

FIRST USE OF ORNITHISCHIAN DINOSAURS FOR BIOSTRATIGRAPHIC ZONATION OF THE UPPER TRIASSIC

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The recently recognized ornithischian dinosaurs *Tecovasaurus murryi* and *Revueltosaurus callenderi* occur stratigraphically superposed at several localities in the Chinle Group in Texas, New Mexico, and Arizona; U.S.A. *Tecovasaurus* occurs at the type locality in the Tecovas Formation in Crosby County, Texas, at the *Placerias* quarry in the Bluewater Creek Formation of eastern Arizona, and from low in the Bluewater Creek Formation near Fort Wingate, New Mexico. These localities are in strata that produce a vertebrate fossil assemblage typical of the Adamanian (latest Carnian) land vertebrate faunachron (M). *Revueltosaurus* is known from its type locality in the Bull Canyon Formation of eastern New Mexico and from the Painted Desert Member of the Petrified Forest Formation in the Petrified Forest National Park in eastern Arizona. These strata have been assigned to the Revueltian Mf of early-mid Norian age on the basis of tetrapod fossils, including phytosaurs and aetosaurs. Because the biostratigraphic zonation of *Tecovasaurus* and *Revueltosaurus* independently support other biostratigraphic correlations, particularly those of tetrapods, we suggest that the dinosaur *Tecovasaurus* is an additional index taxon of the Adamanian Mf, which is generally characterized by the aetosaur *Stagonolepis* and the phytosaur *Rutiodon*. Similarly, *Revueltosaurus* is an index taxon of the Revueltian Mf, in addition to the aetosaur *Typhothorax* and the phytosaur *Pseudopalatus*. To date, *Tecovasaurus* and *Revueltosaurus* are the only Triassic ornithischians identified from multiple localities. This is the first use of dinosaur genera as biostratigraphic indicators in the Upper Triassic and should be useful in future studies of microvertebrates in the Chinle Group.

Introduction

In spite of many recent discoveries of new Triassic dinosaurs, particularly in the Western Hemisphere (e.g., Hunt, 1989; Sereno et al., 1993) and continued work on older, better-known forms (Colbert, 1989; Hunt and Lucas, 1991; Sereno and Novas, 1992; Novas, 1993; Sereno, 1993; Sereno and Novas, 1993), dinosaurs remain poor biostratigraphic indicators of Upper Triassic strata. This is largely due to the endemism of most Triassic dinosaur taxa, which are often limited to a single locality. Consequently, tetrapod-based correlations of Upper Triassic sediments have remained tied to phytosaurs, aetosaurs, and metoposaurs (e.g., Gregory, 1957; Colbert, 1972; Lucas and Hunt, 1993; Lucas, 1997). Although many recent advances in the temporal and spatial distribution of these large tetrapod taxa have greatly improved these correlations (Lucas and Huber, 1998), two facts are readily apparent. First, dinosaurs are conspicuously absent from the present correlation schemes, and second, the bulk of the taxa used for correlation, such as phytosaurs and aetosaurs, are all relatively large (often > 2 m). Here, we document the first use of Triassic microvertebrate fossils to correlate two superposed zones in nonmarine Upper Triassic strata. Interestingly, the fossils themselves are teeth of the ornithischian dinosaurs *Tecovasaurus murryi* (of latest Carnian age) and *Revueltosaurus callenderi* (of early-mid Norian age). Here, MNA refers to the Museum of Northern Arizona, Flagstaff, Arizona, and NMMNH refers to the New Mexico Museum of Natural History, Albuquerque, New Mexico.

Taxa

The fossil record of Triassic ornithischians remains relatively poor, in spite of continued research on Late Triassic faunas. The only undisputed Triassic ornithischians that include material beyond teeth are *Pisanosaurus mertii* from the Ischigualasto Formation of Argentina (Casamiquela, 1967; Bonaparte, 1976) and parts of the holotype of *Technosaurus smalli* from the Bull Canyon Formation of West Texas (Chatterjee, 1984; Sereno, 1991). Hunt (1989) named *Revueltosaurus callenderi* for a collection of ornithischian teeth from a single locality in the Bull Canyon Formation of east-central New Mexico. Hunt and Lucas (1994) named a variety of ornithischian taxa based on teeth from the Upper Triassic of North America, including *Tecovasaurus murryi* from the Tecovas Formation of West Texas. Other taxa named by Hunt and Lucas include *Galtonia gibbidens* (= "*Thecodontosaurus*" *gibbidens* Cope, 1878) from the New Oxford Formation in Pennsylvania, *Pekinosaurus olseni* from the Pekin Formation of North Carolina, USA, and *Lucianosaurus wildi* from the Bull Canyon Formation of New Mexico, USA. At the present time, *Galtonia*, *Pekinosaurus*, and *Lucianosaurus* are known solely from their type localities and thus are not yet biostratigraphically useful. *Tecovasaurus* and *Revueltosaurus*, however, have broader distributions and thus are of biostratigraphic and biochronological interest.

Tecovasaurus murryi

We present the following diagnosis of *Tecovasaurus*, revised slightly from Hunt and Lucas (1994, p. 232): ornithischian with dentary/maxillary tooth crowns that are low and mesio-distally long and markedly asymmetrical, with up to six large and 3-4 small denticles on the steeply inclined, convex, distal margin and approximately twice as many (12-18) small denticles on the gently sloping, flat to concave mesial margin. The distal denticles do not reach the base of the crown and there are no cingula (Fig. 1).

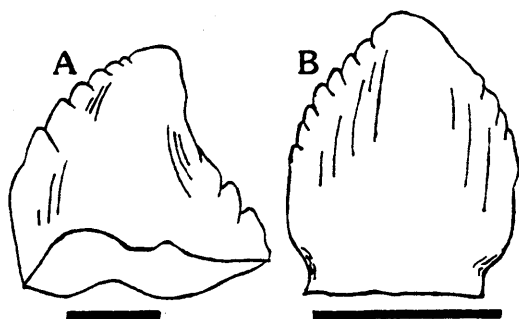


Fig. 1. Tooth crowns of Triassic ornithischian dinosaurs: (A) Tooth crown of *Tecovasaurus murryi* from the Tecovas Formation of west Texas; (B) Maxillary/dentary? tooth of *Revueltosaurus callenderi* from the Bull Canyon Formation of eastern New Mexico. Scale bars: A = 0.5 mm, B = 5.0 mm.

Tecovasaurus murryi is currently known from three localities: (1) the type locality in the Tecovas Formation, in Crosby County, West Texas (Hunt and Lucas, 1994, figs. 12.5G-J, 12.6, 12.7A-B); (2) the *Placerias* quarry in the Bluewater Creek Formation, eastern Arizona (Hunt and Lucas, 1994, fig. 12.6A-B; Kaye and Padian, 1994, fig. 9.108); and (3) the lower Bluewater Creek Formation in western New Mexico (NMMNH locality 2739).

Hunt and Lucas (1994) noted that, in addition to the holotype, NMMNH P-18192, several other teeth of *Tecovasaurus murryi* were present at locality 1430. Since that time, we have confirmed that several additional teeth of *Tecovasaurus* were collected from that locality (e.g., NMMNH P-26417). There were also some ornithischian teeth of strikingly different morphologies and, therefore, presumably, of different taxa. Hunt and Lucas also pointed out that some of the ornithischian teeth assigned to MNA PL. 1704 from the *Placerias* quarry in eastern Arizona pertain

to *Tecovasaurus*. Heckert et al. (1997) briefly noted that, of several ornithischian teeth culled from screen wash material from NMMNH locality 2739 in west-central New Mexico, at least one can be assigned to *Tecovasaurus*.

Tecovasaurus localities in Texas, New Mexico, and Arizona are in strata that produce a tetrapod fauna of Adamanian (latest Carnian) age, including the phytosaur *Rutiodon* and the aetosaur *Stagonolepis*.

Revueltosaurus callenderi

We present the following diagnosis of *Revueltosaurus*, slightly modified from Hunt (1989) and Hunt and Lucas (1994): ornithischian with tall, slightly recurved, "premaxillary" teeth (length/height = 0.72) with denticulated mesial and distal margins. "Premaxillary" tooth crowns are twice the height of "dentary/maxillary" tooth crowns. "Dentary/maxillary" tooth crowns are also tall (length/height = 0.88) and lack accessory cusps. Root:crown ratio of dentary/maxillary teeth of up to 1.75. Teeth are large by the standards of Triassic ornithischians, up to 28 mm in total height from base of root to tip of crown (Fig. 1).

Revueltosaurus callenderi is currently known from two localities: (1) the type locality in the Bull Canyon Formation, east-central New Mexico (Hunt, 1989, pl. 8, E-H, pl. 9A-H; Hunt and Lucas, 1994, figs. 12.7E-F, 12.8C&H); and (2) "Dinosaur Hill" in the Painted Desert Member of the Petrified Forest Formation, Chinle Group, in eastern Arizona (Padian, 1990, fig. 1). Ornithischian teeth referred to *Revueltosaurus* by Long and Murry (1995, fig. 194) superficially resemble *Revueltosaurus* but differ significantly in size and shape and thus probably represent a different taxon.

Padian (1990) recognized teeth of *Revueltosaurus* from the Painted Desert Member of the Petrified Forest Formation in east-central Arizona, but relegated *Revueltosaurus* to the status of form genus. Sereno (1991), in his review of early ornithischian dinosaurs, believed the association of the type and topotypic material of *Revueltosaurus* questionable and thus considered *Revueltosaurus* a *nomen dubium*. Kaye and Padian (1994, fig. 9.71) referred a tooth from the *Placerias* quarry, MNA V3690, to *Revueltosaurus*. However, this tooth is considerably smaller (1 mm mesio-distally) than the type of *Revueltosaurus* and morphologically more similar to *Galtonia gibbidents* than *Revueltosaurus*. Other teeth identified as ornithischian, possibly aff. *Revueltosaurus*, by Kaye and Padian (1994, figs. 9.104, 9.108) do not pertain to that taxon. Instead, V3682 (Kaye and Padian, 1994, fig. 9.104) is not even clearly ornithischian, and V3597 (fig. 9.108) is instead a tooth of *Tecovasaurus*, quite possibly one of the largest yet known for that genus. Ornithischian teeth referred to *Revueltosaurus* by Long and Murry (1995, fig. 194) superficially resemble *Revueltosaurus* but differ significantly in size and shape and thus probably represent a different taxon.

Revueltosaurus localities in New Mexico and Arizona occur in strata that produce a tetrapod fauna of Revueltian (early-mid Norian) age, including the phytosaur *Pseudopalatus* and the aetosaur *Typhothorax*. Based on tooth size, *Revueltosaurus* is one of the largest Triassic ornithischian dinosaurs.

Stratigraphic Distribution

The Tecovas Formation in Texas produces a diverse tetrapod fauna that includes the phytosaur *Rutiodon* (*sensu* Ballew, 1989) and the aetosaur *Stagonolepis* (Case, 1932; Lucas and Hunt, 1993). For a detailed review of the lithostratigraphy and biostratigraphy of the region, see Lucas et al. (1994).

Lucas et al. (1997) discussed the litho- and biostratigraphy of the *Placerias* quarry, and noted that it occurs low in the Bluewater Creek Formation, not in the Blue Mesa Member of the Petrified Forest Formation, as most previous workers had thought. The *Placerias* quarry produces a tetrapod fauna almost identical to that of the type Adamanian (Lucas and Hunt, 1993; Long and Murry, 1995; Lucas et al. 1997), including abundant specimens of the aetosaur *Stagonolepis* and phytosaur skull fragments assignable to *Rutiodon*. Therefore, the Arizona occurrence of *Tecovasaurus* is of undoubted latest Carnian age.

east Arizona/ west New Mexico		faunachron/correlations	east New Mexico/ west Texas	
Rock Point Formation		Apachean lvf	Redonda Formation	
Owl Rock Formation		Revueltian lvf <i>Revueltosaurus</i> localities	Bull Canyon Formation	
Petrified Forest Formation	Painted Desert Member		Dockum Formation	Trujillo Member
	Sonsela Member			Tecovas Member
	Blue Mesa Member	Colorado City Member		
Bluewater Creek Formation		Adamanian lvf <i>Tecovasaurus</i> localities	Camp Springs Member	
Shinarump Formation		Otischalkian lvf		

Fig. 2. Correlation of Chinle Group strata in Arizona, New Mexico, and Texas. Faunachrons are those of Lucas and Hunt (1993). Note that the stratigraphic superposition of *Tecovasaurus* and *Revueltosaurus* independently supports the land vertebrate faunachrons of Lucas and Hunt.

The third occurrence of *Tecovasaurus*, from New Mexico, is also of Adamanian (latest Carnian) age. NMMNH locality 2739, from which a single tooth of *Tecovasaurus* has been recovered, is low in the Bluewater Creek Formation, at a horizon homotaxial to that of the *Placerias* quarry (Heckert, 1997a). In addition to this strong lithostratigraphic evidence for an Adamanian age, the Bluewater Creek Formation in western New Mexico yields a tetrapod fauna that includes *Stagonolepis* (Heckert, 1997a,b). Because there are now three localities that produce teeth identical in size, shape, and overall morphology to the holotype specimen of *Tecovasaurus*, we suggest that *Tecovasaurus murryi* is an index taxon of the Adamanian lvf.

The type locality of *Revueltosaurus* in the Bull Canyon Formation is part of the type area for the Revueltian lvf of Lucas and Hunt (1993), and thus *Revueltosaurus* is clearly of Revueltian (early-mid Norian) age. The Revueltian is characterized by, among other taxa, abundant small metoposaurids of the genus *Apachesaurus*, the phytosaur *Pseudopalatus* (*sensu* Ballew, 1989) and the aetosaur *Typhothorax*. The Painted Desert locality reported by Padian (1990) is also Revueltian, based on the

presence of abundant *Apachesaurus* at the locality itself and numerous specimens of *Pseudopalatus* and *Tyothorax* from correlative localities. Therefore, we propose that *Revueltosaurus* is an index taxon of the Revueltian lfv.

Conclusion

We have presented here the beginnings of an ornithischian-based dinosaur biostratigraphy for Upper Triassic strata. Multiple lines of evidence suggest that *Tecovasaurus* is an index taxon of the Adamanian lfv, and that *Revueltosaurus* is a suitable index taxon of the Revueltian lfv. This constitutes the first use of ornithischian dinosaurs to correlate multiple, stratigraphically superposed localities in the Upper Triassic.

Further collecting should provide a means by which to test the biostratigraphic hypotheses advanced here. We anticipate that, with increasing study of microvertebrate assemblages, these and perhaps other ornithischian dinosaurs will provide an accurate means of correlating strata across the Chinle Group and possibly to other localities. This appears to be especially likely due to the fact that, whereas Triassic ornithischians are generally more poorly known than other dinosaurs, particularly theropods, the high degree of variability in Triassic ornithischians allows for ready identification of taxa. Therefore we expect that the possibilities of correlating by means of microvertebrate fossils in the Upper Triassic will eventually rely heavily on biostratigraphic schemes like the one proposed here.

Acknowledgments

Susan Harris picked much concentrate from NMMNH localities and thus found many of the specimens of *Tecovasaurus* discussed here. The Mesalands Dinosaur Museum in Tucumcari and the Petrified Forest Museum Association supported field work in the Petrified Forest National Park. Tom Olson found additional teeth of *Revueltosaurus* at Dinosaur Hill and aided with field work at the Petrified Forest National Park.

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Muschelkalk Museum Ingelfingen, Germany

After having been closed for more than a year, the Muschelkalk museum in Ingelfingen has re-opened with a modern exhibit that has been expanded from 20 m² to more 300 m². It shows various aspects of the Muschelkalk worldwide, including two large *Placunopsis* reefs, a display of the borehole Ingelfingen drilled between 1857-1863 and of course many fossils from the collection of Dr. Hans Hagdorn with many crinoids and many other collectors from Germany, France and Poland. Also material from Spain southern France and the Southern Alps is shown. A life size model of a swimming Nothosaurus and spectacular specimens *Mastodonsaurus* from the Lettenkeuper of Vellberg given an idea about the vertebrate fauna. The museum is opened on Sundays from 10.30 to 16.00 h and on Wednesdays from 15.00 to 17.00 h. For other arrangements please contact:

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