An unusual ~~archosauromorph~~ archosauriform tooth increases known tetrapod diversity in the lower portion of the Chinle Formation (Late Triassic) of southeastern Utah, USA

Lopez, Andres; St. Aude, Isabella; Alderete, David; Alvarez, David; Aultman, Hannah; Busch, Dominique; Bustamante, Rogelio; Cirks, Leah; Lopez, Martin; Moncada, Adriana; Ortega, Elizabeth; Verdugo, Carlos; Gay, Robert J *.

Mission Heights Preparatory High School, 1376 E. Cottonwood Ln., Casa Grande, Arizona 85122

*rob.gay@leonagroup.com 520-836-9383

Abstract:

An unusual tetrapod tooth was discovered in the ~~Late~~ Upper Triassic Chinle Formation of southeastern Utah. The tooth was originally ~~thought~~ hypothesized to ~~belong~~ pertain to *Revueltosaurus*, but further investigations have rejected that hypothesis. In this paper, we compare MNA V10668 to other known fossil ~~teeth~~ tooth crowns ~~found in~~from the Chinle Formation and ~~identify~~ assign the tooth to the least inclusive clade ~~it may belongs to~~currently available, Archosauriformes, based on the presence of mesial and distal serrations, a distal keel, and a conical mesiodistal profile. Using data found in other publications and pictures of other teeth, we compare this specimen to other Triassic dental taxa. MNA V10668 shares some similarities with *Crosbysaurus*, *Tecovasaurus*, and several other named taxa, including a teardrop-shaped labiolingual profile, but possesses a unique combination of characteristics not found in other ~~diapsid~~ archosauromorph teeth. ~~We conclude that it is most likely an archosauromorph and probably an archosauriform.~~ This increases the known diversity of

Comment [Anon1]: This is unnecessary unless it was published somewhere else?

~~tetrapods~~ archosauromorphs from the Chinle Formation and represents the first tooth of this morphotype ~~completely unique to~~to be found from Utah in the Late Triassic ~~Period~~.

Introduction:

The recovery of vertebrate life from the Permian-Triassic transition resulted in a~~n~~ ~~amazing~~ diverse array of new body forms as life filled ecological voids. This is especially noticeable in the archosaur~~ line diapsids~~omorphs. Many archosauromorph, archosauriform, and archosaurian ~~reptiles~~ reptile-groups ~~adapted and~~ radiated across the globe, filling~~ or creating~~ numerous niches with novel body forms (Nesbitt et al., 2010) and dietary specializations (Heckert, 2004; Parker et al., 2005; Barrett et al., 2011). The ecological revolution of the Triassic Period laid the groundwork for dinosaurs (including modern birds), crocodiles, and mammals to dominate terrestrial vertebrate assemblages for the next 200 million years.

It is perhaps somewhat surprising then that the terrestrial record of the ~~Late~~ Upper Triassic Period from Utah, USA has not reflected the global ~~diversification~~ disparity of tetrapod clades. Some of this may be attributed to the greater attention that Late Triassic deposits in neighboring Arizona and New Mexico have received (e.g., Long and Murr~~a~~y, 1995; Heckert et al., 2005; Parker, 2005; Parker et al., 2006). Until recently (Heckert et al., 2006; Gibson, 2013; Martz et al., 2014) the Triassic vertebrate record published from Utah has mainly consisted of the ubiquitous phytosaurs (Morales and Ash, 1993). This ~~is~~ has especially ~~true~~ been the case when looking only at body fossils~~ only~~. Even with this recent work, Utah's Triassic tetrapod record is low in diversity compared to adjoining states, with the majority of specimens being identified as either phytosaurs or aetosaurs (Martz et al., 2014). While paleontologists were making collections in Utah since at least the late 1800s (e.g., Cope, 1875) most of the collection effort has gone towards finding vertebrate fossils in younger rocks.

Comment [Anon2]: Not entirely, Mike Parrish's work in the 1990s, Yale Universities expeditions in the 2000s, some very early plant work and lots of purported trace fossils. You should just say that Chinle fossils from Utah are not as well known as those from Arizona and New Mexico, thus investigations are important. Parrish 1999; Parker et al., 2006; Gauthier et al., 2011.

In May of 2014 a paleontological expedition to Comb Ridge in southeastern Utah was conducted by Mission Heights Preparatory High School ~~to Comb Ridge in southeastern Utah~~(Figure 1). During the expedition ~~two of the authors (AM and IS) discovered~~ a new, very rich (>300 specimens collected representing 15 taxa in two field seasons) microsite they dubbed "The Hills Have Teeth" (Museum of Northern Arizona Locality 1724), approximately five meters south of~~near~~ a locality that was previously discovered~~ by the senior author (RG)~~. Both at "The Hills Have Teeth" and ~~the alluvial fan~~area immediately adjacent to the west of the hill a dozen partial and complete tetrapod teeth were collected. ~~Most~~ The majority of these teeth belonged to phytosaurs (e.g., MNA V10658, MNA V10659, etc.) and temnospondyls (e.g., MNA V10655, MNA V10656)~~ amphibians~~. Two teeth were notably different ~~from the these~~and not referable to either of the ~~dominant~~ two taxa that dominate the ~~locality~~assemblage. One~~,~~ ~~discovered by IS,~~ ~~is~~ was described elsewhere (Gay and St. Aude, 2015). The other ~~was collected by one of the authors (AM) and defied classification at the time of discovery~~is the subject of this contribution. ~~Since then we have had the opportunity to compare this new specimen to other identified teeth from across the Chinle and Dockum Formations.~~ That ~~speciemen~~specimen, MNA V10668, is compared here to many Triassic diapsids ~~to help classify it~~in order to assign it to a taxon. We compare it to the non-archosauriform archosauromorphs *Azendohsaurus madagaskarensis* (Flynn et al., 2010), *Mesosuchus browni* (Dilkes, 1998), and *Ter~~r~~aterpeton hrynewichorum* (Sues, 2003), several non-archosaurian archosauriforms including *Crosbysaurus harrisae* (Heckert, 2004), ~~*Crosbysaurus sp.* (Gay and St. Aude, 2015),~~ *Krzyzanowskisaurus hunti* (Heckert, 2005), *Lucianosaurus wildi* (Hunt and Lucas, ~~1995~~1994), *Protecovasaurus lucasi* (Heckert, 2004), *Revueltosaurus callende~~a~~ri* (Hunt, 1989), *Tecovasaurus murr~~a~~yi* (Hunt and

Comment [Anon3]: I'm going to suggest again that this tooth be published as part of a broader microvertebrate faunal study as by itself it is not very relevant.

Comment [Anon4]: What is this second locality and why is it relevant?

Comment [Anon5]: Can you abbreviate all future uses or simply refer to it as MNA 1724?

Comment [Anon6]: Are you sure? What characters allow this assignment?

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Comment [Anon7]: Identification?

Comment [Anon8]: But you also compared it to temnospondyls and what about synapsids?

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Comment [Anon9]: You have already noted that it is different than the tooth from the assemblage that was previously described.

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Lucas, 1994), ~~unidentified or~~ unnamed archosauriform teeth (Heckert, 2004), and ~~several~~ various other archosaurs (e.g., Colbert, 1989; Dalla Veccia, 2009; Heckert, 2004).

Materials and Methods:

Standard paleontological field materials and methods were used to collect all specimens from MNA locality 1725, ~~as described in Gay and St. Aude (2015~~including ~~)~~brushes, dental tools, and other small hand tools. Specimens were wrapped in toilet paper and placed in plastic zip-seal bags for transport back to ~~Arizona~~the collection facility. Locality data for MNA ~~V10668~~ 1725 was recorded using Backcountry Navigator Pro running on an Android OS smartphone. ~~It was collected in a zip-seal collection bag after being removed from the surface exposure by a hand.~~ Measurements of MNA V10668 were obtained using a set of Craftsman metal calipers (model 40257) with 0.05mm precision. Figures were created using GIMP 2.8.4. Photos were ~~captured~~ taken with an Olympus E-500 DSLR and PC USB digital microscope. MNA V10668 was collected under Bureau of Land Management permit UT14-001S and is permanently housed at the Museum of Northern Arizona (MNA) along with the exact locality information. Quantitative and qualitative comparisons of MNA V10668 to published photographs, drawings, and descriptions, along with direct comparison to material from the Chinle Formation housed at the MNA were used to assign MNA V10668 to its least-inclusive clade.

Geologic Setting:

MNA V10668 was found at MNA Locality 1725 on the surface of ~~lLower Member member of~~ the Chinle Formation at Comb Ridge, Utah (Figure 1), roughly 6 meters from the base of ~~the~~ a ~~Lower Memberunit~~[describe the unit] along with teeth of phytosaurs (specimen #’s), temnospondyls (specimen #’s), and *Crosbysaurus* sp. (MNA V10666)~~. (Gay & St. Aude 2015) at MNA Locality 1725~~. ~~As with earlier work, we hold that~~The fossil material ~~from~~ found

Comment [Anon10]: What is the spatial error for this device?

Comment [Anon11]: You should have an institutional abbreviations section.

Comment [Anon12]: Float or in-situ?

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at locality 1725 originated at MNA Locality 1724 and has washed down ~~slope from The Hills Have Teeth outcrop, MNA locality 1724~~slope. In May of 2015 the precise fossil-bearing horizon was located at ~~The Hills Have Teeth~~MNA Locality 1724. The fossil-bearing horizon is a ~~fossiliferous~~ light grey mudstone with interspersed carbonaceous clasts ~~and numerous teeth~~ (Figure 2). This mudstone is 13 cm below ~~the~~ a red brown mudstone-grading-to-shale, 8.75 meters above the base of the Chinle Formation (Gay and St. Aude, 2015; figure 4). The fossil-bearing layer, informally referred to as, "the Hills Have Teeth bed," is exposed locally for about half a kilometer in the Rainbow Garden (MNA Locality 1721) area. Preliminary stratigraphic work done in the summer of 2015 shows that this bed is discontinuous. ~~and appears be~~ It is present where the base of the Chinle Formation is exposed ~~all~~ along the western face of Comb Ridge between the Rainbow Garden area and the San Juan River. At the northern end of Comb Ridge the lower ~~member~~portion of the Chinle Formation is dominated by multiple thick (>10 m) channel sandstones and conglomerates. ~~At this time it is unknown if these channel deposits are laterally equivalent to the Hills Have Teeth fossil-bearing bed or whether they are incised into the lower membergrey bed (?) from younger portions of the Chinle Formation.~~

Although the stratigraphy of the Chinle Formation has generally been well studied (e.g., citations), no detailed work has been published on the exposures at Comb Ridge. Superficial work conducted by Bennett (1955), Lucas et al. (1997), and Molina-Garza et al. (2003) have suggested various correlations for the uppermost reddish ~~member~~unit . Most recently, Martz et al. (2014) have ~~suggested that~~assigned the uppermost Chinle Formation at Comb Ridge ~~correlates~~ to the Church Rock Member, as seen in Lisbon Valley to the northeast. We have elsewhere agreed with this correlation (Gay and St. Aude, 2015).

Comment [Anon13]: Is there in-situ material at 1725? Otherwise the fossil is actually from 1724 and should be described as from such, noting that it weathered out. Considering the float to be a new distinct locality is confusing.

Comment [Anon14]: What is in between then? Do you mean that the fossil horizon is 13 cm below the red mudstone?

Comment [Anon15]: Generally geologic units are named for geographical areas or characteristics of the bed. Thus I would suggest rainbow garden bed or grey mudstone bed.

Comment [Anon16]: What is this? Is 1725 and 1724 part of 1721?

Comment [Anon17]: It lenses out.

Comment [Anon18]: Is this an official geographic name?

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Comment [Anon19]: Need to trace this out.

Comment [Anon20]: And what do they consider it to be?

Comment [Anon21]: How far below the Church Rock is your locality?

The ~~lower member~~grey bed is more difficult to correlate with other members of the Chinle Formation exposed in southwestern Utah. The studies mentioned above looked primarily at the upper ~~member~~units of the Chinle Formation. ~~The otherwise very extensive, Stewart et al. (1972) monograph on Chinle sedimentology and stratigraphy did not discuss Comb Ridge in any depth, though they do suggest that it correlates with the Monitor Butte Member but only included one sampling locality ("Comb Wash") without specifying precisely where the formation was observed along Comb Wash. In addition the cross section path provided (Stewart et al., 1972; figure 10) does not approach Comb Ridge or Comb Wash so we cannot assess with confidence their sampling. In the same publication Stewart et al. (1972) state that the Monitor Butte cannot be definitively separated from the overlying Petrified Forest Member (=Church Rock Member of Martz et al. 2014). We disagree with this statement as we find the lower member to be distinct throughout the exposure of Comb Ridge compared to the Church Rock Member. Stewart et al. (1972) also state that the Moss Back Member is found in southeastern Utah interbedded with the Monitor Butte, a condition we do not see at Comb Ridge. The Monitor Butte tends to express on the surface as a more greenish-grey (Stewart et al., 1972) than the blue-grey seen at Comb Ridge but the abundant bentonite in the member supplies the characteristic "popcorn" weathering seen at Comb Ridge and described by Stewart et al. (1972) for the Monitor Butte.~~

Lithologically the lower ~~member~~part of the Chinle Formation at Comb Ridge is dominated by grey to light grey bentonitic muds and shales with rare localized conglomerates and coarse-grained sandstones. These conglomerates tend to be calcium-cemented and are dominated by sandstone clasts, though chert clasts can occur. These resistant beds tend to be clastically homogeneous and are rarely over 2 meters in thickness. At The Hills Have Teeth beds carbonized plant remains are common but have not been noted at other localities within the

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Comment [Anon22]: The lower portion or all of it? My guess would be that your bed is in the Monitor Butte, but more work would need to be done to support this.

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Comment [Anon23]: You are simply providing excuses here. Simply state that your locality is in a grey mudstone x meters below the base of the Church Rock Member (Martz et al., 2014).

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Comment [Anon24]: subjective

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lower member where trenching has been conducted and stratigraphic sections measured whereas both the Kane Springs beds to the northeast and Monitor Butte Member to the south and west preserve abundant carbonized plant fragments and occasional well-preserved plant material (Stewart et al., 1972; Martz et al., 2014).

Biostratigraphy is difficult. The unionid bivalves found in the lower memberpart of the Chinle Formation at Comb Ridge do not allow tight age constraints and no diagnostic vertebrate remains have yet been found outside of *Crosbysaurus* sp. (Gay and St. Aude, 2015). This places the lower memberportion being deposited during the latest Carnian or earliest Norian stages of the Triassic Period (Heckert and Lucas, 2006). While the Kane Springs memberbeds of the Chinle Formation in Lisbon Valley hasve occasional body fossils (Martz et al., 2014), virtually no fossil material outside of the Rainbow Garden/Hills Have Teeth area have been recovered from the lower portion of the Chinle. This is despite extensive prospecting in May and December of 2014, and March, May, and June of 2015.

Fieldwork is ongoing to determine the precise stratigraphic correlation of the lower member gray bed, but at this time we can at least say that MNA V10668, coming from MNA Locality 1724, is from the oldest portion of the Chinle Formation (Gay and St. Aude, 2015) and predates the deposition of the Church Rock Member at Comb Ridge.

Description:

MNA V10668 is a single tooth crown that is labiolingually flattened labiolingually and concial conical in profile. It measures 5 mm apicobasally and 3mm mesiodistally. The distal side of the tooth crown has a continuous serrated edge from the base to the apex. We interpret this to be the distal edge as it presents a more vertical profile when viewed in labial or lingual view. These The distal serrations are 0.1 mm in lengthapicobasally. There are with a density of eight

Comment [Anon25]: This is much more appropriate. Describe but do not assign if you are not sure.

Comment [Anon26]: Identified?

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Comment [Anon27]: But you said that you have phytosaurs and metoposaurs? What do you really mean?

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Comment [Anon28]: Based on what evidence? You just said that you have none. If you have no data just say so concisely in the upper section.

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Comment [Anon29]: Where, all of Utah, Arizona, New Mexico? Again think carefully about what you really mean here.

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Comment [Anon30]: The entire formation?

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serrations per millimeter. ~~with an~~We ~~estimated~~ estimate there are thirty serrations along the entirety of the distal keel. The serrations show increasing wear apically with the apex itself completely worn away during the Mesozoic. We interpret this structure as a wear facet (Figures 3, 4). ~~These~~ The distal serrations are stacked apicobasally and ~~do~~ are not labiolingually staggered as they progress to the apex of the specimen. The mesial side of the crown is missing most of its enamel so identification of features is difficult. None-the-less the dentine does preserve ~~the~~ traces of several apical serrations. It is possible that a pronounced mesial keel existed in this region but there is no evidence of ~~a pronounced keel mesially~~this in the preserved dentine (though this does not rule out the possibility of an enameled keel). The wear on the apex is well rounded with no jagged edges. ~~There is~~Coupled with the fact that no root is preserved and a small resorbtion pit is present on the base~~,~~, we suggest~~ing~~ ~~this~~ that MNA V10668 is a shed tooth crown. The loss of enamel from the majority of the tooth surface does not appear recent, as all the enamel edges are smooth. It is possible that this tooth was digested. Although there is no pitting observed on the preserved enamel surface the dentine shows occasional pitting. We have interpreted these pits as transport damage, but the presence of both coprolites and a digested theropod or rauisuchian tooth (uncatalogued MNA specimen) collected in the 2015 field season do not allow us to rule out this second option. The tooth has a small chip on its base, likely a result of recent weathering and transport due to the freshness of the break, distal to the midline (Figure 3, 4).

Systematic Paleontology:

Diapsida Osborn, 1903

Archosauromorpha Von Huene, 1946

?Archosauriformes Gauthier, 1986

Comment [Anon31]: An actual count isn't possible?

Comment [Anon32]: ?? You mean by tooth wear not from a taphonomic effect?

Comment [Anon33]: Does this poor preservation affect the taxonomic identification?

Comment [Anon34]: What does this mean….not broken? The figured specimen shows that serrations are present on both edges.

Comment [Anon35]: ??

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Comment [Anon36]: If you question this ID, then you can only identify the specimen to Archosauromorpha.

Diagnosis:

~~Teeth from various Triassic animals are common in microvertebrate assemblages and many are difficult to diagnose (Heckert, 2004). This can be due to both plesiomorphic tooth structure across clades as well as variation within tooth rows. None the less,~~ we can diagnose MNA V10668 as being an archosauriform based on the following characters from Godefroit and Cuny (1997): tooth conical in mesiodistal profile with a single cusp and possesses serrations on both the mesial and distal edges. The tooth (at least on the distal edge) possesses an enamel keel and is labiolingually compressed. Since MNA V10668 is a shed tooth crown we cannot assess the character of deep thecodont implantation, though Godefroit and Cuny (1997) regard this as a dubious character in any case.

~~Differential Diagnosis~~Comparisons:

MNA V10668 differs from most described Triassic teeth with serrations ~~on~~ only along one ~~side~~edge. Because ~~this morphology may be due to taphonomic processes discussed above~~the tooth is heavily damaged, we compare MNA V10668 to other ~~diapsids~~ archosauromorphs with thecodont or sub-thecodont dentition with both mesial and distal serrations as well as those only possessing distal serrations.

Azendohsaurus madagaskarensis is an archosauromorph ~~reptile~~ from Madagascar known from reasonably complete remains (Flynn et al., 2010). Its dentition is well documented and illustrated, allowing comparisons to be made ~~easily~~(Flynn et al., 2010). *Azendohsaurus* teeth are slightly recurved with a basal constriction ~~while~~ whereas MNA V10668 appears to be conical with no mesiodistal constriction apical to the base. The teeth of *Azendohsaurus* do not possess

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Comment [Anon37]: Unnecessary. Just provide the diagnosis.

Comment [Anon38]: Tooth is conical (but labiolingually compressed), serrated, and covered in enamel. I don't believe this diagnoses to Archosauriformes. Archosauromorpha given the presumed thecodont implantation.

Comment [Anon39]: You should still be able to tell.

Comment [Anon40]: You can see in the provided figure that there are serrations on both edges of the tooth.

Comment [Anon41]: Where was this discussed?

Formatted: Font: (Default) Times New Roman, 12 pt significant wear facets or worn denticles, as MNA V10668 does. The denticles that exist on the teeth of *Azendohsaurus* are apically directed. In MNA V10668 the preserved distal denticles appear perpendicular to the long axis of the tooth. The denticles of *Azendohsaurus* are also much larger (>0.5 mm) and fewer in number than those of MNA V10668, having between four to 18 on the carinae, depending on tooth position. MNA V10668 ~~clearly does not represent a specimen of~~cannot be assigned to *Azendohsaurus*. Flynn et al. (2010) also report that the teeth of *Azendohsaurus* do not possess wear facets, a feature that is seen in MNA V10668.

Mesosuchus browni is a basal rhynchosaur, deeply nested within A~~a~~rchosauromorpha, (Dilkes, 1998), and is known from ~~multiple specimens~~at least four specimens. The dentition of *Mesosuchus* is rounded in cross-section and conical in profile. The tooth-jaw junction is not well preserved enough to say whether the teeth had thecodont implantation. Dilkes (1998) noted an unusual wear facet on the teeth of *Mesosuchus*, which is why it is included here. Despite MNA V10668 and *Mesosuchus* both having erosional surfaces, those on *Mesosuchus* are mesiolabially directed ~~while~~ whereas in MNA V10668 the wear is mesiobasal. *Mesosuchus* dentition also lacks serrations or denticles. Indeed the mesial and distal faces, as illustrated and described by Dilkes (1998) show teeth round to square in cross section and conical in labial or lingual view. ~~Coupled with the differences in cross-sectional profile~~Taken all together the teeth of *Mesosuchus* are not a good match for ~~,~~ MNA V10668 and as such does not represent a specimen of *Mesosuchus* or any rhynchosaur by extension.

The ~~unusual~~ archosauromorph *Ter~~r~~aterpeton hrynewichorum* from the Triassic of Nova Scotia was first described by Sues (2003). ~~The teeth of *Terraterpeton* are as odd as the rest of its skull.~~ The teeth are round to oval in cross-section, with the posterior-most teeth being much broader labiolingually than mesiodistally. The teeth have a distal triangular cusp and a flattened

Comment [Anon42]: This can be the result of individual variation, even between teeth in the same jaw.

Comment [Anon43]: The type of implantation is known for rhynchosaurs.

Comment [Anon44]: Wear facets aren't a good comparative character.

area mesially on each occlusal surface. The narrow, conical profile and labiolingually compressed cross-section of MNA V10668 strongly differs from the teeth of *Te~~r~~raterpeton* in all these aspects~~, excluding it as the animal that possessed MNA V10668 during the Triassic~~.

Crosbysaurus harrisae (Heckert, 2004) is an archosauriform that has serrations on both mesial and distal sides of the tooth, with the distal serrations being much larger than those on the mesial keel. These denticles are subdivided and on the distal keel they point apically. ~~*Crosbysaurus harrisae* and MNA V10668 have a similar shape and size.~~ Both MNA V10668 and *Crosbysaurus* teeth are similar in size apicobasally and have the same triangular shape in labial and lingual views. *Crosbysaurus* teeth are distally curved on the apicomesial keel, a condition not ~~seen~~ present in MNA V10668.

Comment [Anon45]: Maybe. Should be rediagnosed.

~~MNA V10668 and MNA V10666, referred to *Crosbysaurus sp.* by Gay and St. Aude (2015), were both found at the same locality~~~~. Because of the close association between these two specimens we paid special attention to MNA V10666 when considering the affinities of this new specimen.~~. ~~MNA V10666~~ ~~does~~ ~~lack~~s ~~serrations on the mesiobasal keel, as~~ ~~does~~ ~~MNA V10668~~ appears to as well. ~~That is where the similarities end.~~ ~~The tooth referred to as *Crosbysaurus sp.* by Gay and St. Aude (2015) has clear mesial denticles towards the apex. The distal denticles are much larger and subdivided, as in all other *Crosbysaurus* teeth~~ (Heckert, 2004). ~~While~~ Whereas MNA V10668 is labiolingually compressed like MNA V10666 and other known *Crosbysaurus* teeth, it is not as mesiodistally narrow. Considering that *Crosbysaurus* serrations are larger, present on the mesial side, apically directed, and the teeth tend to be mesiodistally narrower it is doubtful that MNA V10668 is a *Crosbysaurus* tooth.

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Comment [Anon46]: You are not sure?

Krzyzanowskisaurus hunti (Heckert 2005) is a ~~(presumably)~~ small (presumably) herbivorous ~~pseudousuchian~~archosauromorph known only from dental remains. It ~~superficially~~

Comment [Anon47]: Can't tell this just from the teeth.

resembles *Revueltosaurus* *callenderi* but can be diagnosed by the presence of a cingulum on the base of the tooth (Heckert, 2002). Since MNA V10668 does not have a cingulum it ~~is obvious that it~~ cannot ~~be a~~presently be ~~specimen of~~ referred to *Krzyzanowskisaurus*.

Lucianosaurus wildi (Hunt and Lucas, 1995) is similar to other isolated Triassic teeth described in the literature by having enlarged denticles and a squat shape with convex mesial and distal edges, being mesiodistally broad while apicobasally short. MNA V10668 is taller than it is long and has relatively small denticles. MNA V10668 does not represent *Lucianosaurus*.

Protecovasaurus lucasi (Heckert, 2004) is diagnosed by having a recurved mesial surface where the apex is even with or overhangs the distal margin. The denticles on both the mesial and distal keels are apically directed. In all these features the teeth of *Protecovasaurus* do not match the features seen in MNA V10668.

Revueltosaurus *callenderi* (Hunt, 1989; Heckert, 2002; Parker et al., 2005) has serrations on both the mesial and labial sides. Its serrations are proportionally larger and closer together. The teeth of *Revueltosaurus* are broader mesiodistally compared to their apicobasal height. In general, *Revueltosaurus* teeth have more serrations on the distal keel of the tooth than at the mesial side of the tooth. ~~Furthermore, *Revueltosaurus* has been distinguished by more than it's teeth (Parker et al., 2005).~~ MNA V10668 is labiolingually narrower than the teeth of *Revueltosaurus*. These differences rule out the possibility that MNA V10668 is *Revueltosaurus*.

Heckert (2004) described some tetrapod teeth found from other localities across the Chinle Formation. Some of these teeth are from phytosaurs (Heckert, 2004, figure 43). NMMNH P-30806 for example is roughly conical in outline and somewhat labiolingually compressed. The serrations are ~~orientied~~ perpendicular to the long axis of the tooth. In these regards young phytosaur teeth are similar to MNA V10668. Unlike MNA V10668, however, these teeth are

Comment [Anon48]: You are assuming that K. hunti is not heterodont.

Comment [Anon49]: All of the comparisons in this section could have been done in the description of MNA V10668.

moderately curved lingually and have serrations on their mesial surface. In addition the serrations on phytosaur teeth, like ~~the ones~~those figured in Heckert (2004), are ~~more dense~~denser (>14 per millimeter) compared to MNA V10668. Phytosaur teeth in general, especially the teeth from segments of the jaw posterior to the premaxillary rosette, tend to be more robust than MNA V10668. Although phytosaurs are the most common taxa represented at ~~The Hills Have Teeth~~MNA V1724 it not likely MNA V106668 is a phytosaur tooth.

Heckert described another specimen, NMMNH P-34013 (Heckert, 2004, figure 20 A-C), that is roughly the same size as MNA V10668. Both have a resorption pit at the base and, unusual for predatory Triassic archosauriformes, a wear facet on the tip. This is a feature shared with MNA V10668. However the serrations on NMMNH P-34013 are smaller (<0.1 mm) than MNA V10668, and has a slight curve unlike MNA V10668. Heckert described this tooth as belonging to an indeterminate archosauriform~~es~~. Despite their differences this tooth, NMMNH P-34013, is the closest in morphology to the tooth ~~to~~ MNA V10668 yet identified.

~~Based on the examination of an uncatalogued skull cast of the theropod dinosaur *Coelophysis bauri* (Cleveland Museum 31374) at Mission Heights Preparatory High School and from the literature (Colbert, 1989), it can be seen that teeth from the mid-posterior region of the maxilla of *Coelophysis* *Coelophysis* and MNA V10668 have a similar tooth shapemorphology in labial view and sizeapicobasal length. This is especially true for teeth from the mid-posterior region of the maxilla of *Coelophysis*. Both teeth are 5mm tall from the apex to the base. When they are looked at closely many things stand out as to why they are different.~~They differ ~~by~~from *Coelophysis* teeth ~~are~~ being naturally recurved, at least slightly, whereas MNA V10668 does not have a noticeable curve to it. *Coelophysis* teeth (CM 31374; Colbert, 1989) have small serrations along the mesial and distal sides. *Coelophysis* teeth tend to be even more mesiodistally

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compressed and the serrations at the distal side are completely different. *Coelophysis* tooth serrations are smaller and are closer together to each other. We can conclude that ~~-~~MNA V10668 cannot be a *Coelophysis* tooth and indeed is unlikely to be a theropod dinosaur at all. Although the enamel of MNA V10668 is not well preserved, it does not preserve any surface features such as longitudinal grooves, ridges, fluting, or undulations that are characteristic of theropod dinosaur teeth (Hendrickx et al., 2015). In addition, while MNA V10668 is moderately laterally compressed, Triassic theropod dinosaur teeth are compressed even more so (Colbert, 1989).

While pterosaurs are rare from the Triassic of North America, several good examples are known from Europe. Perhaps the best illustrated in terms of dentition is *Austriadactylus* ~~teeth~~ (Dalla Veccia, 2009). ~~and~~ MNA V10668 ~~are completely different~~ differs from *Austriadactylus* in shape and size. *Austriadactylus* teeth are smaller and sharper; also they have serrations at the mesial and labial sides of the tooth. The serrations are completely different because they are larger and possess more distinct tips. *Austriadactylus* has a few different types of teeth. Most teeth are small, have three cusps, and a slight curve to them. Other teeth have only one distinct cusp and have a slight curve to them. They have very few and large serrations. MNA V10668 differs from all of the *Austriadactylus* teeth as it has no visible curve, and serrations along the mesial side. Seeing this, MNA V10668 does not represent *Austriadactylus*.

~~Reported~~ P~~ro~~urported Chinle ~~prosauropod~~ early sauropodomorph teeth, such as those figured in Heckert (2004, figures 45, 83, 84) are extremely mesiolaterally compressed. They also exhibit serrations on the mesial and labial sides of the tooth. Its serrations are relatively larger, closer together, and are apically directed. Also early sauropodomorph ~~prosauropod~~ teeth have a distinctly "pointy" apex with no wear facets. Its shape is completely different ~~because this~~; MNA V10668 is relatively wider labiolingually and apicobasally smaller than the reported early

Comment [Anon50]: Needs a better description.

sauropodomorph ~~prosauropod~~ specimens. There is no ~~possibility that the~~reason to classify this specimen is an early sauropodomorph~~prosauropod~~. It should also be noted that the extreme convergence seen in *Az~~h~~endo~~u~~hsaurus* (Flynn et al., 2010) makes the identification of early sauropodomorphs ~~prosauropods~~ from the Chinle Formation tentative at best (Nesbitt et al., 2007).

~~The~~ Some of the most common vertebrate remains from the Chinle Formation are phytosaur teeth (Heckert, 2004; Martz et al., 2014; pers. obs.). Despite the small size of MNA V10668 it is possible that this specimen pertains to a juvenile phytosaur. To test this hypothesis two ~~juvenile~~ phytosaur snouts identified as juveniles in ~~were examined at the~~the collections at the Museum of Northern Arizona were examined. One of these, PEFO 13890/MNA V1789 was collected by George Billingsley in 1979 from the ~~Upper~~ Petrified Forest Member of the Chinle Formation in Petrified Forest National Park (PEFO). It represents articulated paired premaxillae with 15 preserved alveoli on the right and 14 on the left, all of which save one are empty. The total preserved length of this specimen is 9.3 cm. While identified in collections as ~~*Pseudopalatus*~~ *"Machaeroprosopus" zunii* there are no preserved autapomorphies to support this assignment.

The second specimen, MNA V3601, is a partial right dentary from the Blue Mesa Member (Parker and Martz, 2011 said this not Ramezani et al., 2014) of the Chinle Formation ~~(Ramezani et al., 2014)~~ *Placerias* Quarry, near St. Johns, Arizona identified as *Leptosuchus sp.* (Long and Murry, 1995). MNA V3601 is 4.95 cm in length, preserving the anterior tip and eight alveoli. In this specimen several of the tooth crowns are present and show wear ~~while~~ whereas others are broken off at the ~~gum line~~oral margin or inside the alvelolus.

Comment [Anon51]: But you said above that it does not.

Comment [Anon52]: Not correct as according to Stocker (2010) Leptosuchus occurrences are presently restricted to Texas.

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In ~~both~~ PEFO 13890/MNA V1789 ~~specimens the juvenile phytosaurs exhibit remarkable~~the tooth row exhibits homodonty in the alveolar cross sections (Figure 5). We infer that while crown height may have varied the crowns themselves would have had relatively uniform labiolingual profiles. This is supported by the single unerupted tooth crown present in an alveolus in the right premaxilla. This tooth is lingually curved and symmetrical in mesiodistal profile. The tooth lacks any visible serrations (Figure 6).

Comment [Anon53]: Variation, not true for all juvenile specimens. This could also be because it is not erupted?

In MNA V3601 the erupted crown heights vary but their labiolingual and mesiodistal profiles are remarkably similar (Figure 5)~~,~~. ~~especially~~ This is notable considering the heterodonty ~~seen~~ present in more mature phytosaurs (Heckert, 2004) though we do acknowledge that not having complete juvenile skulls available limits the inferences we can make about overall tooth form. ~~While~~ Whereas MNA V10668 is roughly the right size of tooth to have come from a juvenile phytosaur similar in ontogenetic age to PEFO13890/MNA V1789 or MNA V3601, the basal structure of the tooth is unlike any of the preserved juvenile phytosaur teeth or alveoli. Both undisputed ~~juvenile~~ phytosaur specimens have round alveoli with serrated or unserrated conical teeth preserved (Figure 7, 8~~5~~). In addition, all preserved teeth in MNA V3601 do not show any lingual curvature as seen in MNA V10668. While ~~adult~~ larger phytosaurs, presumed to be ontogenetically more mature, have triangular, lingually curved teeth in their dentition, especially as one moves posteriorally (Long and Murr~~a~~y, 1995; Hungerbühler, 2000; Heckert, 2004), these seem to be absent in juveniles from the preserved portions specimens ~~we have on hand~~observed at the MNA, though additional juvenile phytosaur jaws would help refine our comparison. The lingually curved teeth of adult phytosaurs are also much more robust, with labiolingually wide basal and mid-crown section, unlike the laterally compressed and teardrop-shaped base of MNA V10668. It may be that phytosaur dentition changed during ontogeny to

Comment [Anon54]: Right, so you really cannot do what you are trying to accomplish here.

Comment [Anon55]: Obviously.

adapt to a changing diet, similar to what has been proposed to *Tyrannosaurus* (Horner et al., 2011; Bates and Falkingham, 2012) and is seen today in *Alligator* (Subalusky et al., 2009 and references therein). Even considering this we do not think that MNA V10668 can be assigned to the ~~phytosauria~~ Phytosauria ~~due to~~because of the marked differences between it and all other known phytosaur teeth.

Conclusions:

MNA V10668 cannot be identified as any previously described Triassic taxon as it does not have any distinguishing autapomorphies and ~~preserved~~preserves a unique combination of characters. However, this tooth can be identified at least as A~~a~~rchosauriformes ~~*incertae sedis*~~. MNA V10668 has many ~~characteristics~~ character states that match up with other archosauriformes, including labiolingual compression and the presence of serrations on distinct carinae. Another taxonomically indeterminate tooth, NMMNH P-34013, is the closest tooth morphologically to MNA V10668 and likely belongs to the morphogroup Morphotype T of Heckert (2004).~~.~~ Despite their similarities it is obvious that MNA V10668 is morphologically distinct from NMMNH P-34013, primarily due to the smaller serrations and slight lingual curvature found in NMMNH P-34013. Although isolated teeth have been described before from Utah (Heckert et al., 2006; Gay and St. Aude, 2015) this is the first occurrence of tooth M~~m~~orphotype T described from Utah ~~and the first to not be assigned to an existing genus of Triassic tetrapod~~. It is likely that other teeth now in collections may also represent unique morphotypes or previously described morphotypes not previously identified from Utah. As such it may represent an animal endemic to what is now Utah, though it may also represent a previous identified taxon for which little is known of its dentition.

Comment [Anon56]: Is this a real term?

Comment [Anon57]: Bold claim.

Comment [Anon58]: This is why the material should be covered as an assemblage paper.

Comment [Anon59]: No because Heckert describes it from outside of Utah.

Comment [Anon60]: This makes no sense. You mean nothing is known from the rest of the skeleton. You know the dentition from the tooth.

~~These findings are important since they demonstrate the existence of a previously unrecognized clade of diapsids from the Chinle Formation in Utah. In addition, most of the tetrapod record from Utah's Chinle Formation has come from the Church Rock Member (Martz et al., 2014; RG pers. obs.) This specimen, coming from the Llowerst portionMember of the Chinle Formation, demonstrates increased diversity in an older part of the formation that has not been studied until recently (Gay and St. Aude, 2015).~~

~~Work is ongoing at Comb Ridge by crews from Mission Heights Preparatory High School. The tetrapod diversity of Chinle Formation at Comb Ridge will continue to increase as new discoveries come to light. It is hoped that additional taxa can be added to the growing faunal list assemblage with additional fieldwork in the near future.~~

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Comment [Anon61]: Not true. Parrish, 1999; Parker et al., 2006; Gauthier et al., 2011 all describe vertebrate material from the lower part of the Chinle Formation of Utah.

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