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The first occurrence of the enigmatic archosaur *Crosbysaurus* (Heckert 2004) from the Chinle Formation of Southern Utah

ABSTRACT - Originally identified as an ornithisichian dinosaur, *Crosbysaurus* has been found in New Mexico, Arizona, and the type locality in Texas, the genus has been reassessed by other workers in light of revelations about the postcrania of another putative Triassic ornithischian, *Revueltosaurus*. The understanding of Triassic dental faunas has become more complicated by the extreme convergence between pseudosuchian archosaurus and ornithichian dinosaur dental morphologies. This new specimen does not help resolve the affinities of *Crosbysaurus* but does extend the range of this taxon into southern Utah. This specimen may also represent the youngest-known member of this genus.

INTRODUCTION

In May of 2014 10 students from Mission Heights Preparatory High School went to southeastern Utah. Despite temperatures over 100° F the students were able to prospect the Chinle Formation exposed at Comb Ridge, Utah as well as open a test pit at a possible metoposaur site located by the first author in March. While several of the students did not meet with success the second author, accompanied by another student, discovered a rich locality to the south of the metoposaur site. The second author and another student named this rich microsite “The Hills Have Teeth.” While combing the ground near the base of The Hills Have Teeth locality (MNA Locality 1724) the second author discovered and unusual tooth, MNA V10666 to the west-southwest of the main outcrop. This second locality is designated MNA Locality 1725. The students brought this tooth to the first author’s attention. It was documented, collected and finally brought back to the lab at Mission Heights Preparatory High School (MHPRO).

The history of *Crosbysaurus* is more complicated than the events leading to the collection of MNA V10666. When it was first described by Heckert in 2004 the assumption was that it, like the better-known *Revueltosaurus*, was an ornithischian dinosaur. Several purported ornithischian tooth taxa were named, leading several authors to suggest that herbivorous dinosaurs were widespread across Pangea (Hunt and Lucas, 1984; Heckert 2002, 2004, 2005). This contrasted sharply with the previous views on ornithischian diversity and stood in sharp contrast with the non-dental fossil record of ornithischian diversity outside of the southern hemisphere.

This interpretation of the fossil record was challenged by Parker et al. (2005) with the discovery of the postcrania of *Revueltosaurus* from the Petrified Forest of Arizona. Not only did this revise how *Revueltosaurus* was seen but it called into question all of North America’s supposed ornithischian dinosaurs from the Triassic Period (Irmis et al. 2006). Without any supporting skeletal remains it was no longer parsimonious to assign “fabrosaur”-type teeth to any known dinosaur clade. While *Revueltosaurus* is now known from postcrania, other

supposed ornithischians known from only teeth like *Tecovasaurus* and *Crosbysaurus* can only be identified as being either archosaurs or archosauriforms of uncertain affinity. While some authors have suggested that ornithischians were present in the Late Triassic of North America (Heckert 2005) virtually all authors are in agreement that *Crosbysaurus* does not represent a dinosaur and instead is an archosauriform. While this new record does not add any clarity to the taxonomic affiliations of *Crosbysaurus* it does significantly extend its range. Previous reports of *Crosbysaurus* have been limited to Texas (the type locality), New Mexico, and Arizona (Heckert 2004). Comb Ridge in southeastern Utah is approximately 245 kilometers away from the closest reported *Crosbysaurus* remains in the Chinle Formation of Arizona.

MATERIALS AND METHODS

Abbreviations - Mission Heights Preparatory High School (MHPRO), Museum of Northern Arizona (MNA)

Materials - Standard paleontological hand tools were used to collect MNA V10666. Geographic locality data were recorded via BackCountry Navigator Android Application running on a Samsung Galaxy S4. All specimens were collected under Bureau of Land Management paleontology permit UT14-001S issued to the first author and are curated at the Museum of Northern Arizona. Figures and line drawings were produced using GIMP 2.8.4.

Locality - MNA V10666 comes from locality MNA 1725 in San Juan County, Utah (Figure 1). The exact coordinates remain on file at the Museum of Northern Arizona. This locality, named The Hills Have Teeth, produced numerous partial and complete phytosaur and metoposaur teeth along with several dinosaur or dinosauromorph teeth. MNA V10666 was found approximately 4 meters west-southwest of The Hills Have Teeth as surface float. We presume it to have originated at The Hills Have Teeth. This is corroborated by the presence of phytosaur tooth fragments found close to MNA V10666 which the second author was able to connect with fragments collected at the main deposit at The Hills Have Teeth.

This area has not been mapped in detail but this portion of the Chinle Formation has been reported to be or correlate to the Petrified Forest Member (Bennett, 1955). Further work by the authors and others is ongoing and the relationships between the beds at Comb Ridge and elsewhere in the Chinle Formation will be clarified in the near future. None the less it is clear that MNA V10666 originally was deposited near the base of the Chinle Formation as part of the earliest fauna recorded in the Comb Ridge area (Figure 2).

Description - MNA V10666 is a single nearly complete shed tooth. Since *Crosbysaurus* is known only from dental material it is not possible to confidently assign a tooth row position to the tooth. Heckert (pers. comm., 2014) suggested to the first author that this tooth may be from the premaxilla based on the relative robustness. The tooth itself is laterally compressed and anterio-posteriorally expanded at the base tapering towards the apex. There is an obvious resorption pit at the base of the tooth and the tip is worn and broken (Figure 3). These data suggest that MNA V10666 is a shed tooth.

The tooth is 3.7mm from the base to the apically-most preserved point and 3mm anterio-posteriorally. Mediolaterally the tooth measures 1 mm (Figure 4). The enamel is a light tan to mottled brown color, typical of many of the teeth from The Hills Have Teeth locality. The posterior edge of the tooth is curved posteriorly and has six equally spaced denticles. The basalmost denticle is approximately 0.3 mm in basal-apical height while the apical-most is 0.2 mm in height. Above the apical-most denticle is a thin ridge of enamel. Since the tooth has been worn and was shed during life additional denticles may have been present further up the posterior side. This is not possible to evaluate at this time due to the premortem and postmortem wear of the tooth. The posterior denticles that are present appear to have possessed smaller accessory denticles. Most of these are worn but one denticle preserves four accessory denticles on the basal edge and three on the apical edge (Figure 5).

The anterior edge of the tooth is expanded 2 mm from the base of the tooth, approximately even with the level of the last posterior denticle. Very fine (<0.1 mm) denticles cover the anterior edge of this ridge which extends for 1 mm.

RESULTS AND DISCUSSION

MNA V10666 closely matches the published illustrations and descriptions of *Crosbysaurus* (Heckert, 2004). The complex posterior denticles coupled with the recurved nature of the tooth itself are diagnostic to the genus (Heckert, 2004). None the less several differences exist between MNA V10666 and all other published specimens which warrant some discussion.

Teeth referred to *Crosbysaurus* by other workers fall into two morphotypes: laterally compressed and highly recurved or basally wide and moderately recurved (see Heckert, 2004 for examples). MNA V10666 falls into neither category. While the tooth is moderately recurved it is also laterally compressed, especially compared to other *Crosbysaurus* teeth in the literature. The posterior denticles bear fewer accessory denticles than any other *Crosbysaurus* teeth in the literature. The anterior denticles are much smaller, not compound, and are not found along the complete length of the anterior surface of the tooth.

It is tempting to think that these differences may be systematically significant. We refrain from using these differences to taxonomically segregate MNA V10666 from other *Crosbysaurus* specimens, however, for several reasons. The sample size from Utah is low (n=1) and individual variation within this taxon has not been quantified. In addition we lack any other body fossil remains from *Crosbysaurus* so it is unknown what role tooth position has in tooth morphology. Coupled with the taxonomic and systematic problems associated with *Revueltosaurus* (Hunt, 1989; Hunt and Lucas, 1994; Heckert, 2002; Parker et al., 2005; Heckert, 2005, Irmis et al., 2006, Heckert et al., 2012), a taxon whose relationship and taxonomy has been radically altered by the discovery of body fossils, we refrain from adding to the confusing plethora of tooth taxa known from the Late Triassic of North America.

Previous authors have suggested that *Crosbysaurus* is useful as a biostratigraphic index taxon of the St. Johnsian division of the Adamanian LVF assemblage (late Carnian in age) (Heckert and Lucas, 2006). If these previous workers are correct MNA V10666 may provide an important lower limit on the age of the Chinle Formation at Comb Ridge, an area that has received little paleontological or stratigraphic work. Such correlations should be treated as highly tentative, however, pending further stratigraphic work at Comb Ridge by the authors and

others. Considering the different morphology found in MNA V10666 and other specimens of *Crosbysaurus* it is possible that this taxon may not be as useful as an index fossil as originally suggested. This view is bolstered by the discovery of a single isolated tooth of *Reticulodus synergus* (MNA V10652) at a similar stratigraphic level north of The Hills Have Teeth locality by the first author. *R. synergus* has been regarded as an index taxon for the Norian-aged Revueltian LVF (Heckert and Lucas, 2006). While detailed stratigraphic work remains to be done the data available at this time suggest that MNA V10666 is Norian in age. The occurrence of two index taxa from different LVFs in the same area would reduce or eliminate the utility of those taxa to biostratigraphy. It is hoped that additional remains of both taxa will be recovered at Comb Ridge by future workers to provide additional data to bolster these conclusions.

CONCLUSIONS

The discovery of *Crosbysaurus* from the Chinle Formation of southeastern Utah extends the geographic range of this taxon by over 400 kilometers. *Crosbysaurus* was apparently a rare but cosmopolitan species during Chinle deposition times. The single tooth recovered, MNA V10666, bears unique morphological characteristics that separate from other published specimens of *Crosbysaurus* as well as other contemporaneous herbivorous archosaurs such as *Revueltosaurus*. These characters may represent various tooth positions within the jaw, variation between individuals, or taxonomic differences. The sample size and preservation of known specimens of *Crosbysaurus* does not allow us to discriminate between these sources of variation at this time so we refrain from making any statements about what the primary cause is. The near co-occurrence of *Reticulodus synergus* and *Crosbysaurus* may have implications for the utility of these taxa as biostratigraphic index fossils. The Chinle Formation at Comb Ridge has been mapped as the Petrified Forest Member (Bennett, 1955). If further investigations support this then MNA V10666 represents the youngest occurrence of *Crosbysaurus* and extends its stratigraphic range into the Norian. It is hoped that future work by Mission Heights' field crews can help better clarify the stratigraphic and taxonomic relationships of this enigmatic archosaur.

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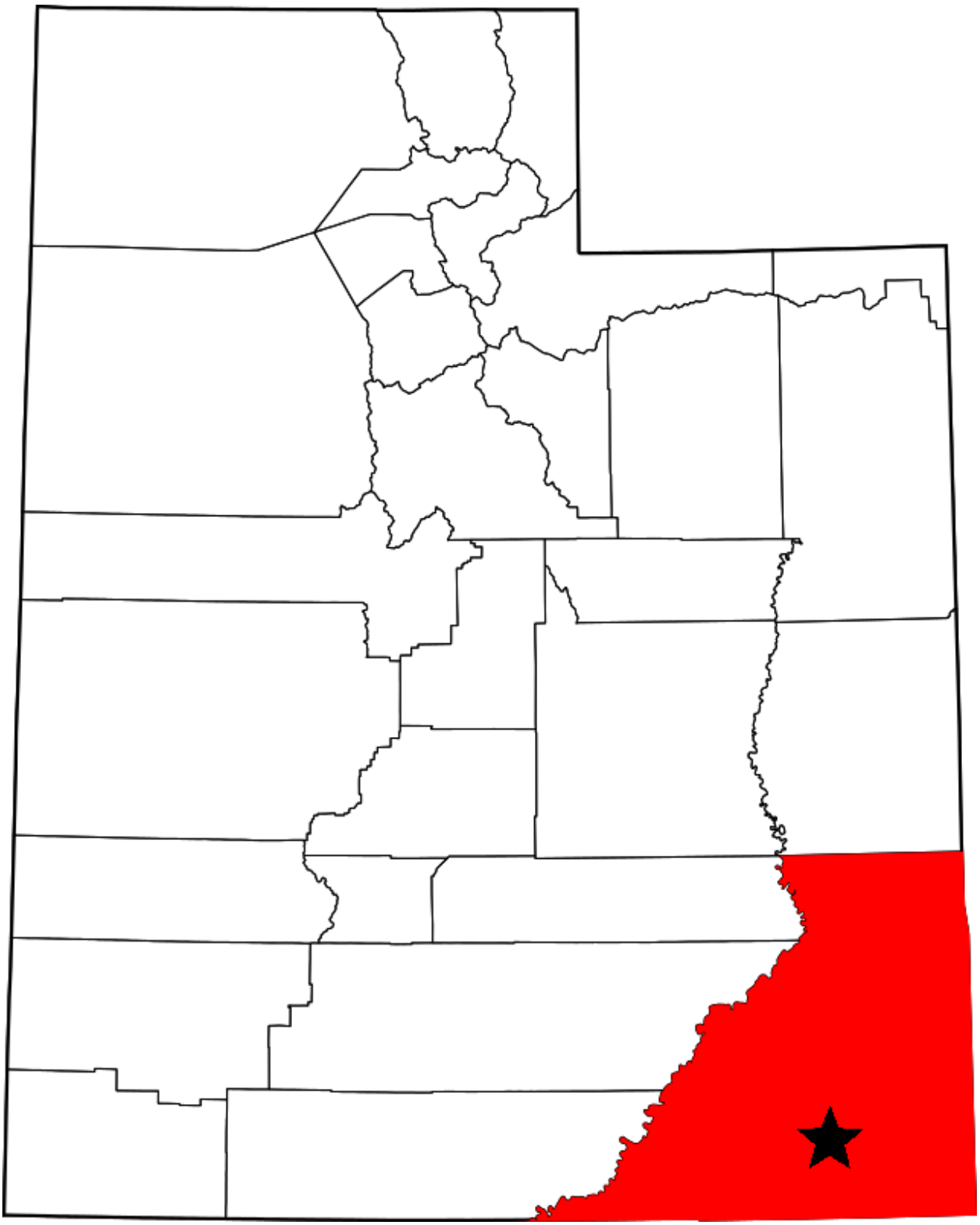

Figure 1: Map showing the location of MNA Locality 1725, The Hills Have Teeth (starred), San Juan County (highlighted), Utah, USA

Figure 2: MNA Locality 1725, showing relative stratigraphic position of MNA V10666 to the surrounding sediments. A) location where MNA V10666 was discovered B) The second author sitting at The Hills Have Teeth (MNA Locality 1724) C) Top of the Chinle Formation at Comb Ridge.

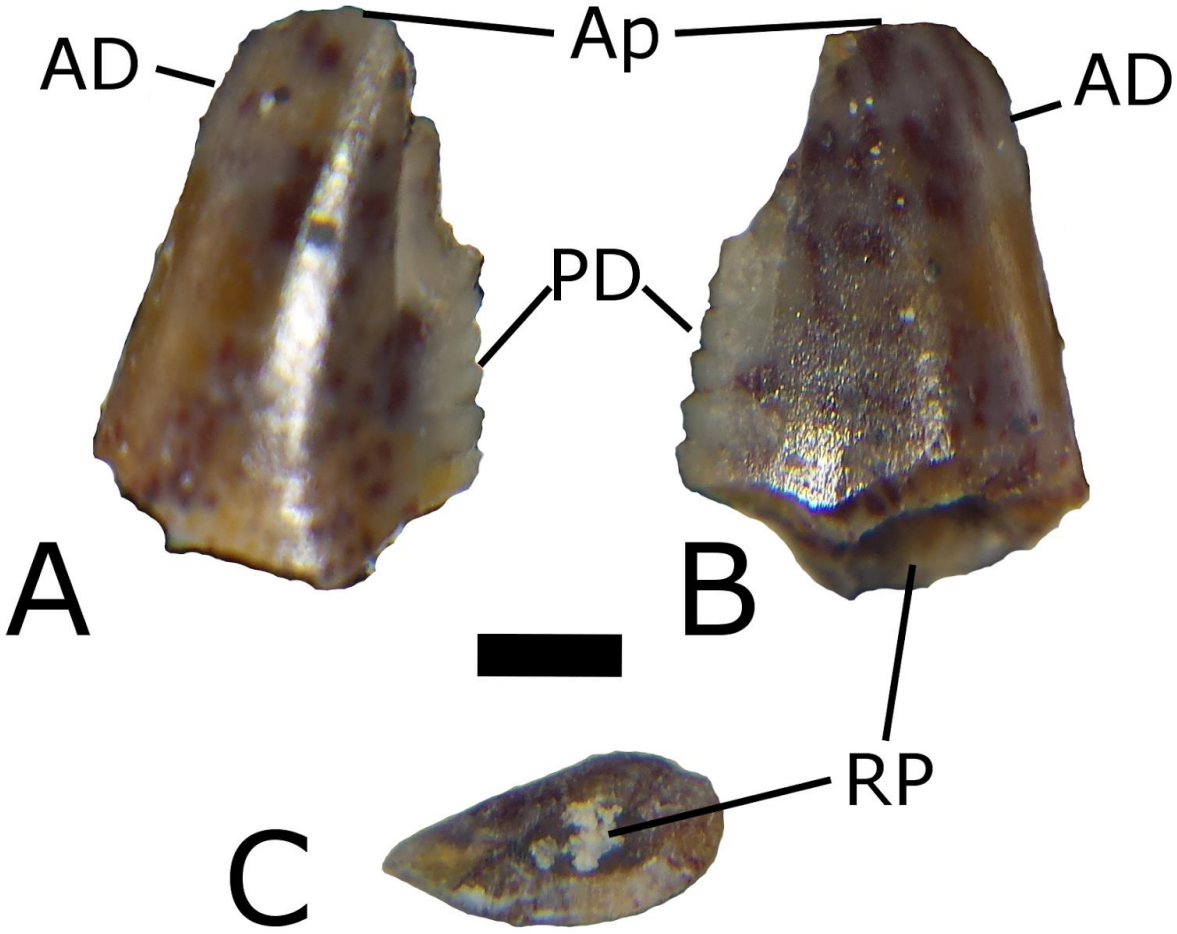

Figure 3: MNA V10666, *Crosbysaurus sp.*, from MNA Locality 1725 in A) presumed left lateral B) presumed right lateral C) basal views. Abbreviations: Ap, apex; AD, anterior denticles, PD, posterior denticles; RP, resorption pit. Scale = 1 mm.

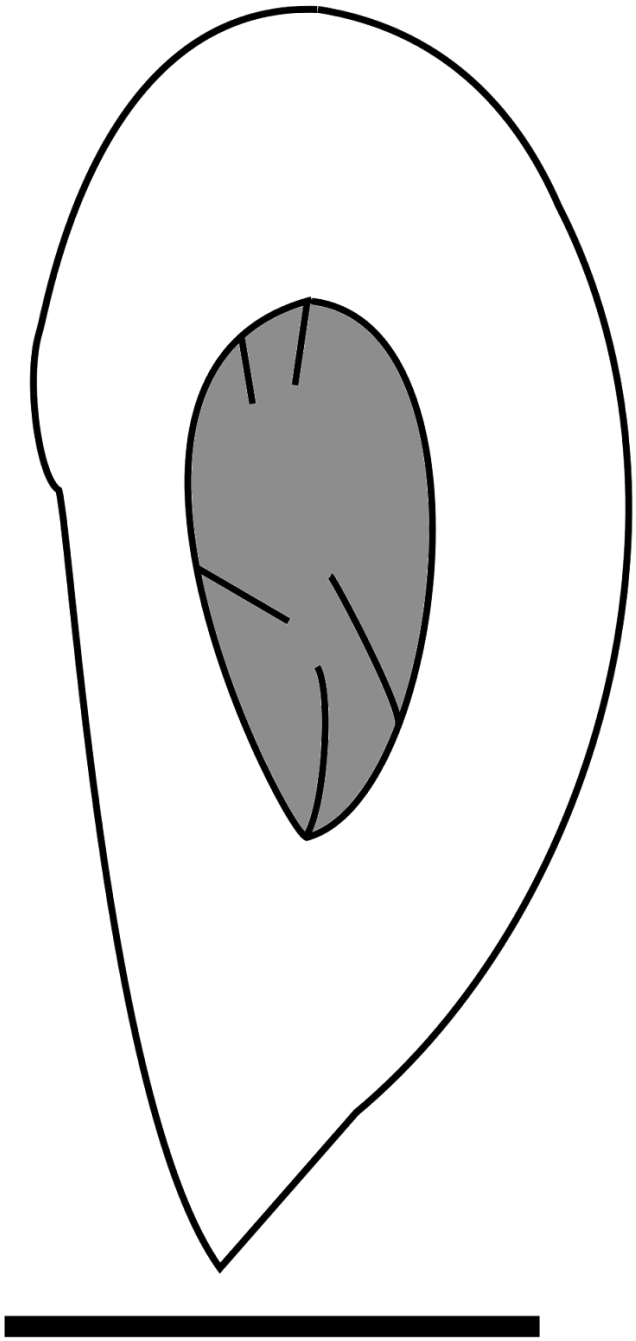

Figure 4: Line drawing of MNA V10666 in basal view. Posterior is towards the bottom of the image. Gray area indicates the resorbtion pit. Scale = 1 mm.

Figure 5: Line drawing of posterior denticles of MNA V10666. Apex is to the right, the base is to the left. Scale = 1 mm.