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Forum Comment

Direct U-Pb dating of Cretaceous and Paleocene dinosaur bones, San Juan Basin, New Mexico

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Fassett et al. (2011, herein) analyzed fossil bone fragments from the San Juan Basin of New Mexico and claim to have achieved the "first successful direct dating of fossil vertebrate bone" (p. 159). This claim is asserted to establish the survival of dinosaurs into the Paleogene, thus supporting a view championed by J. Fassett for nearly 30 years (Fassett, 1982). This would be a unique discovery if valid and, consequently, the burden of proof is high. Unfortunately, the data presented by Fassett et al. are unconvincing for several reasons.

The samples were fossils, not bones composed of unaltered hydroxyapatite, and as such they have been open systems whose uranium and lead uptake/leaching histories are conjectural. Uranium typically adsorbs preferentially in dinosaur bones buried within the local water table (Gillette, 1994), and many elements are drawn from surrounding sediments during fossilization (Goodwin et al., 2007, and references therein). The best that can be hoped for, if the isotopic composition of non-radiogenic lead is known and early absorbed uranium and its radiogenic lead are quantitatively retained (none of which is demonstrated by Fassett et al.), is that a minimum age for the bone can be postulated. How closely such a minimum age coincides with the pre-mortem age of the animal or with the depositional age of entombing sediments depends on many taphonomic variables, sediment geochemistry, groundwater flux history, and the porosity of fossil bone.

Both samples analyzed (22799-D and BB1) are fossil bone fragments rather than articulated fossil skeletons and are therefore suspect *a priori* of being reworked. Failure to recognize faunal reworking of isolated dinosaur teeth in the uppermost Hell Creek Formation of northeastern Montana resulted in a similar conclusion that dinosaurs survived into the Paleocene. Detailed stratigraphic and faunal analysis (Fastovsky and Dott, 1986; Lofgren, 1995) disproved this sensational claim, and the so-called "Bug Creek Problem" is considered by most workers to be resolved.

Decades of fieldwork above the Cretaceous-Paleogene boundary in the Western Interior has produced dozens of articulated skeletons and/or skulls of champsosaurs, crocodilians, lizards, turtles, and mammals firmly in place in Paleocene sediments. To date, no dinosaur skulls, skeletons, or nests—fossils unlikely to survive reworking unrecognized—are recorded in museum collections across North America from these or contemporaneous formations (www.paleodb.org; ucmpdb.berkeley.edu; muse.museum.montana.edu/paleodb_pub/; collections.nmnh.si.edu/search/paleo/). A long term, multi-institutional field study (1999–2009) of the geology and paleontology of the Hell Creek Formation produced no evidence of non-avian dinosaurs in situ above the Cretaceous-Paleogene boundary (Horner et al., 2011).

As in the "Bug Creek Problem," it is entirely possible that the fossil fragments studied by Fassett et al. were reworked postmortem. U-uptake may have occurred at any time postmortem and could have continued during its subsequent history. There is no way to prove, based on the data presented, that this was not the case. After highly subjective data selection, Fassett et al. interpreted a U/Pb age of the control sample (22799-D) to be in agreement with a $^{40}Ar/^{39}Ar$ age for a volcanic ash bed at "virtually the same stratigraphic level" (p. 159) some 3.5 km away. Terrestrial facies can change dramatically over such distances, and chronostratigraphic correlation on even much shorter length scales can be difficult—a lesson of the "Bug Creek Problem." Even if the correlation is correct, a reworked fossil fragment could easily acquire a U/Pb age coeval with deposition, which would have little bearing except as a one-sided constraint on the pre-mortem age of the bone. The two oldest inferred, but rejected, ages for sample 22799-D could be an indication that uranium uptake began prior to 80 Ma, long before the interpreted depositional age, and therefore indicate that the fossil fragment was reworked.

The data of Fassett et al. support their conclusions if and only if highly subjective data interpretation is employed. Even if such data could be used to date early postmortem diagenesis, taphonomic and stratigraphic evidence must be used to establish that the age of U-uptake places a valid constraint on the age of the animal. The claim for Paleocene dinosaurs in this case is simply not credible based on the evidence presented.

REFERENCES CITED

Fassett, J.E., 1982, Dinosaurs in the San Juan Basin, New Mexico, may have survived the event that resulted in creation of an iridium-enriched zone near the Cretaceous-Tertiary boundary, *in* Silver, L.T., and Schultz, P.H., eds., Geological Implications of Impacts of Large Asteroids and Comets on the Earth: Geological Society of America Special Paper 190, p. 435–447.

Fassett, J.E., Heaman, L.M., and Simonetti, A., 2011, Direct U-Pb dating of Cretaceous and Paleocene dinosaur bones, San Juan Basin, New Mexico: Geology, v. 39, p. 159–162, doi:10.1130/G31466.1.

Fastovsky, D.E., and Dott, R.H., Jr., 1986, Sedimentology, stratigraphy, and extinctions during the Cretaceous-Paleogene transition at Bug Creek, Montana: Geology, v. 14, p. 279–282, doi:10.1130/0091-7613(1986)14<279:SSAEDT>2.0.CO;2.

Gillette, D.D., 1994, Seismosaurus: The Earth Shaker: New York, Columbia University Press, 205 p.

Goodwin, M.B., Grant, P.G., Bench, G., and Holroyd, P.A., 2007, Elemental composition and diagenetic alteration of dinosaur bone: Distinguishing micron-scale spatial and compositional heterogeneity using PIXE: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 253, p. 458–476, doi:10.1016/j.palaeo.2007.06.017.

Horner, J.R., Goodwin, M.B., and Myhrvold, N., 2011, Dinosaur census reveals abundant *Tyrannosaurus* and rare ontogenetic stages in the Upper Cretaceous Hell Creek Formation (Maastrichtian), Montana, USA: PLoS ONE, v. 6, no. 2, e16574, doi:10.1371/journal.pone.0016574.

Lofgren, D.E., 1995, The Bug Creek Problem and the Cretaceous-Tertiary Transition at McGuire Creek, Montana: Geological Sciences, v. 140: University of California Press, 185 p.