, and aetosaurs (Case, 1916; Lucas, 1991; Lucas and Heckert, 1994; Heckert, 1999), all of which indicate a Late Triassic age. A record of *Desmatosuchus* from the San Pedro Arroyo Formation (Lucas and Heckert, 1994) indicates a mid-Late Triassic (Adamanian-Revueltian) age (Heckert and Lucas, 2000). Regional correlation of the San Pedro Arroyo For-

mation, particularly with the Bluewater Creek Formation to the west, also indicates a probable Adamanian age for the Ojo Huelos Member (Lucas, 1991, 1993, 1997; Lucas and Heckert, 1994; Heckert, 1999).

#### DEPOSITIONAL INTERPRETATION

The laminated mudstones and fine-grained carbonates of the Ojo Huelos Member are one of the few *bona fide* occurrences of lacustrine lithofacies in the lower Chinle Group (Lucas, 1991; Heckert and Lucas, 1997). The fossiliferous horizons are, in ascending order, a mottled, dark yellowish-orange to yellowish-brown, pisolitic limestone (A), a yellowish-gray sandy mudstone with thin limestone ledges (B), and a dusky yellow to light gray pisolitic limestone (C) (Fig. 1). The fossiliferous pisolitic limestones have nearly planar upper and lower contacts and are laminar to massive. They lack any evidence of pedogenesis, such as nodules, brecciation, or pedogenic silica. We interpret them as clastic sediment-starved lacustrine deposits, unlike the predominantly pedogenic and palustrine limestones of the Owl Rock Formation, which contain the only widespread carbonates in the Chinle Group (Lucas and Anderson, 1993; Tanner, 2000). Siliciclastic rocks dominate most other pond and lake deposits in the Chinle, including the Redonda Formation in east-central New Mexico (Hester, 1988; Hester and Lucas, 2001) and a series of localized pond deposits in the lower Bluewater Creek Formation in west-central New Mexico (Ash, 1978; Lucas and Hayden, 1989). Indeed, the only other truly lacustrine carbonates in the Chinle Group are other outcrops of the Ojo Huelos Member and several square km of similar deposits low in the Bluewater Creek Formation in west-central New Mexico (Lucas, 1991; Heckert and Lucas, 1997). The latter have been misinterpreted as a cave deposit (Cooley, 1959) or Paleozoic strata (Lucas and Hayden, 1989).

Carbonates of unambiguous lacustrine origin are clearly rare in the Chinle, and this fauna documents the first discovery of microvertebrate tetrapods in lacustrine limestones of the Chinle Group. Similarly, most Chinle calcareous microfossils come from siliciclastic strata, not carbonates (Kietzke, 1987, 1989). Because this microvertebrate fauna is clearly from an aquatic environment, this favors an aquatic (not scatologic) origin for similar fish-dominated microvertebrate faunas in the Chinle.

The fossil assemblage from localities sampled here includes the ostracodes *Darwinula* sp., and *Gerdalia* sp., "spirorbid polychaetes," the hyodont shark *Lissodus*, several morphotypes of actinopterygian fish, including redfieldiids and semionotids, fragmentary labyrinthodont amphibians, and indeterminate reptiles (Lucas, 1991; Heckert et al., 2001; Table 1). Following Kietzke's identifications (cited in Lucas, 1991 and from museum labels) the ostracodes from NMMNH locality 354 consist primarily of shells or tests of *Darwinula* with considerably rarer *Gerdalia*.

TABLE 1. The microfauna of the Ojo Huelos locality (NMMNH locality 354).

<b>Ostracoda</b>	<i>Darwinula</i> sp. <i>Gerdalia</i> ? sp.
<b>"Spirorbidae"</b>	"Spirorbidae" indet.
<b>Chondrichthyes</b>	<i>Lissodus humblei</i> Chondrichthyes indet.
<b>Osteichthyes</b>	Actinopterygii indet. Redfieldiidae indet. Semionotidae? indet.
<b>Amphibia</b>	Labyrinthodontia indet.
<b>Reptilia</b>	Reptilia indet.

#### SYSTEMATIC PALEONTOLOGY

##### OSTRACODA Latreille, 1802

##### PODOCOPIDA Müller, 1894

##### DARWINULACEA Brady and Norman, 1889

##### DARWINULIDAE, Brady and Robertson, 1885

##### *Darwinula* sp.

Specimens of the ostracode *Darwinula* are abundant in the Ojo Huelos Member. They can be described as having reniform valves that are elongate ovals in lateral view (Fig. 2A-C). The dorsal margin is slightly arched, whereas the ventral margin is slightly concave. The greatest height is slightly posterior of the midpoint, and the left valve overlaps the right on the ventral, anterior and posterior margins. The anterior end of the valve is pointed, whereas the posterior end is more rounded. The surface of the valves is smooth or very faintly punctate.

Complex taxonomic schemes of Triassic darwinulids have been proposed, especially by Russian and Chinese workers (e.g., Schleipher, 1966; Xu, 1988). We are skeptical of species and even some generic distinctions made by these workers, so we simply refer almost all darwinulid ostracodes from the Ojo Huelos Member to *Darwinula* sp. (also see Kietzke, 1989). The exception is specimens referred to *Gerdalia* (see below). Specimens of *Darwinula* sp. from the Ojo Huelos Member (e.g., Fig. 2A-C) are characteristic Chinle ostracodes; this type of ostracode is found throughout Chinle Group strata (Kietzke, 1987, 1989; Lucas, 1997).

##### *Gerdalia* sp.

Specimens of the ostracode *Gerdalia* have highly elongate valves that are oval in shape (Fig. 2D-F). Their length is much greater than height in lateral view. The anterior margin is acutely rounded, whereas the posterior margin is evenly rounded. The right valve overlaps the left slightly on the ventral and posterior margins. These specimens closely resemble *Gerdalia* (cf. Belousova, 1961), though that genus may be synonymous with *Darwinula* (Kietzke, 1989). Specimens of *Gerdalia* are found throughout Chinle Group strata (Kietzke, 1989; Lucas, 1997).

##### "Spirorbidae"

Coiled, calcareous "tubes" that superficially resemble spirorbid polychaetes are rare in the Ojo Huelos Member (Fig. 2G) but common in some other Chinle Group strata (Kietzke, 1989). They are more likely vermiform gastropods than true spirorbids (Kietzke and Lucas, 1991). The sole specimen recovered here is not well preserved.

##### CHONDRICHTHYES Huxley, 1880

##### ELASMOBRANCHII Bonaparte, 1838

##### EUSELACHII Hay, 1902

##### HYBODONTOIDEA Zangerl, 1981

##### POLYACRODONTIDAE Glückman, 1964

##### *Lissodus* Brough 1935 (= *Lonchidion* Estes, 1964)

Elongate tooth crowns of the hyodont shark *Lissodus* are the most common generically identifiable vertebrate fossils recovered from NMMNH locality 354 (Figs. 3-4). Almost all of the *Lissodus* teeth recovered lack roots, but are otherwise well preserved. In general, the labial peg is pronounced, in some cases projecting nearly as far labially as half the TCL (total crown length). Based on the preserved crown-root base, the roots were relatively short, approximately one-half the TCL. The occlusal crest bears only the central principal cusp and is smooth, lacking vertical stria-

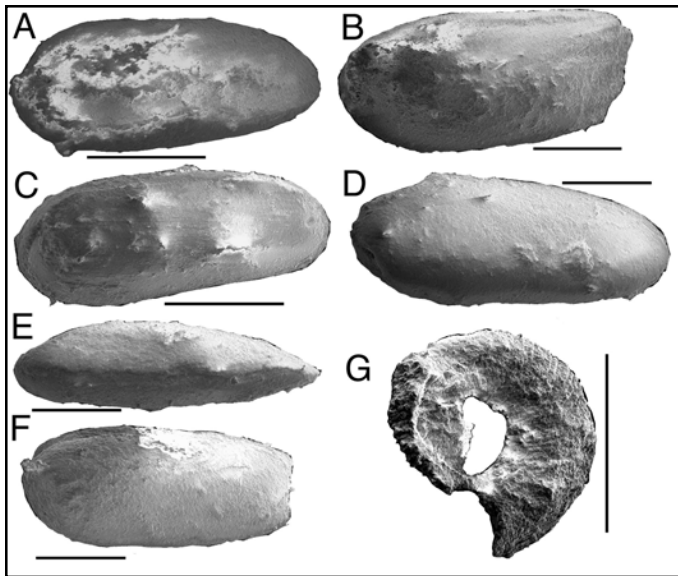


FIGURE 2. Ostracodes (A-F) and spirorbid (G) from NMMNH locality 354. A-C, *Darwininula* sp. (NMMNH P-31601), shells in right lateral views; D-F, right valves of *Gerdalia* sp. (NMMNH P-31602) in D, lateral, E, ventral, and F, lateral views; G, indeterminate "spirorbid polychaete" (gastropod?) (NMMNH P-31603) in side view. Scale bars = 200 microns (A-F) and 500 microns (G).

tions. These teeth well match the diagnoses of *L. humblei* provided by Murry (1981) and Duffin (1985). Specifically, the tooth crowns are small, low-crowned, lack accessory cusps, and generally possess a very prominent labial peg surmounted by a transverse ridge that intersects the otherwise smooth, unornamented occlusal crest.

The teeth of *L. humblei* from NMMNH locality 354 are noteworthy both in their size and diverse morphologies. These teeth are the smallest yet reported for the genus, with many tooth crowns less than 0.8 mm TCL (Fig. 4) and some as small as 0.5 mm TCL. Most species of *Lissodus* are much larger (Duffin, 1985) and only *L. microselachos* (Estes and Sanchiz) may be as small as the teeth from Ojo Huelos (Duffin, 1989). These teeth also exhibit a range of morphotypes typical of *L. humblei* teeth (Fig. 3) to teeth that are relatively short antero-posteriorly but tall (Fig. 4C-D) and longer teeth with concave bases preserving prominent pulp cavities (Fig. 4A-B). Together, this combination of size and diverse morphotypes most likely represents preservation of several tooth positions in the tooth row (e.g., Duffin, 1985, figs. 12,13). We describe and illustrate several of the most representative and noteworthy teeth here.

On a typical tooth of *L. humblei* (NMMNH P-31607a —Fig. 3C-D), the labial peg, while clearly present, is weakly developed. The principal cusp has only slightly steeper sides than the rest of the tooth crown, much like paratype specimens of *L. humblei* illustrated by Murry (1981, figs. 3, 4a, 5a), although Murry (1981, figs. 1a, 2a) also illustrated teeth with much more pronounced cusps. NMMNH P-31607b is similar but shorter (lower TCL), with a considerably more substantial labial peg (Fig. 3A-B). At the other end of the spectrum, NMMNH P-31639 exhibits very little labial peg development (Fig. 3E). All three teeth still fall well within the variation Murry (1981) documented for *L. humblei*.

Somewhat more divergent *L. humblei* morphotypes include NMMNH P-31634 (Fig. 4A-B) and P-31635 (Fig. 4C-D). NMMNH P-31634 possesses a strongly concave crown-root base, which we interpret as a particularly well developed pulp cavity. This tooth also possesses one of the longer roots (proportionately) known from this locality. NMMNH P-31635 is one of the shortest and

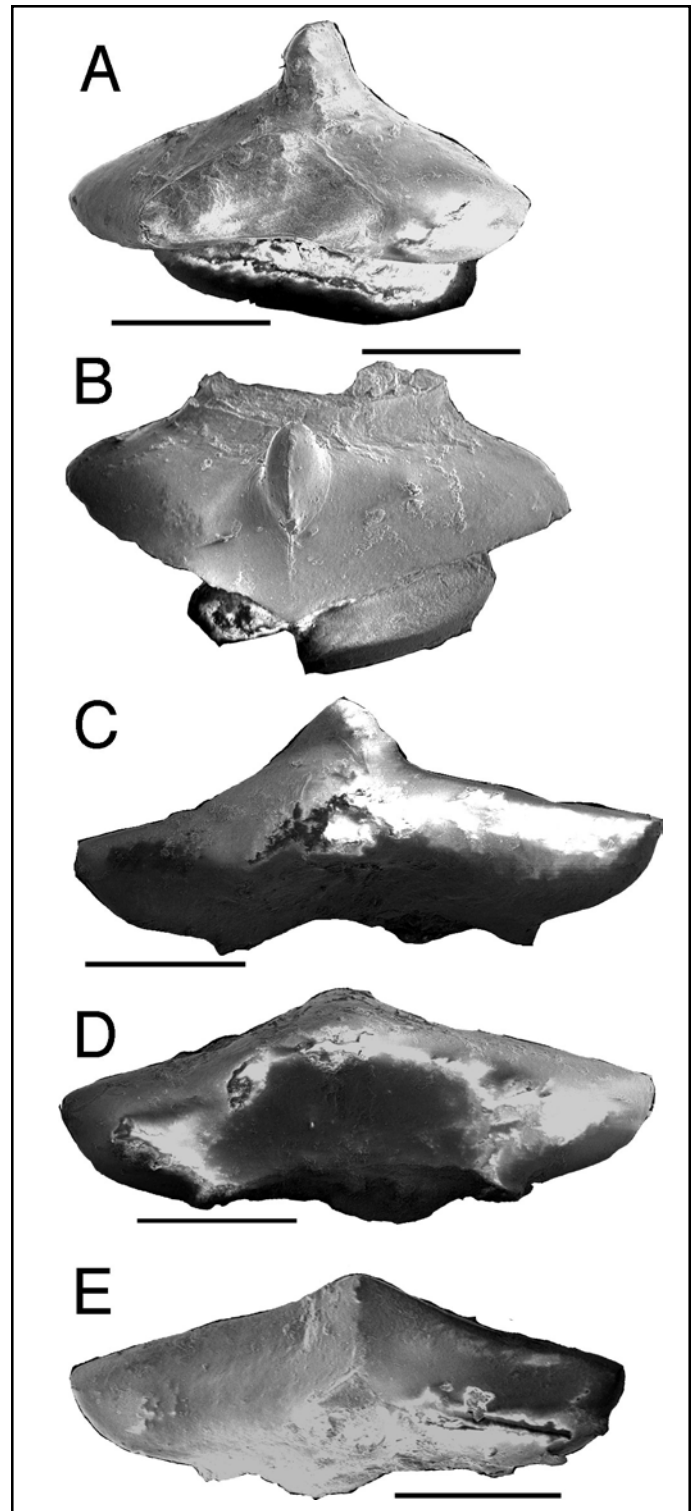


FIGURE 3. Teeth of *Lissodus humblei* from NMMNH locality 354. A-B, NMMNH P31607b in A, oblique basal and B, labial views; C-D, NMMNH P-31607a in C, labial and D, oblique lingual views; E, NMMNH P-31639 in occlusal view. Scale bars = 500 microns (A-B) or 200 microns (all others).

proportionately tallest *L. humblei* tooth crowns known. The labial peg is exceptionally strongly developed and very slightly off-center. The principal cusp is also tall, but not strongly differentiated from the overall slope of the occlusal crest in labio-lingual view.

The smallest tooth of *L. humblei* recovered, NMMNH P-31620, is exceptionally short (TCL ~ 0.5 mm), yet relatively tall

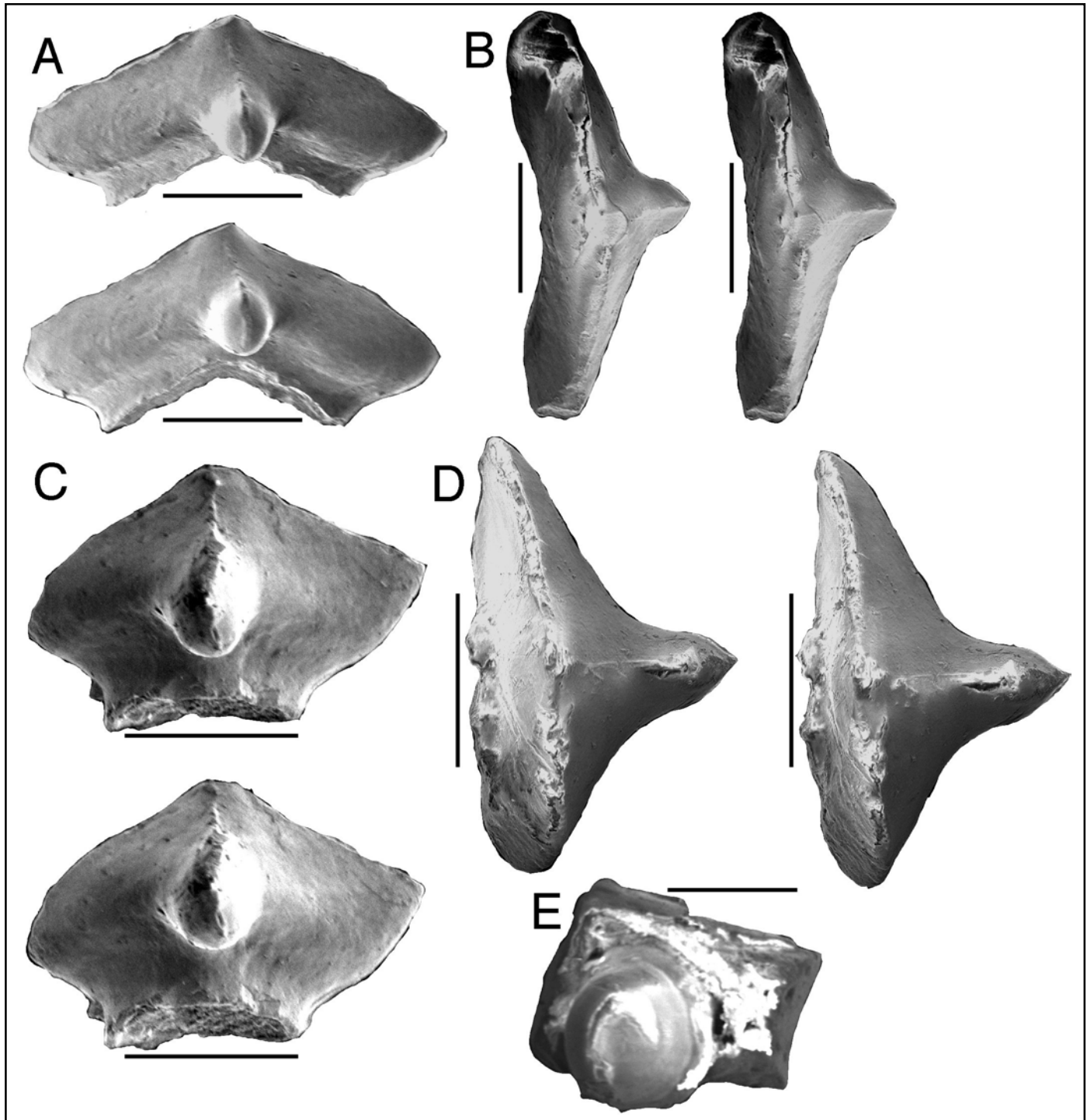


FIGURE 4. Teeth of *Lissodus humblei* (A-D) and an indeterminate chondrichthyan denticle (E) from NMMNH locality 354. A-B, NMMNH P-34634 in A, stereo labial and B, stereo occlusal views; C-D, NMMNH P-34635 in C, stereo labial and D, stereo occlusal views. E, NMMNH P-31608, denticle in dorsal(?) view. All scale bars = 200 microns.

and broad, with a concave base for the root attachment. The labial peg and principal cusp are reduced relative to many of the other *Lissodus* teeth from this locality.

Complete, articulated dentitions of *L. humblei* are unknown, and tooth position for these and most other *Lissodus* teeth is thus extrapolated from *Lissodus africanus* (Broom, 1935; Duffin, 1985). From this taxon and other hybodont sharks, Duffin (1985) indicated that, in *Lissodus* generally, antero-posteriorly shorter teeth possessing strong labial pegs are anteriormost, with larger teeth that either lack or bear reduced labial pegs occupying the

middle (lateral) portion of the tooth row. Slightly shorter teeth that have similarly weak labial pegs are typically posterior teeth. Duffin's (1985, fig. 12) reconstruction of a quarter of the dentition of *L. nodosus* contains 11 tooth whorls. Because all of the *Lissodus* teeth we describe here well match published descriptions of *L. humblei* by both Murry (1981, 1986, 1989a,b,c) and Duffin (1985), we identify all of these teeth as *L. humblei* and ascribe most of their variation to different tooth whorl positions and, most likely, ontogenetic differences in size. Thus, following Duffin (1985), NMMNH P-34635 is probably an anterior tooth, as may be P-

31607b, NMMNH P-31634 is probably slightly posterior to those teeth, and P-31607a and P-31639 are probably from posterior (lateral) tooth rows.

#### **Chondrichthyes indet.**

We recovered an enigmatic fossil that we interpret as a broken selachian denticle (NMMNH P-31608—Fig. 4E). This fossil is a round, smooth knob affixed to a broad, flat surface. The knob is slightly taller than it is wide (lateral diameter) with a rounded top. It is definitely not the denticle of a xenacanth shark as it lacks the “bundled spines” typical of xenacanth (Murry, 1989). It is also distinct from probable denticles of *Lissodus humblei* illustrated by Murry (1989). Overall, it is most similar in size and shape to contemporaneous selachian denticles found in marine deposits of British Columbia (Johns et al., 1987). It most closely resembles the relatively unornamented *Complanicorona glabora* Johns et al. (1987, pl. 37 figs 1-5) but has, in our interpretation a much larger (proportionately) root and smaller crown. Consequently, we believe that this fossil is a selachian denticle, but at present it is not determinate below the level of Chondrichthyes.

#### **OSTEICHTHYES Huxley, 1880**

#### **ACTINOPTERYGII Klein, 1885**

#### **Actinopterygii indet.**

Numerous actinopterygian teeth were recovered from all three levels of NMMNH locality 354. These teeth all preserve the classic actinopterygian morphology consisting of a conical crown and deeply striated root. Unfortunately, isolated teeth are nearly impossible to ascribe to a given actinopterygian taxon with certainty, and precise identifications usually require extensive collections of both teeth and more complete material (e.g., Thies and Mudroch, 1996). We distinguish three broad morphotypes from the Ojo Huelos collection, although none of the three are generically determinate (Fig. 5).

The first morphotype, represented here by NMMNH P-31642 (Fig. 5A-B) and NMMNH P-31643 (Fig. 5C), consists of actinopterygian teeth that are moderately to very tall (TCH = 1.5-3.0TCL), laterally compressed, and conical with very sharp, unserrated carinae or flanges. The bases of these teeth are somewhat expanded labial-lingually.

The second morphotype consists of moderately tall to tall (TCH = 1.5-2.5TCL), conical teeth with prominent roots that are circular in occlusal view (e.g., NMMNH P-31644, Fig. 5D-E; NMMNH P-31645, Fig. 5F-G). The most significant difference between these and the first type is the conical crowns that are circular in occlusal view relative to the laterally compressed teeth of the first morphotype.

The third morphotype is essentially identical to the second, except that the teeth are lower, and thus generally moderately low to low (TCH = 1.0-1.5TCL) and conical with prominent roots that are circular in occlusal view. NMMNH P-31646 (Fig. 5H) and NMMNH P-31628 (4I-J) are representative.

Actinopterygian teeth are a relatively common component of Chinle microvertebrate faunas (e.g., Murry, 1982; Huber et al., 1993; Kaye and Padian, 1994). However, no study has successfully matched these teeth to a more specific taxon, in spite of the fact that redfieldiids and palaeoniscids are known from more complete material and are locally common throughout much of the Chinle (Schaeffer, 1967; Murry, 1982; Huber et al., 1993).

#### **REDFIELDIFORMES Berg, 1940**

#### **REDFIELDIIDAE Berg, 1940**

#### **Redfieldiidae indet.**

Because of the small size of the screens, isolated scales were seldom complete. NMMNH P-31609 is a typical redfieldiid scale, and other fragmentary scales from NMMNH locality 354 probably represent redfieldiids as well. These scales are unornamented rhomboid, ganoid scales with one side nearly twice as long as wide. Some possess peg-and-socket articulations. These scales well match descriptions of redfieldiid scales provided by Schaeffer (1967) and Murry (1982, 1986). Indeed, Murry (1982, 1986) described similar scales and assigned them to the “*Lasalichthyes/Synorichthyes*” species complex (cf. Schaeffer, 1967). The scales we recovered that lack peg-and-socket articulations could pertain to *Cionichthyes* (Murry, 1982) but are not well enough preserved to be determinate. Consequently, we identify NMMNH scales as indeterminate redfieldiids.

#### **HALECOSTOMI Regan, 1923**

#### **SEMIONOTIFORMES Arambourg and Bertin, 1958**

#### **SEMIONOTIDAE Woodward, 1890**

#### **Semionotidae? indet.**

As with redfieldiids, scales of semionotids are uncommon in the sample from NMMNH locality 354. A possible semionotid scale, NMMNH P-31610 (Fig. 5K), is illustrated here. Semionotid scales are also ganoid but less rhomboid than those of redfieldiids (McCune et al., 1984; McCune, 1987), although they generally have few distinguishing characteristics that positively identify them as semionotid (Huber et al., 1993). Still, this scale lacks characteristics of other typical Chinle fish, particularly palaeoniscids, redfieldiids, or colobodontids, and compares well to semionotids in the NMMNH collection from younger Chinle deposits and the Newark Supergroup, so we tentatively note its semionotid affinities here. Neither McCune and co-workers (e.g., McCune et al., 1984; McCune and Thomson, 1986; McCune, 1987) nor Olsen (1988) recognized any pre-Norian semionotids in the Newark Supergroup. Consequently, the Chinle records from this locality and the *Placerias* quarry (e.g., Kaye and Padian, 1994), both of which are of undisputed Carnian age, could be a significant temporal range extension.

#### **Osteichthyes indet.**

Other, indeterminate osteichthyans from NMMNH locality 354 include fragmentary teeth, bones, and scales. Most of these are too small to be identified further. A complete list is provided in the Appendix, together with a list of indeterminate vertebrates that may include some tetrapod fossils.

#### **AMPHIBIA Linnaeus, 1758**

#### **TEMNOSPONDYLI Zittel, 1888**

Two unserrated teeth (NMMNH P-31612), one recurved, the other conical, with weakly labyrinthodont structure were recovered from NMMNH locality 354. The conical tooth is illustrated in Figure 6A-B. These teeth are very small, and could represent embryonic or hatchling metoposaurid amphibians, the most common labyrinthodonts in the Chinle (see Hunt, 1993), although other, laticrepid amphibians are also known (Wilson, 1948; Bolt and Chatterjee, 2000). The tooth we illustrate here is not as strongly infolded as many small metoposaurid teeth (see papers by Zanno et al. and Rinehart et al. in this volume), but is still labyrinthodont, so we consider it a probable temnospondyl. These teeth are so small that they could be confused with individual teeth of colobodontid fish, except that they lack the strongly developed longitudinal striations of colobodontids and adult metoposaurs

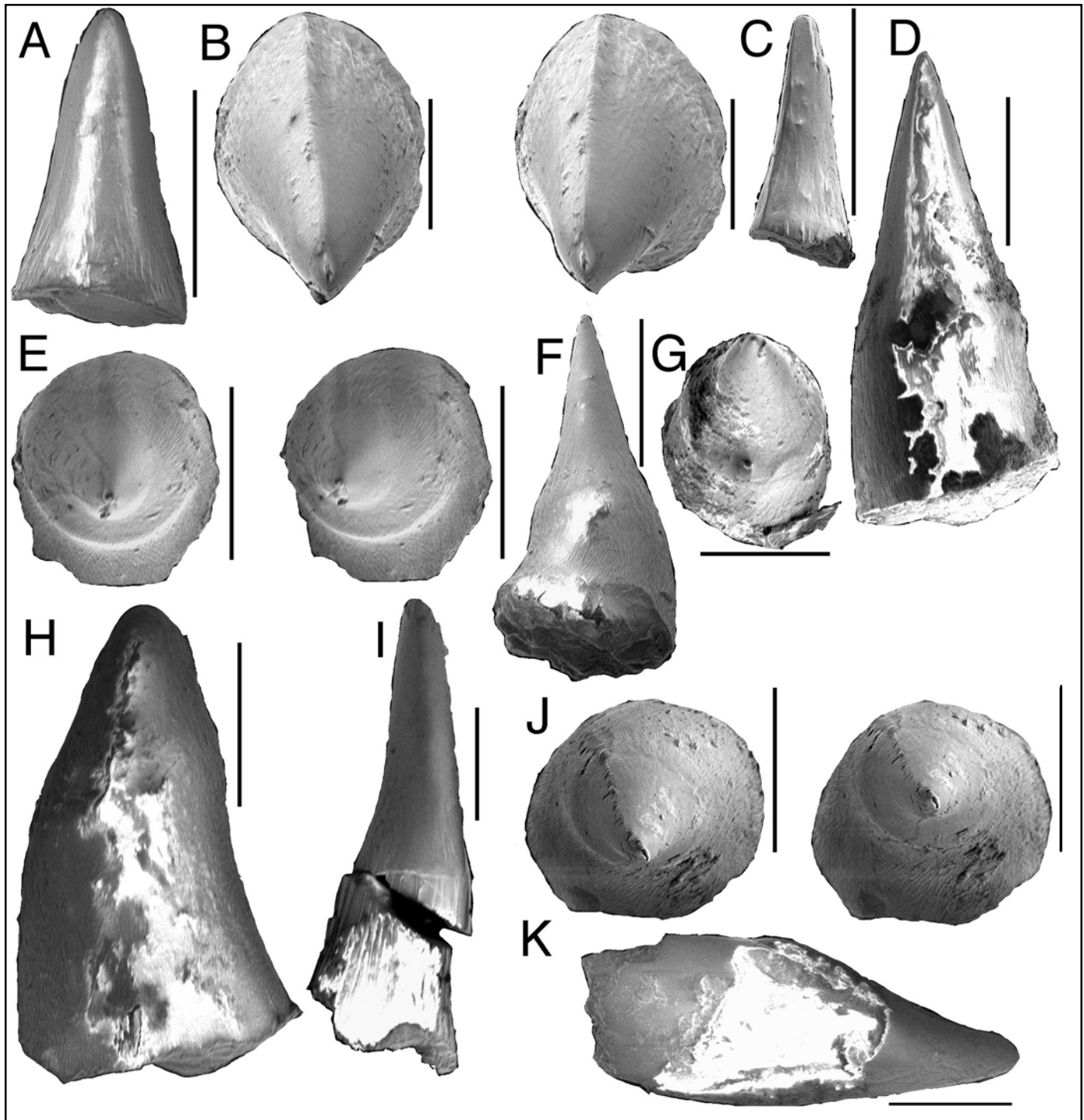


FIGURE 5. Fossil actinopterygian teeth (A-J) and semionotid scale (K) from NMMNH locality 354. **A-B**, first actinopterygian morphotype (NMMNH P-31642) in **A**, side and **B**, stereo occlusal views; **C**, first actinopterygian morphotype (NMMNH P-31643) in side view; **D-E**, second actinopterygian morphotype (NMMNH P-31644) in **D**, side, and **E**, stereo occlusal views; **F-G**, second actinopterygian morphotype (NMMNH P-31645) in **F**, side and **G**, occlusal views; **H**, third actinopterygian morphotype (NMMNH P-31646) in side view; **I-J**, third actinopterygian morphotype (NMMNH P-31628) in **I**, side and **J**, stereo occlusal views; **K**, NMMNH P- 31610, semionotid scale in lateral view. Scale bars = 500 microns (A) or 200 microns (all others).

(Murry, 1986; Hunt, 1993).

#### REPTILIA Linnaeus, 1758

##### Reptilia indet.

A single tooth with an elongate root (NMMNH P-31613) appears to represent a reptile (Fig. 6C-E). The tooth itself is moderately low, laterally compressed, and weakly recurved.

#### Trace fossils

There are no unambiguous trace fossils at NMMNH locality 354. The most likely candidates for trace fossils, NMMNH P-31617, consist of various tubular structures we interpret as invertebrate and vertebrate coprolites and/or burrows. These range in shape from bulbous to elongate. All are of microvertebrate (mm-scale) size.

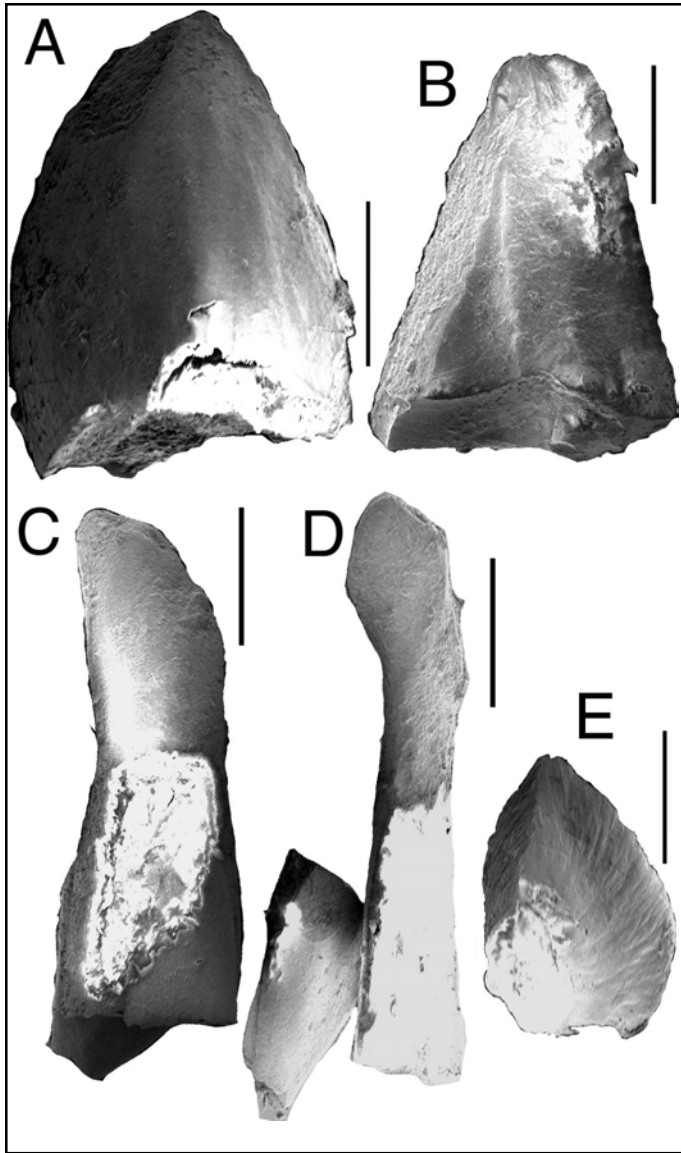


FIGURE 6. Tetrapod fossils from NMMNH locality 354. **A-B**, NMMNH P-31612a, labyrinthodont tooth in **A**, labial, and **B**, antero-posterior? views; **C-E**, NMMNH P-31613, reptile tooth with extensive root in **C**, labial, **D**, mesio-distal, and **E**, occlusal views. Scale bars = 200 microns.

**DISCUSSION**

Among the assemblage as a whole, invertebrates greatly outnumber vertebrates, with tests of *Darwinula* the most common fossil. Within the invertebrates, almost all fossils are ostracodes—the only exception is the “spirorbid” illustrated here.

Osteichthyans constitute the overwhelming majority (69%) of the identifiable vertebrate fossils (Fig. 7A). The hybodont shark *Lissodus* constitutes almost all of the selachians (27% of all vertebrate fossils), and tetrapods are extremely rare. Taxic richness (Fig. 7B) is more difficult to ascertain. The two scale morphotypes indicate the presence of at least two families, and thus genera, of osteichthyans. The three actinopterygian tooth morphotypes may represent a single heterodont taxon or, alternately, three or more homodont taxa.

The abundance of *Lissodus* and the absence of other sharks is unusual, but may be in part an artifact of using extremely small screens. We suspect that sifting a coarser size fraction would increase the diversity of sharks, as other typical Chinle sharks (e.g.,

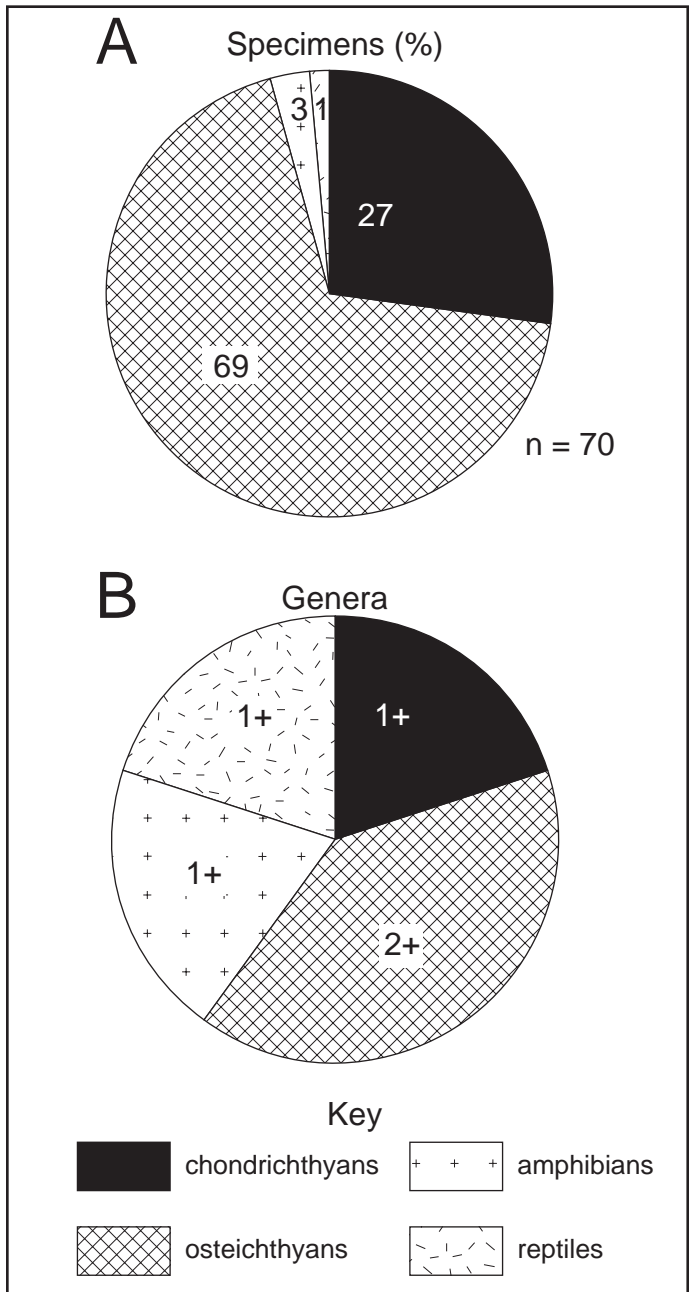


FIGURE 7. Pie charts showing the relative proportions of different vertebrate groups by preserved specimens (A) and genera (B).

*Xenacanthus*, *Acrodus*) have larger and/or more complex teeth (Murry, 1982; Huber et al., 1993; Heckert et al. 2001). Larger fossils would probably also include larger specimens of *Lissodus*, and we place no taxonomic significance on the small size of these fossils, as they are otherwise indistinguishable from *Lissodus humblei* (Murry, 1981; Duffin, 1985).

The fact that tetrapods are exceptionally rare relative to “fish” further supports our interpretation of the Ojo Huelos Member as a principally lacustrine deposit. None of the fossils display evidence of digestion, such as pitting, cracking, or enamel dissolution, that are typical of ingested microvertebrate remains (e.g., Dodson and Wexlar, 1979; Rensberger, 1987; Rensberger and Krentz, 1988). Consequently, we doubt that these fossils were recovered from coprolites or regurgitalites. Similar fish-dominated microvertebrate faunas in the Chinle thus are also likely of lacus-

trine origin (Murry, 1986; Huber et al., 1993). Future exploration of the Ojo Huelos should reveal taxa also present in the lacustrine Newark Supergroup deposits and enhance existing Newark Supergroup-Chinle correlations.

## CONCLUSIONS

The Ojo Huelos Member yields abundant fossils of both ostracodes and microvertebrates. This fauna is from lacustrine facies, one of the rare occurrences of truly lacustrine carbonates in the Chinle. Although the fauna is dominated by the ostracode *Darwinula*, a substantial microvertebrate fauna was also recovered using screens suited for ostracodes and "spirorbids." Particularly significant records include at least three morphotypes of actinopterygian teeth as well as many teeth of *Lissodus*, some of

which are the smallest yet known for the genus. The abundance of microvertebrates recovered suggests that microvertebrate workers should use the much finer sieves of microfossil (ostracode- and charophyte-) workers with at least some sediment at localities screenwashed in the traditional fashion for microvertebrates.

## ACKNOWLEDGMENTS

The vertebrate portions of this study were previously described as part of a dissertation by the senior author (Heckert, 2001), and the discussions here benefited from the careful editing of B.S. Kues. Ken Kietzke washed and picked this fauna. A. Hunt and P. Murry reviewed an earlier draft of this paper. The NMMNH supported this research, including SEM work at the Institute of Meteoritics at the University of New Mexico.

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## APPENDIX—REFERRED SPECIMENS

### OSTRACODA Latreille, 1802

#### PODOCOPIDA Müller, 1894

#### DARWINULACEA Brady and Norman, 1889

#### DARWINULIDAE, Brady and Robertson, 1885

##### *Darwinula* sp.

NMMNH P-31601, 31618, 31626, and 31627, numerous valves, many complete and articulated (Fig. 2A-C).

##### *Gerdalia* sp.

NMMNH P-31602, numerous shells, several complete and articulated (Fig. 2D-F).

##### “Spirorbidae”

“Spirorbid polychaete” (gastropod?): NMMNH P-31603, single shell (Fig. 2G).

### EUSELACHII Hay, 1902

#### HYBODONTOIDEA Zangerl, 1981

#### POLYACRODONTIDAE Glückman, 1964

##### *Lissodus* Brough, 1935

##### *Lissodus humblei* (Murry, 1981)

NMMNH P-31607, two teeth (Fig. 3A-D); NMMNH P-31620, tiny tooth; NMMNH P-31633, four teeth; NMMNH P-31634, tooth; NMMNH P-31635, tooth; NMMNH P-31636, four incomplete teeth; NMMNH P-31639, tooth (Fig. 3E); NMMNH P-31640, tooth.

##### Chondrichthyes? indet.

NMMNH P-31608, two denticles (Fig. 4E).

### OSTEICHTHYES Huxley, 1880

#### ACTINOPTERYGII Klein, 1885

#### REDFIELDIIDAE Berg, 1940

##### Redfieldiidae indet.

NMMNH P-31609, scale.

### HALECOSTOMI Regan, 1923

#### SEMIONOTIFORMES Arambourg and Bertin, 1958

#### SEMIONOTIDAE Woodward, 1890

##### Semionotidae? indet.

NMMNH P-31610, scale (Fig. 5K); NMMNH P-31631, scale.

#### ACTINOPTERYGII Klein, 1885

##### Actinopterygii indet.

**First morphotype:** NMMNH P-31604, 15 moderately tall to tall, laterally compressed teeth; NMMNH P-31641, tooth; NMMNH P-31642, tooth (Fig. 5A-B); NMMNH P-31643, tooth (Fig. 5C); **second morphotype:** NMMNH P-31605, 14 moderately tall to tall, conical teeth; NMMNH P-31644, tooth (Fig. 5D-E); NMMNH P-31645, tooth (Fig. 5F-G); **third morphotype:** NMMNH P-31606, seven moderately low, conical teeth; NMMNH P-31614, two teeth; NMMNH P-31628, tooth (Fig. 5I-J); NMMNH P-31646, tooth (Fig. 5 H); NMMNH P-31647, tooth; NMMNH P-31648, tooth. **Others:** NMMNH P-31616, two teeth; NMMNH P-31619, tooth; NMMNH P-31629, curved tooth; NMMNH P-61630, two teeth.

### AMPHIBIA Linnaeus ,1758

#### TEMNOSPONDYLI Zittel, 1888

##### Temnospondyli indet.

NMMNH P-31612, two teeth (Fig. 6A-B).

### Reptilia LINNAEUS, 1758

##### Reptilia indet.

NMMNH P-31613, tooth (Fig. 6C-E).

##### Vertebrata indet.

NMMNH P-31615, two slides of miscellaneous fragmentary tooth, bone and scale fragments.

##### Trace fossils

NMMNH P-31617, 20+ burrows or coprolites.