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## A new Lower Triassic ichthyopterygian assemblage from Fossil Hill, Nevada

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We report a new ichthyopterygian assemblage from Lower Triassic horizons of the Prida Formation at Fossil Hill in central Nevada. Although fragmentary, the specimens collected so far document a diverse fauna. One partial jaw exhibits isodont dentition with blunt tipped, mesiodistally compressed crowns and striated enamel. These features are shared with the Early Triassic genus *Utatusaurus* known from coeval deposits in Japan and British Columbia. An additional specimen exhibits a different dentition characterized by relatively small, rounded posterior teeth resembling other Early Triassic ichthyopterygians particularly *Grippia*. This Nevada assemblage marks a southward latitudinal extension for Early Triassic ichthyopterygians along the eastern margin of Panthalassa and indicates repeated circum-oceanic dispersal events in Early Triassic ichthyopterygians.

1 A new Lower Triassic Ichthyopterygian assemblage from Fossil Hill, Nevada

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24 Abstract

25 We report a new ichthyopterygian assemblage from Lower Triassic horizons of the Prida  
26 Formation at Fossil Hill in central Nevada. Although fragmentary, the specimens collected so far  
27 document a diverse fauna. One partial jaw exhibits isodont dentition with blunt tipped,  
28 mesiodistally compressed crowns and striated enamel. These features are shared with the Early  
29 Triassic genus *Utatusaurus* known from coeval deposits in Japan and British Columbia. An  
30 additional specimen exhibits a different dentition characterized by relatively small, rounded  
31 posterior teeth resembling other Early Triassic ichthyopterygians particularly *Grippia*. This  
32 Nevada assemblage marks a southward latitudinal extension for Early Triassic ichthyopterygians  
33 along the eastern margin of Panthalassa and indicates repeated circum-oceanic dispersal events  
34 in Early Triassic ichthyopterygians.

35

36 Main article text

37 Introduction

38 Nevada has been an important source of Triassic marine reptile fossils since the 19<sup>th</sup> Century  
39 producing abundant and well-preserved Middle Triassic (Leidy, 1868; Merriam, 1905, 1908,  
40 1910; Sander et al., 1994, 1997; Fröbisch et al., 2006, 2013) and Late Triassic (Camp 1976,  
41 1980) ichthyopterygian and sauropterygian fossils. Notably Early 20<sup>th</sup> Century field work led by  
42 John Merriam and Annie Alexander at the Fossil Hill locality in the Humboldt Range produced  
43 several specimens of the ichthyosaur *Cymbospondylus* (Merriam 1908)—previously described by  
44 Leidy (1868) on the basis of fragmentary remains—as well as the type specimens of  
45 *Omphalosaurus nevadanus* (Merriam, 1906) and *Phalarodon fraasi* (Merriam 1910). Later work

46 by Camp (1976, 1980), Sander et al. (1994, 1997) and others illuminated rich Middle and Late  
47 Triassic marine reptile assemblages preserved in Nevada.

48

49 In contrast, knowledge of Early Triassic marine reptile fossils in this region is scant. The only  
50 published Early Triassic marine reptile occurrence from Nevada is based on a partial jaw referred  
51 to the enigmatic marine reptile genus *Omphalosaurus* and described as a second species, *O.*  
52 *nettarhynchus* Mazin and Bucher, 1987. This specimen was collected from the Spathian-aged  
53 informally designated “lower member” of the Prida Formation in the Humboldt Range, which  
54 sits immediately below the well-known Fossil Hill Member of the Prida Formation famous for its  
55 rich marine reptile assemblage including the aforementioned *Cymbospondylus*, *Phalarodon* and  
56 *Omphalosaurus nevadanus*. Fragmentary, float-derived remains of Early Triassic ichthyosaurs  
57 have been reported from Spathian horizons in southeastern Idaho (Massare and Callaway, 1994;  
58 Scheyer et al., 2014) roughly 500 km to the northeast of the Fossil Hill locality. Even further to  
59 the east, the early sauropterygian *Corosaurus alcovensis* Case, 1936 is known from the Alcova  
60 limestone in Wyoming whose Early Triassic age was recently confirmed (Lovelace and  
61 Doebbert, 2015).

62

63 Here, we report a new Early Triassic ichthyopterygian assemblage from the “lower member” of  
64 the Prida Formation at the Fossil Hill Locality. These fossils are Spathian (Lower Triassic) in age  
65 based on conodonts and ammonoids and sit stratigraphically below the diverse Middle Triassic  
66 marine reptile assemblage from the Fossil Hill Member of the Prida Formation. These  
67 occurrences extend the southward latitudinal range of early ichthyopterygians in North America  
68 and demonstrate that early in their evolutionary history, multiple ichthyopterygian taxa quickly

69 dispersed around or across wide expanses of ocean and ranged from sub-tropical to high  
70 temperate waters on the eastern margin of northern Panthalassa.

71 *Institutional Abbreviations*. USNM, National Museum of Natural History, Smithsonian  
72 Institution, Washington, D.C., U.S.A.

73

74 Materials and Methods

### 75 **Geological and Stratigraphic Setting**

76 The new fossils reported here were collected from multiple horizons within the unnamed lower  
77 member of the Prida Formation of the Star Peak Group at Fossil Hill, on the eastern flank of the  
78 Humboldt Range in Pershing County, Nevada (Fig. 1). The Star Peak Group consists of a  
79 sequence of syndepositionally deformed carbonate-dominated units deposited on what was then  
80 the western shelf of North America (Nicholls & Silberling, 1977; Wyld, 2000). In the study area,  
81 the lower member of the Prida Formation forms the base of the Star Peak Group and sits  
82 unconformably atop the Permian/Lower Triassic aged Koipato Group volcanics (Wyld, 2000).

83

84 The lower member of the Prida formation transitions from siliciclastic sand and conglomerate  
85 layers near the contact with the underlying Koipato Group to dark-grey limestone above with  
86 intermittent microbialite, conglomerate and chert-dominated beds. The presence of  
87 conglomerates and microbialites indicate relatively shallow conditions with a general trend  
88 towards deeper water facies characteristic of the overlying Fossil Hill Member (Wyld, 2000).

89 Gastropods and bivalves are abundant in lower layers whereas conodonts and ammonoids are  
90 found locally within middle and upper layers of the lower member. Scattered vertebrate fossils  
91 occur in multiple horizons within the lower member (Fig. 1), but are most abundant in the middle

92 carbonate layers where they are associated with the conodont *Triassospathodus symmetricus*  
93 (Orchard, 1995) and the ammonoid *Prohungarites gutstadi* (Guex et al., 2010) indicating a late  
94 Spathian age (Subcolumbites ammonoid biozone).

95 Results

## 96 **Systematic Paleontology**

97 Ichthyopterygia Owen, 1840

98 cf. *Utatusaurus* Shikama, Kamei and Murata, 1978

99

100 **Referred specimen.** USNM 559349 Partial mandible including teeth. (Fig. 2)

101 **Locality.** Fossil Hill, Humboldt Range, Pershing County, Nevada.

102 **Horizon and age.** Found as surface float within an outcrop of Lower Triassic (upper Spathian)  
103 lower member of Prida Formation, Star Peak Group. Based on location and matrix lithology this  
104 jaw is inferred to derive from horizon FH1-7 (Fig. 1), which is Spathian based on the occurrence  
105 of the ammonoid *Prohungarites gutstadi* (i.e. Subcolumbites Zone of Guex et al., 2010) and  
106 conodonts *Triassospathodus symmetricus* (Orchard, 1995) and *Neostrachanognathus* sp.  
107 extracted from the matrix.

108

109 **Description.** USNM 559349 is a partial mandible measuring 82 mm long. The jaw fragment  
110 preserves portions of the dentary, surangular and splenial. The surfaces of the dentary and  
111 surangular are heavily striated and the orientation of these striations differs between the bones.  
112 Judging from the arrangement of the bones, the fragment likely represents a relatively posterior  
113 portion of the left mandibular ramus.

114

115 Thirteen lower teeth are present, along with an additional isolated tooth, which may be either a  
116 disarticulated upper or lower tooth. The teeth are set within alveoli along a continuous groove.  
117 No distinct bony septa between alveoli are visible but may be present at the bottom of the dental  
118 groove, being concealed in matrix that is very difficult to remove through mechanical  
119 preparation. The roots of some teeth are clearly expanded at the base and exhibit plications that  
120 are coarser than crown striation. The most anterior tooth is completely exposed anteriorly,  
121 revealing its root structure inside the dental groove. It is seen there that the root ceases its  
122 expansion once inside the groove, and teeth are embedded to both the labial wall and the base of  
123 the groove. A narrow gap emerges between the lingual wall and the root toward the dentigerous  
124 margin. Tooth implantation is likely subthecodont (*sensu* Motani, 1997a), although histological  
125 study is necessary to firmly establish this. The root cross-section is much wider than long, as  
126 reported for *Utatusaurus hataii* (Motani, 1996).

127

128 Teeth are isodont and conical with striated crowns. Tooth roots are extensively exposed above  
129 the alveolar margin such that they account for half or more of the exposed height of each tooth.  
130 Tooth crowns are distinguished from these exposed roots by a distinct margin and most crowns  
131 are slightly constricted at their base. Some crowns exhibit slightly higher convexity of their  
132 anterior surface relative to the posterior surface given them a slightly recurved appearance. The  
133 teeth are also recurved lingually toward the tip, as clearly seen in the most anterior tooth (Fig  
134 2B). This curvature closely resembles what was described for *Utatusaurus hataii* (Motani,  
135 1996:Fig. 3). The tips of the teeth are relatively blunt. Tooth crowns are approximately 5mm tall  
136 and 1.5mm mesiodistal diameter, spacing between teeth ranges from 3mm to 6mm more widely  
137 spaced teeth may have replacement teeth between them. One 10mm gap along the tooth row



138 likely to represents at least one missing tooth. Several teeth are broken, either at the root or the  
139 crown, revealing a pulp cavity without evidence of infolding of the dentine.

140

141 **Remarks.** The tooth morphology observed in this specimen closely resembles that described for  
142 *Utatusaurus hataii* from the Lower Triassic Osawa Formation of Kitakami, Japan (Shikama et  
143 al., 1978). Most notably, the teeth curve lingually and slightly posteriorly toward the tip, which is  
144 a feature that is uniquely known in *Utatusaurus* among basal ichthyosaurs. Other shared  
145 features include: isodont dentition, tall exposed roots, blunt conical striated crown, slightly  
146 constricted base of some crowns, and absence of infolding in the pulp cavity. No other Early  
147 Triassic or later ichthyopterygian exhibits this suite of dental characters. The teeth of this  
148 specimen do diverge from *Utatusaurus hataii* in their much larger size. The maximum tooth  
149 exposed height in this specimen is 10mm, whereas the maximum crown height and width are  
150 5mm and 1.5mm respectively, compared with 3.3mm, 1.7mm and 0.9mm for the same  
151 measurements in the holotype of *Utatusaurus hataii* (Motani, 1996). However, the holotype  
152 represents a juvenile (Motani, 1997c) so the size difference may partly be explained as age  
153 difference.

154

155 A partial skull from the Lower Triassic Vega Phroso Member of the Sulphur Mountain  
156 Formation from British Columbia, Canada was referred to *Utatusaurus* sp. by Nicholls and  
157 Brinkman (1993), based largely on the presence of the same dental features detailed above. The  
158 teeth of the British Columbia specimen are similar in size to those of the Nevada specimen  
159 described here (Nicholls & Brinkman, 1993) and distinctly larger than those found in the  
160 holotype of *Utatusaurus hataii* from Japan (Motani, 1996). It is therefore possible that these

161 larger-toothed specimens from the eastern margin of Panthalassa (Nevada, British Columbia)  
162 represent a form allied with but distinct from *Utatusaurus hataii*; however more complete  
163 material is needed before this can be confirmed. Recently, Cuthbertson et al. (2014) described  
164 another partial skull from the Vega Phroso Member, which they also referred to *Utatusaurus*  
165 sp., although they concluded that the material originally referred to this genus by Nicholls and  
166 Brinkman (1993) was non-diagnostic at the genus level. Unfortunately this recently described  
167 material lacks a lower jaw or teeth and cannot be compared to USNM 559349.

168

169 Ichthyopterygia Owen, 1840

170 cf. Grippida Wiman, 1929

171

172 **Referred specimen.** USNM 559350 Partial maxilla including teeth. (Fig. 3)

173 **Locality.** Fossil Hill, Humboldt Range, Pershing County, Nevada.

174 **Horizon and Age.** Collected from FH1-5 (Fig. 1) horizon which is Spathian based on the  
175 occurrence of the ammonoid *Prohungarites gutstadi* (Guex et al., 2010) and conodonts including  
176 *Triassospathodus* and *Neostrachanognathus*. This horizon is also characterized by distinctive  
177 spherical structures originally interpreted as microbial (i.e. ‘oncoids’) but more recently  
178 suggested to represent sponge “reefs” (Brayard et al., 2011) see further discussion below.

179 **Description.** USNM 559350 (Fig. 3) is a partial maxilla measuring 20mm and bearing five teeth  
180 exposed in medial view. The teeth are robust cones exhibiting a trend of posteriorly increasing  
181 basal diameter whereas the crown height remains constant giving the posteriormost preserved  
182 tooth a distinctly rounded shape. There is a distinct constriction below the crown separating it  
183 from the root below, however the constriction is very slight in the anteriormost tooth. The

184 anteriormost crown height and width are 1.0mm and 0.7mm respectively; in the second  
185 posteriormost tooth, which is better preserved than the posteriormost tooth, crown width and  
186 height are 2.1mm and 0.9mm. The tooth enamel appears smooth and polished with little  
187 indication of striation, however, this could be attributed to tooth wear. Faint plication is visible  
188 on some roots. Although some teeth are abraded none expose the pulp cavity clearly enough to  
189 determine presence or absence of infolded dentine.

190

191 In medial view the teeth are attached to the lingual wall of the maxilla (pleurodont). An  
192 expanded bone of attachment conceals the bases of the two posteriormost teeth, suggesting the  
193 modified form of pleurodony termed subpleurodony (Motani, 1997a) at least in the posterior  
194 region of the maxillary tooth row. While only a single row of teeth is observed, a shallow  
195 depression on the lingual margin of the tooth row immediately anterior to the second  
196 posteriormost tooth could represent the attachment facet of a missing tooth. If this were the case  
197 it would most likely represent a second row immediately lingual to the preserved teeth. Wide  
198 spacing between the four anteriormost teeth would easily accommodate an additional offset tooth  
199 row as observed in the maxillary dentition of *Grippia* (Motani, 1997b) and *Gulosaurus*  
200 (Cuthbertson et al., 2013).

201

202 **Remarks.** Among Early Triassic ichthyopterygians small, robust teeth similar to those reported  
203 here are typical of the posterior dentition of *Grippia* (Motani, 1997b). Rounded teeth are also  
204 observed in the Early Triassic genus *Chaohusaurus* (Motani & You, 1998) and, to a lesser  
205 extent, *Gulosaurus* (Cuthbertson et al. 2013). *Grippia* was previously reported from the Lower  
206 Triassic Vega Phroso Member of the Sulphur Mountain Formation in British Columbia

207 (Brinkman et al., 1992). This specimen was later redescribed as a distinct taxon, *Gulosaurus*  
208 *helmi* (Cuthbertson et al., 2013) and found to be sister taxon to *Grippia longirostris*. Similarly,  
209 recent work by Ji et al. (in press a), established a new clade Grippioidea including *Grippia*,  
210 *Gulosaurus*, *Utatusaurus Parvinatator* although the precise relationships among these taxa  
211 varied somewhat depending on taxon and character inclusion. The enigmatic marine reptile  
212 *Omphalosaurus nettarhynchus* (Mazin & Bucher, 1987) previously reported from Spathian  
213 Lower Member of the Prida Formation also possesses rounded dentition, but is distinct from this  
214 specimen by its much larger size and in exhibiting a broad pavement of rounded teeth on the  
215 mandible.

216

217 Alternatively this specimen may have some affinity with *Chaohusaurus*, an Early Triassic  
218 ichthyopterygian from China in which some specimens also show distinctly rounded posterior  
219 dentition (Motani & You, 1998), although these teeth are generally smaller and more tightly  
220 packed than in USNM 559350, averaging approximately ten teeth over 20mm rather than the  
221 five teeth observed over the same distance in this specimen. *Chaohusaurus* was previously  
222 regarded as a grippidian partly on the basis of possessing multiple maxillary tooth rows and  
223 rounded posterior dentition (Motani, 1999) however more recent analyses (Cuthbertson et al.  
224 2013, Ji et al., in press a) do not support this placement. Thus the dentition observed in USNM  
225 559350 is strongly suggestive of affinity with other Early Triassic ichthyopterygians but more  
226 precise placement will require more complete skeletal material.

227

228 Discussion

229 Despite the fragmentary nature of the remains described here their resemblance with the  
230 distinctive dentitions of other Early Triassic ichthyopterygians allows tentative comparisons to  
231 be drawn. The presence of *Utatusaurus*-like and *Grippia* or *Chaohusaurus* -like forms suggests  
232 similarity with the Lower Triassic Vega Phroso assemblage from the Wapiti Lake region of  
233 British Columbia, from which *Utatusaurus* (Nicholls & Brinkman, 1993; Cuthbertson et al.,  
234 2014) and Grippidians (Brinkman et al., 1992; Cuthbertson et al., 2013) have also been reported.  
235 However, the type locality of *Utatusaurus* is in the Osawa Formation of Japan (Shikama et al.,  
236 1978), whereas the type localities of *Grippia* and *Chaohusaurus* are in the Vikinghøgda  
237 Formation (= “Sticky Keep Formation” of older references) of Spitsbergen (Wiman, 1929, 1933;  
238 Hounslow et al., 2008) and the Nanlinghu Formation of Anhui Province, China (Young & Dong,  
239 1972) respectively. Thus Early Triassic ichthyopterygian taxa were widely distributed around the  
240 margins of northern Panthalassa (Cuthbertson et al., 2013).

241

242 This broad distribution early in their evolutionary history, from numerous Late Spathian  
243 (Subcolumbites Zone) localities of broadly coeval age (Scheyer et al., 2014), has made it  
244 difficult to pinpoint the biogeographic origins of the group. However, recent work in China has  
245 extended the occurrence of ichthyopterygians down into the underlying Procolumbites Zone  
246 (Motani et al., 2014; Ji et al., in press b). Furthermore, the occurrence of diverse and endemic  
247 hupehsuchians, widely regarded as the ichthyopterygian sister-group and the plesiomorphic  
248 ichthyosauromorph *Cartorhynchus* (Motani et al., 2015) are consistent with an origin of  
249 ichthyopterygians near the south China block in equatorial western Panthalassa.

250

251 The inferred nearshore lifestyle of most Early Triassic ichthyosaurs has led others to propose that  
252 these marine reptiles dispersed along coastlines or across transient epicontinental corridors  
253 (Cuthbertson et al., 2013). However, the biogeographic history of other aquatic and even  
254 terrestrial reptile groups is marked by occasional transoceanic dispersals (e.g. Rocha et al., 2006;  
255 Velez-Juarbe et al., 2007). Brayard et al. (2009) identified trans-Panthalassan distribution  
256 patterns in Spathian ammonoid, with similar ammonoid faunas in Nevada, Kitakami and British  
257 Columbia, which they attributed to oceanographic currents. The occurrence of some Early  
258 Triassic marine reptile taxa (e.g. *Utatsusaurus*) on opposite shores of Panthalassa might reflect  
259 sporadic crossing of deep ocean basins by these lineages, potentially facilitated by the same  
260 ocean currents that mediated transoceanic dispersals of contemporaneous marine invertebrates.  
261 The wide distribution of early Triassic sauropterygians, including the South China Block (Jiang  
262 et al., 2014) and western margin of North America (Storrs, 1991; Lovelace & Doebbert, 2015)  
263 on opposite shores of Panthalassa indicates to a similar dispersal history in the early members of  
264 that marine reptile clade. Isolated terranes such as South Kitakami, South Primoyre and Chulitna  
265 could have served as stepping-stones for shallow marine taxa. Dispersal along coastlines around  
266 the northern margins of Panthalassa remains an alternative scenario that could explain the broad  
267 distribution of Early Triassic ichthyopterygians, however, the apparent absence ichthyopterygian  
268 fossils from high latitudes on the west coast of northern Panthalassa remains a puzzle under this  
269 scenario.

270

271 Intriguingly, the oldest marine reptile bearing horizons at Fossil Hill are associated with a  
272 prominent limestone marker bed bearing distinctive spherical structures ~1–2 cm in diameter  
273 (Fig. 4). We initially interpreted these structures as microbial ‘oncoids.’ Widespread

274 microbialite-dominated facies are characteristic of Lower Triassic strata globally including in the  
275 Western United States (Pruss & Bottjer, 2004; Baud et al., 2007) and are interpreted as a  
276 byproduct of the end-Permian mass extinction and subsequent delayed biotic recovery of  
277 metazoan reefs (Pruss et al., 2004). A similar association between the basal sauropterygian  
278 *Corosaurus* and stromatolites in the Lower Triassic Alcova limestone has been reported  
279 previously (Storrs, 1991). More recently, similar spheroidal structures from the Humboldt Range  
280 and other localities in western North America have been interpreted as ‘transient sponge reefs’  
281 (Brayard et al., 2011). Thus, the diversification and dispersal of Early Triassic marine reptiles  
282 was apparently well underway at the end of the Early Triassic (Scheyer et al., 2014) despite some  
283 lingering signs of continued environmental stress preserved in the same strata. Future work at  
284 this new locality, and elsewhere, may help to clarify the role that large-scale environmental  
285 changes played in shaping the early evolutionary history of Mesozoic marine reptiles.

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289

#### 290 Literature Cited

291 Baud, A., Richoz, S., and Pruss, S. 2007. The Lower Triassic anachronistic carbonate facies in  
292 space and time. *Global and Planetary Change*, 55:81–89.

293 DOI:10.1016/j.gloplacha.2006.06.008

294 Brayard, A., Escarguel, G., Bucher, H., and Brühwiler, T. 2009. Smithian and Spathian (Early  
295 Triassic) ammonoid assemblages from terranes: paleoceanographic and paleogeographic  
296 implications. *Journal of Asian Earth Sciences*, 36:420–433.

- 297 DOI:10.1016/j.jseae.2008.05.004
- 298 Brayard, A., Vennin, E., Olivier, N., Bylund, K. G., Jenks, J., Stephen, D. A., Bucher H.,  
299 Hofmann, R., Goudemand, and N., Escarguel, G. 2011. Transient metazoan reefs in the  
300 aftermath of the end-Permian mass extinction. *Nature Geoscience*, 4:693–697.  
301 DOI:10.1038/ngeo1264
- 302 Brinkman, D. B., Xijin, Z. H. A. O., and Nicholls, E. L. 1992. A primitive ichthyosaur from the  
303 Lower Triassic of British Columbia, Canada. *Palaeontology*, 35:465–474.
- 304 Camp, C. L. 1976. Vorläufige Mitteilung über große Ichthyosaurier aus der oberen Trias von  
305 Nevada. *Sitzungsberichte der Österreichischen Akademie der Wissenschaften*,  
306 *Mathematisch-naturwissenschaftliche Klasse, Abteilung I*, 185:125–134.
- 307 Camp, C. L. 1980. Large ichthyosaurs from the Upper Triassic of Nevada. *Palaeontographica*  
308 *Abteilung A* 170:139–200.
- 309 Case, E. C. 1936. A nothosaur from the Triassic of Wyoming. *University of Michigan*  
310 *Contributions from the Museum of Paleontology* 5:1–36.
- 311 Cuthbertson, R. S., Russell, A. P., and Anderson, J. S. 2013. Cranial morphology and  
312 relationships of a new grippidian (Ichthyopterygia) from the Vega-Phroso Siltstone  
313 Member (Lower Triassic) of British Columbia, Canada. *Journal of Vertebrate*  
314 *Paleontology*, 33:831–847. DOI:10.1080/02724634.2013.755989
- 315 Cuthbertson, R. S., Russell, A., and Anderson, J. 2014. The first substantive evidence of  
316 *Utatusaurus* (Ichthyopterygia) from the Sulphur Mountain Formation (Lower–Middle  
317 Triassic) of British Columbia, Canada: a skull roof description with comparison to other  
318 early taxa. *Canadian Journal of Earth Sciences*, 51:180–185. DOI: 10.1139/cjes-2013-  
319 0185



- 320 Fröbisch, N. B., Sander, P., and Rieppel, O. 2006. A new species of *Cymbospondylus* (Diapsida,  
321 Ichthyosauria) from the Middle Triassic of Nevada and a re-evaluation of the skull  
322 osteology of the genus. *Zoological Journal of the Linnean Society*, 147:515–538. DOI:  
323 10.1111/j.1096-3642.2006.00225.x
- 324 Fröbisch, N. B., Fröbisch, J., Sander, P. M., Schmitz, L., and Rieppel, O. 2013. Macropredatory  
325 ichthyosaur from the Middle Triassic and the origin of modern trophic  
326 networks. *Proceedings of the National Academy of Sciences*, 110:1393–1397. DOI:  
327 10.1073/pnas.1216750110
- 328 Guex, J., Hungerbühler, A., Jenks, J.F., O'Dogherty, L., Atudorei, V., Taylor, D.G., Bucher, H.  
329 and Bartolini, A. 2010. Spathian (Lower Triassic) ammonoids from western USA (Idaho,  
330 California, Utah and Nevada). *Mémoires de Géologie (Lausanne)*, 49.
- 331 Hounslow, M. W., Peters, C., Mørk, A., Weitschat, W., and Vigran, J. O. 2008.  
332 Biomagnetostratigraphy of the Vikinghøgda Formation, Svalbard (Arctic Norway), and  
333 the geomagnetic polarity timescale for the Lower Triassic. *Geological Society of America*  
334 *Bulletin*, 120:1305–1325. DOI: 10.1130/B26103.1
- 335 Ji, C., Jiang, D., Motani, R., Rieppel, O., Hao, W., and Sun, Z. *in press a*. Phylogeny of the  
336 Ichthyopterygia incorporating the recent discoveries from South China. *Journal of*  
337 *Vertebrate Paleontology*.
- 338 Ji, C, C. Zhang, D. Jiang, H. Bucher, R. Motani, and A. Tintori. *in press b*. Ammonoid age  
339 control of the Early Triassic marine reptile from Chaohu. *Paleoworld*. Available online 8  
340 December 2014. DOI: 10.1016/j.palwor.2014.11.009
- 341 Jiang, D., Motani, R., Tintori A., Rieppel O., Chen G., Huang J., Zhang R., Sun, Z. and Ji, C.

- 342 2014. The Early Triassic Eosauropterygian *Majiashanosaurus discocoracoidis*, Gen. Et  
343 Sp. Nov. (Reptilia, Sauropterygia), from Chaohu, Anhui Province, People's Republic of  
344 China. *Journal of Vertebrate Paleontology*, 34(5): 1044-1052. DOI:  
345 10.1080/02724634.2014.846264□
- 346 Leidy, J. 1868. Notice of some reptilian remains from Nevada. *Proceedings of the Academy of*  
347 *Natural Sciences of Philadelphia* 109:177–178.
- 348 Lovelace, D. M., and Doebbert, A. C. 2015. A new age constraint for the Early Triassic Alcova  
349 Limestone (Chugwater Group), Wyoming. *Palaeogeography, Palaeoclimatology,*  
350 *Palaeoecology*, 424:1–5. DOI: 10.1016/j.palaeo.2015.02.009
- 351 Massare, J. A., and Callaway, J. M. 1994. *Cymbospondylus* (Ichthyosauria: Shastasauridae) from  
352 the Lower Triassic Thaynes Formation of southeastern Idaho. *Journal of Vertebrate*  
353 *Paleontology*, 14:139–141. DOI: 10.1080/02724634.1994.10011545
- 354 Mazin, J. M., and Bucher, H. 1987. [*Omphalosaurus nettarhynchus*, une nouvelle espèce  
355 d'Omphalosauridé (Reptilia, Ichthyopterygia) du Spathien de la Humboldt Range  
356 (Nevada, USA)]. *Comptes rendus de l'Académie des sciences. Série 2, Mécanique,*  
357 *Physique, Chimie, Sciences de l'univers, Sciences de la Terre*, 305:823–828. [French with  
358 English Abstract]
- 359 Merriam, J. C. 1905. A primitive ichthyosaurian limb from the Middle Triassic of Nevada.  
360 University of California Publications. *Bulletin of the Department of Geology*, 4:33–38.
- 361 Merriam, J. C. 1906. Preliminary note on a new marine reptile from the Middle Triassic of  
362 Nevada. University of California Publications, *Bulletin of the Department of Geology*  
363 5:75–79
- 364 Merriam, J. C. 1908. Triassic Ichthyosauria, with special reference to the American forms.

- 365           Memoirs of the University of California 1:1–196
- 366 Merriam, J. C. 1910. The skull and dentition of a primitive ichthyosaurian from the Middle  
367           Triassic. University of California Publications, Bulletin of the Department of Geology  
368           5:381–390
- 369 Motani, R. 1996. Redescription of the dental features of an Early Triassic ichthyosaur,  
370           *Utatusaurus hataii*. Journal of Vertebrate Paleontology, 16:396–402. DOI:  
371           10.1080/02724634.1996.10011329
- 372 Motani, R. 1997a. Temporal and spatial distribution of tooth implantation in ichthyosaurs; pp.  
373           81–103 in Callaway, J. M. and E. L. Nicholls (eds.), Ancient Marine Reptiles. Academic  
374           Press, London and New York.
- 375 Motani, R. 1997b. Redescription of the dentition of *Grippia longirostris* (Ichthyosauria) with a  
376           comparison with *Utatusaurus hataii*. Journal of Vertebrate Paleontology, 17:39–44.  
377           DOI: 10.1080/02724634.1997.10010951
- 378 Motani, R. 1997c. New information on the forefin of *Utatusaurus hataii* (Ichthyosauria).  
379           Journal of Paleontology 71:475–479.
- 380 Motani, R. 1999. Phylogeny of the Ichthyopterygia. Journal of Vertebrate Paleontology, 19:473–  
381           496. DOI: 10.1080/02724634.1999.10011160
- 382 Motani, R. and You, H. 1998. Taxonomy and limb ontogeny of *Chaohusaurus geishanensis*  
383           (Ichthyosauria), with a note on the allometric equation. Journal of Vertebrate  
384           Paleontology 18:533-540. DOI: 10.1080/02724634.1998.10011080
- 385 Nicholls, E. L., and Brinkman, D. 1993. A new specimen of *Utatusaurus* (Reptilia:  
386           Ichthyosauria) from the Lower Triassic Sulphur Mountain Formation of British  
387           Columbia. Canadian Journal of Earth Sciences, 30:486-490. DOI: 10.1139/e93-037

- 388 Nicholls, E. L., and Brinkman, D. B. 1995. A new ichthyosaur from the Triassic Sulphur  
389 Mountain formation of British Columbia; pp. 521–535 in W. A. S. Sarjeant  
390 (ed.), *Vertebrate Fossils and the Evolution of Scientific concepts*. Gordon and Breach,  
391 Switzerland.
- 392 Nichols, K. M., and Silberling, N. J. 1977. Stratigraphy and depositional history of the Star Peak  
393 Group (Triassic), northwestern Nevada (Vol. 178). Geological society of America.
- 394 Orchard, M.J. 1995. Taxonomy and correlation of Lower Triassic (Spathian) segminate  
395 conodonts from Oman and revision of some species of *Neospathodus*. *Journal*  
396 *Paleontology*, 69: 110-122. DOI: 10.1017/S0022336000026962
- 397 Owen, R. 1840. Report on British fossil reptiles. Part I. Report of the British Association for the  
398 Advancement of Science, Plymouth,9: 43-126.
- 399 Rocha, S., Carretero, M. A., Vences, M., Glaw, F., and James Harris, D. (2006). Deciphering  
400 patterns of transoceanic dispersal: the evolutionary origin and biogeography of coastal  
401 lizards (*Cryptoblepharus*) in the Western Indian Ocean region. *Journal of Biogeography*,  
402 33(1), 13-22. DOI: 10.1111/j.1365-2699.2005.01375.x
- 403 Pruss, S. B., and Bottjer, D. J. 2004. Late Early Triassic microbial reefs of the western United  
404 States: a description and model for their deposition in the aftermath of the end-Permian  
405 mass extinction. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 211:127–137.  
406 DOI: 10.1016/j.palaeo.2004.05.002
- 407 Sander, P. M., Rieppel, O. C., and Bucher, H. 1994. New marine vertebrate fauna from the  
408 Middle Triassic of Nevada. *Journal of Paleontology*, 68:676–680. DOI:  
409 10.1017/S0022336000026020
- 410 Sander, P. M., Rieppel, O. C., and Bucher, H. 1997. A new pistosaurid (Reptilia: Sauropterygia)

- 411 from the Middle Triassic of Nevada and its implications for the origin of the  
412 plesiosaurs. *Journal of Vertebrate Paleontology*, 17:526–533. DOI:  
413 10.1080/02724634.1997.10010999
- 414 Scheyer, T. M., Romano, C., Jenks, J., and Bucher, H. 2014. Early Triassic Marine Biotic  
415 Recovery: The Predators' Perspective. *PloS one*, 9(3). DOI:  
416 10.1371/journal.pone.0088987
- 417 Schmitz, L., Sander, P. M., Storrs, G. W., and Rieppel, O. 2004. New Mixosauridae  
418 (Ichthyosauria) from the Middle Triassic of the Augusta Mountains (Nevada, USA) and  
419 their implications for mixosaur taxonomy. *Palaeontographica, Abteilung A*, 270:133-162.  
420 DOI: 10.1073/pnas.1216750110
- 421 Shikama, T., Kamei, T., and Murata, M. 1978. Early Triassic Ichthyosaurus, *Utatusaurus*  
422 *hataii* gen. et sp. nov., from the Kitakami massif, Northeast Japan. *Science Reports of the*  
423 *Tohoku University, Sendai, Second Series (Geology)*, 48:77-97.
- 424 Silberling, N. J. 1962. Stratigraphic distribution of Middle Triassic Ammonites at Fossil Hill,  
425 Humboldt Range, Nevada. *Journal of Paleontology*, 153-160.
- 426 Storrs, G. W. 1991. Anatomy and relationships of *Corosaurus alcovensis* (Diapsida:  
427 Sauropterygia) and the Triassic Alcova Limestone of Wyoming. *Peabody Museum of*  
428 *Natural History, Yale University*.
- 429 Vélez-Juarbe, J., Brochu, C. A., and Santos, H. 2007. A gharial from the Oligocene of Puerto  
430 Rico: transoceanic dispersal in the history of a non-marine reptile. *Proceedings of the*  
431 *Royal Society B: Biological Sciences*, 274:1245-1254. DOI: 10.1098/rspb.2006.0455
- 432 Wiman, C. 1929. Eine neue Reptilien-Ordnung aus der Trias Spitzbergens. *Bulletin of the*  
433 *Geological Institution of the University of Upsala* 22: 183-196.

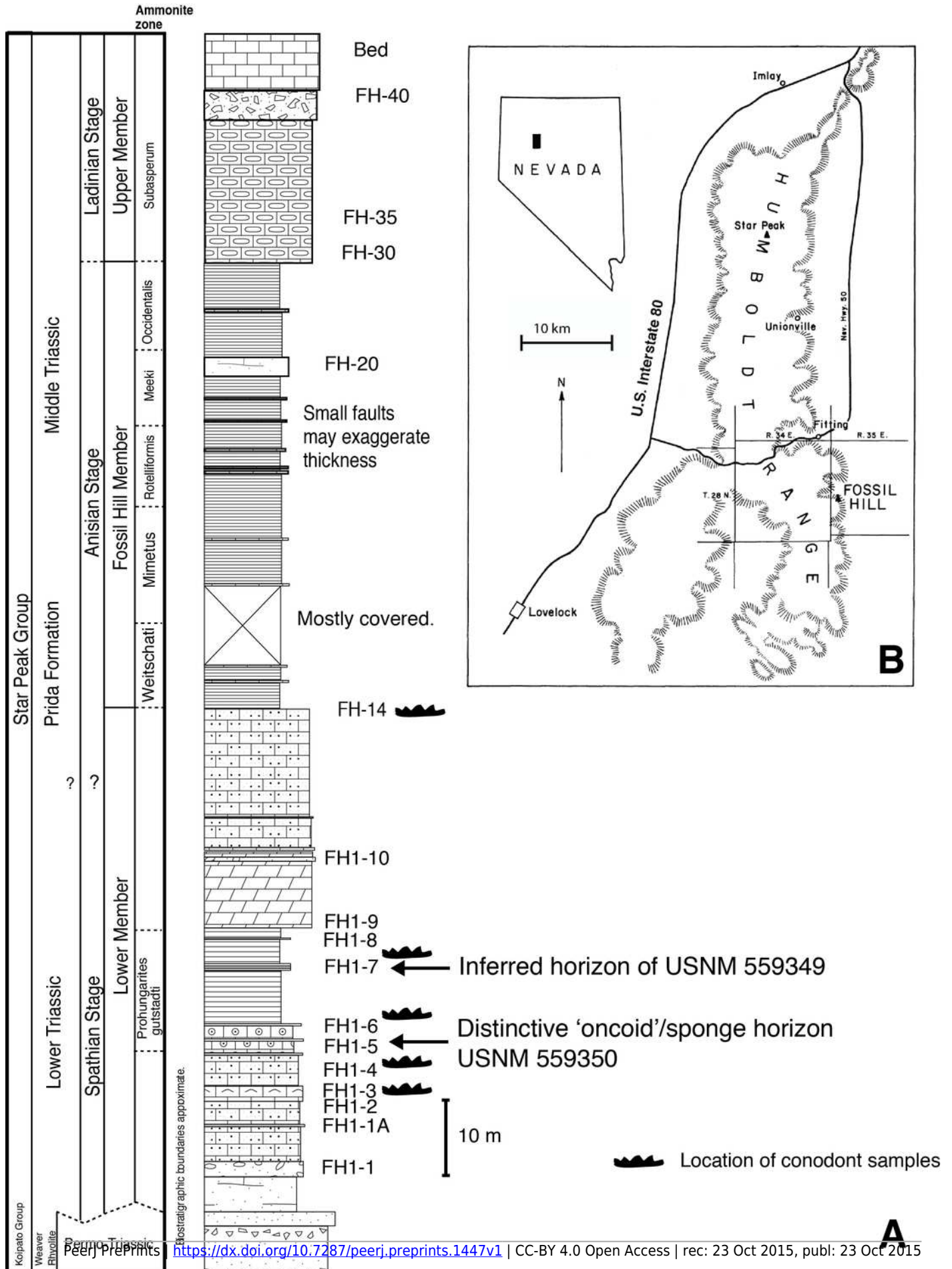
- 434 Wiman, C. 1933. Uber Grippia longirostris. Nova Acta Regiae Societatis Scientiarum  
435 Upsaliensis, ser. 4, 9: 1-19.
- 436 Wyld, S. J. 2000. Triassic evolution of the arc and backarc of northwestern Nevada, and  
437 evidence for extensional tectonism. Special Papers Geological Society of America:185–  
438 208.
- 439 Young, C. C., and Dong, Z. M. 1972. *Chaohusaurus geishanensis* from Anhui  
440 Province. Academia Sinica, Institute of Vertebrate Paleontology and Palaeoanthropology,  
441 Memoir, 9:11–14.

# 1

Summarized stratigraphy and regional map

(A) Stratigraphy of the Triassic Prida Formation near Fossil Hill in the Humboldt Range, Nevada indicating horizons of specimens USNM 559349 and 559350 and conodont samples.

(B) Regional map, modified from Silberling (1962).





## 2

Specimen USNM 559349, partial ichthyopterygian jaw cf. *Utatsusaurus*.

(A) Complete specimen, in labial view, anterior to the left. Squares on scale bar equal 5 mm.

(B) Magnified view of anterior dentition, squares on scale bar equal 1 mm.



**B**

3

USNM 559350 Partial ichthyopterygian maxilla cf. *Grippidia*.

Partial maxilla in lingual view, anterior to the left. Squares on scale bar equal 1 mm. White arrow indicates possible attachment facet for tooth in second lingual tooth row.



## 4

Distinctive sedimentary structures associated with horizon of USNM 559350

Spherical structures in FH1-5 that may represent microbial structures or sponges. This appears to be a widespread and distinctive regional Lower Triassic facies associated with recovery from the end-Permian mass-extinction. Vertebrate fossils also occur in this horizon including USNM 559350 described here. Hammer for scale is approximately 30 cm in length.

