

Revision of tyrannosaurid specimen census and comments on dinosaur biostratigraphy.

Comment on: TAKING COUNT: A Census of Dinosaur Fossils Recovered From the Hell Creek and Lance Formations (Maastrichtian).

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INTRODUCTION

There has been considerable debate about whether the extinction of non-avian dinosaurs occurred gradually or suddenly. Stein (2019) brought a census of dinosaur fossils from the Upper Maastrichtian Hell Creek and Lance formations and concluded that there are considerable amounts of dinosaur fossils from these strata, which support the sudden extinction of dinosaurs. Herein, I make several revisions on the appendix presented by Stein (2019) and comment on the stratigraphic range of several dinosaur taxa. However, it is likely that comments made here do not significantly impact the original conclusion.

REVISION ON THE TYRANNOSAURID SPECIMEN CENSUS

Herein, a preliminary revision of the “FOREIGN MUSEUMS AND INSTITUTIONS” appendix made by Stein (2019) is presented. Note, however, that this revision is only made on the specimen census of tyrannosaurid specimens in Japanese museums so the effect of this revision only minimally expands the number of specimens. Moreover, Stein (2019) also noted that the data presented by him should be considered the minimum number and not the actual number. Therefore, I agree with Stein (2019) that the actual numbers are likely considerably higher.

The National Museum of Nature and Science, Tokyo has two catalogued specimens of *Tyrannosaurus rex*: NSM PV 23851 and NSM PV 23852. Parts described in each specimen are “teeth”, so it is possible that they consist of multiple specimens. While most individual *Tyrannosaurus* teeth consist of shed and not rooted teeth, they still constitute an important resource to help us understand diversity and could probably affect the census since most animals did not otherwise leave a record of their existence.

The Kanagawa Prefectural Museum of Natural History has two specimens of Maastrichtian tyrannosaurid teeth (Mitsuharu Oshima, pers. comm., January 2019): KPM-NNV000003 (“*Nanotyrannus lancensis*” tooth found in Harding County, South Dakota) and KPM-NNV101014 (*Tyrannosaurus rex* tooth found in Montana). Based on the geographic information, it is very likely that these teeth are from the Hell Creek or Lance Formations.

One important natural history museum/science institute neglected by Stein (2019) is Ibaraki Nature Museum. The museum has one *Tyrannosaurus rex* tooth specimen, catalogued in the Collection Database as INM-4- 385.

COMMENTS ON THE DINOSAUR BIOSTRATIGRAPHY PRIOR TO K-Pg EXTINCTION EVENT

To estimate the dinosaur diversity just prior to Cretaceous-Paleogene extinction event, Stein (2019) catalogued dinosaur specimens ranging throughout the Hell Creek and Lance Formations. However, strata from both formations which bear dinosaur remains, span less than 1 Ma (Lehman et al., 2006; Fowler, 2017), and several cases of dinosaur faunal changes were reported.

Recently, it was found that two currently recognized species of Triceratops (*T. horridus*, *T. prorsus*) are stratigraphically separated and represent an anagenetic lineage. *T. horridus* is found in the lower half of the formation, while *T. prorsus* is found in the upper third of the formation (Scannella et al., 2014). Therefore, *T. horridus* became extinct more than 1Ma year prior to the K-Pg extinction event, so its specimens are irrelevant to dinosaur diversity just prior to the extinction event.

Although detailed stratigraphic information of many specimens of *Pachycephalosaurus* and *Stygimoloch* are missing (Saurian, 2016), certain specimens of *Pachycephalosaurus* and *Stygimoloch* are stratigraphically separated (Fowler, 2017). Specimens of *Pachycephalosaurus* with detailed stratigraphic data are from the lower part of the Hell Creek Formation, while *Stygimoloch* specimens are from the upper layers (Fowler, 2017). Therefore, it is possible that *Pachycephalosaurus* was extinct prior to the extinction event and also may not be relevant to dinosaur diversity just prior to K-Pg extinction. Many specimens of other dinosaur taxa in the Hell Creek fauna lack detailed stratigraphic information, so a detailed, future survey is warranted.

Based on these cases and to minimize potential errors, I recommend counting only the specimens from the upper deposits of the upper Maastrichtian formations to estimate the true diversity of dinosaurs just prior to extinction event in order to discover if the extinction of dinosaurs was gradual or sudden. However, this approach is preliminary because the absence of specimens might just reflect preservational bias or lack of publication rather than extinction of taxa. For example, *Torosaurus latus* was assumed to be present only in the lower deposits of the Hell Creek assemblage (Scannella et al., 2014) but recently, specimens of this species were reported from the upper third of the Hell Creek Formation (McDonald et al., 2016).

CONCLUSION

Several Japanese museums have specimens of *Tyrannosaurus rex* and “*Nanotyrannus lancensis*”, which expand the number originally provided by Stein (2019). Moreover, some taxa from the Hell Creek fauna became extinct much before the main extinction event (*Triceratops horridus*, possibly *Pachycephalosaurus*) so there could be a potential exaggeration of diversity of dinosaur taxa in the latest Maastrichtian. Therefore, I recommend using only specimens from the upper deposits for studies dealing with dinosaur diversity before the extinction.

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