Radiocarbon in Dinosaur Bones Revisited: Problems with Collagen

Philip J. Senter

Abstract
Evidence from isotopes other than radiocarbon shows that dinosaur fossils are millions of years old. Despite that, bone mineral from Mesozoic dinosaur fossils yields a falsely young radiocarbon “date” of less than 50,000 years, due to its accumulation of new radiocarbon via recrystallization. Similarly, the so-called collagen fraction of Mesozoic fossil bone (actually the total organic fraction) yields a falsely young “date,” due to the presence of organic contaminants, including glue that is added during fossil excavation. The contaminants are responsible for the falsely young radiocarbon “date.” That problem can be overcome by the HYP method: subjecting only the hydroxyproline (the part of the “collagen” fraction that is specific to collagen) in the “collagen” fraction to radiocarbon dating. Science educators need to be aware of the details of these phenomena, so as to be able to advise students whose acceptance of biological evolution has been challenged by young-Earth creationist arguments that are based on radiocarbon in dinosaur bone “collagen.”

Key Words: dinosaurs; creationism; radiocarbon; collagen; recrystallization; carbonate; contamination; fossilization.

Radiocarbon (¹⁴C) has a half-life too short for measurable amounts of original radiocarbon to remain in fossils that are millions of years old. Despite that, young-Earth creationist (YEC) teams have subjected Mesozoic dinosaur bones to radiocarbon dating and found enough radiocarbon in the bones to yield radiocarbon “dates” of less than 50,000 years. In most cases, the “dates” are between 20,000 and 40,000 years (Dahmer et al., 1990; Fields et al., 1990; Helfinstine & Roth, 2007; Thomas & Nelson, 2015; Miller et al., 2019). As a result, YEC authors now argue in an ever-increasing number of books and DVDs that radiocarbon in dinosaur fossils demonstrates that the fossils have since accumulated new radiocarbon, which yields a falsely young radiocarbon “date.”

When contamination with new radiocarbon produces a falsely young radiocarbon “date,” that “date” does not exceed 50,000 years. If one observes a graph of the curve that expresses the ratio between a sample’s actual age and the falsely young radiocarbon “date” that contamination causes, one sees that the curve flattens at a little over 40,000 years of actual age (e.g., Figure 3 in Wood, 2015). This means that whether a sample is 50,000 or 50 million years old, a given level of contamination will yield the same falsely young “date.” For example, if 99% of a fossil bone’s radiocarbon is original and 1% of it is new, that level of contamination will yield a falsely young “date” of 35,000 years for a 50,000-year-old bone, and it will also yield the same falsely young “date” of 35,000 years for a 50-million-year-old bone, or a 500-million-year-old bone (Wood, 2015). One therefore expects false radiocarbon “dates” of a few tens of thousands of years for Mesozoic dinosaur bone. That is because both the mineral fraction and the collagen fraction of fossil bone are prone to contamination with new radiocarbon. The only way to get around the problems posed by contamination in both fractions is to use a procedure that is designated by the abbreviation HYP, described ahead. None of the YEC teams that subjected Mesozoic dinosaur bone to radiocarbon dating...
used the HYP procedure. As I will explain below, this means that all the radiocarbon “dates” that they found for Mesozoic bone are falsely young.

For science educators and students, appropriate responses to YEC arguments regarding radiocarbon are not always at hand, because the finer details of radiocarbon dating and the fossilization process that show how radiocarbon in dinosaur bones is consistent with an age of millions of years are not widely known outside the circle of specialists in radiometric dating. In a previous article in The American Biology Teacher (Senter, 2020), I attempted to alleviate that difficulty for science educators and students, by explaining how problems with the mineral fraction of fossil bone cause it to yield a falsely young radiocarbon “date.” Unfortunately, in that article, I did not address the problems with the collagen fraction of fossil bone that cause the collagen fraction to similarly yield falsely young radiocarbon “dates.” It would be helpful to review such problems with the collagen fraction, and it is of particularly timely importance, now that YEC researchers have reported radiocarbon “dates” from the collagen fraction of several dinosaur bones, thereby avoiding the problems with the mineral fraction (Miller et al., 2019). Here, therefore, I present an overview of the relevant details, so as to arm science educators and their students with the information they need to recognize such YEC misinterpretations as incorrect.

**Review of Problems with Fossil Bone Mineral**

To explain the problems with radiocarbon dating of the mineral fraction of fossil bone, it will be helpful to review some background material: the basics of radiocarbon dating and the problems with the mineral fraction of fossil bone. Radiocarbon has a short half-life of only about 5700 years, so it is useful only for dating materials younger than about 50,000 years (van der Plicht & Palstra, 2016). Mainstream scientists therefore do not use radiocarbon dating for fossil bone older than the latest part of the Pleistocene Epoch—which began about 2.58 million years ago and ended about 11,800 years ago (Ogg et al., 2016). Most Pleistocene fossils are too old to date with radiocarbon, but radiocarbon can be used to date those that are less than 50,000 years old.

Mainstream scientists do not use radiocarbon to date Mesozoic fossils, because radiometric dating of Mesozoic strata using radioisotopes other than radiocarbon (e.g., $^{238}\text{U}/^{206}\text{Pb}$, $^{235}\text{U}/^{207}\text{Pb}$, $^{87}\text{Sr}/^{86}\text{Sr}$, $^{40}\text{K}/^{40}\text{Ar}$, $^{40}\text{Ar}^{39}\text{Ar}$) shows that the sediments that entomb Mesozoic fossils are between 65 million and 251 million years old (Gradstein et al., 2005), far too old for any measurable amount of original radiocarbon to remain in them. However, over the millennia, the fossils accumulate new radiocarbon, enough of it to yield a false radiocarbon “date” of thousands, not millions, of years.

The concentration of radiocarbon in bone drops as the radiocarbon undergoes radioactive decay and as the bone loses organic material to decay. In most organic materials (e.g., animal skins, plant fibers), the death of the organism can therefore be dated by measuring the amount of remaining radiocarbon. However, when it comes to radiocarbon, bone behaves differently from other materials. In buried bone, the initial drop in radiocarbon is later offset as bone gains new radiocarbon from its environment. In buried bone, new carbonate (with new radiocarbon) is added to the bone mineral in three ways: permineralization, encrustation, and recrystallization. Permineralization occurs as bacteria precipitate calcite (a form of CaCO$_3$) and other minerals into voids where osteocytes (bone cells) and blood vessels had been but have decayed away (Wings, 2004; Carpenter, 2005). Encrustation occurs as carbonates and other ions precipitate from groundwater onto the external and internal surfaces of bone, creating mineral crusts (Pfretzschner, 2004; Wings, 2004). Recrystallization occurs as carbonates and other ions precipitate from groundwater onto the bone, replacing the ions in the bone mineral (Pfretzschner, 2004; Pfretzschner & Tütken, 2011; Kendall et al., 2018). During recrystallization, some of the calcium in bone mineral is replaced by uranium and other ions, and some of the phosphate in bone mineral is replaced by carbonate and other ions (Pfretzschner, 2004). Replacement of the phosphate with carbonate occurs on a large scale in carbonate-rich environments (Fernández-Jalvo et al., 2016).

The new carbonate and other contaminants that arrive via permineralization and encrustation can be removed with certain pretreatment procedures (Cherkinsky, 2009; Zazzo & Saliege, 2011). But the carbonate that has arrived via recrystallization is trapped in the crystal structure of the bone mineral. The bone mineral is therefore irreversibly stuck with this contaminant, which contains new radiocarbon that is derived from the dissolution of atmospheric CO$_2$ into rainwater and groundwater (Olsen et al., 2008; Zazzo, 2014). This new radiocarbon causes bone mineral to yield falsely young “dates” (Senter, 2020).

In uranium-rich environments, recrystallization introduces uranium into the crystal structure of buried bone. The uranium is another source of radiocarbon, because radioactive emissions from $^{238}\text{U}$ add new radiocarbon by converting certain other isotopes into radiocarbon (Jull et al., 1985; Bonvicini et al., 2013), and some of the daughter isotopes of $^{238}\text{U}$ themselves emit radiocarbon nuclei during radioactive decay (Ronen, 1997; Bonvicini et al., 2013). Buried bone readily takes up uranium via groundwater (Hedges & Millard, 1995) and concentrates it, so fossil bone usually has a higher uranium content than the surrounding sediment (Goodwin et al., 2007; Kiseleva et al., 2019). In uranium-rich environments, uranium also contaminates materials other than fossil bone (e.g., petroleum) in which the uranium contamination may be too small to significantly affect radiocarbon dating (Table 2 of Bonvicini et al., 2013). However, the uranium content of uranium-contaminated fossil bone is orders of magnitude higher than it is in uranium-contaminated petroleum (Table 1 of Goodwin et al., 2007; Table 1 of Kiseleva et al., 2019), and its radiocarbon contribution is therefore also likely to be orders of magnitude higher.

It has long been known that the mineral fraction of fossil bone mineral yields falsely younger dates than the collagen fraction (e.g., Arslanov & Svezhentsev, 1993), and it was once thought that removal of the carbonate that had arrived via permineralization and encrustation was sufficient to get the mineral fraction to yield a correct radiocarbon date, because such removal brought the mineral fraction’s radiocarbon date into better agreement with the collagen fraction’s radiocarbon date (Cherkinsky, 2009). However, it is now known that the collagen fraction is subject to contamination that yields a falsely young radiocarbon date (see the following section), so the collagen fraction’s radiocarbon date is not a reliable standard for evaluating the correctness of the mineral fraction’s radiocarbon date.

Before the study by Miller and colleagues (2019), when YEC teams subjected Mesozoic dinosaur bone to radiocarbon dating (Dahmer et al., 1990; Fields et al., 1990; Helfinstine & Roth, 2007; Thomas & Nelson, 2015), they failed to remove the mineral fraction from the bone. As a result, the problem of recrystallization rendered the bones’ radiocarbon “dates” (between 9000 and 40,000 years) unreliable.
**Problems with Fossil Bone Collagen**

Most of the organic fraction of bone consists of the protein collagen. As bone decays, collagen breaks down (Pfretzschner, 2004; Kendall et al., 2018). However, under certain circumstances, fragments of collagen molecules can survive in fossil bone (Senter, 2021).

Unfortunately, there are factors that complicate the radiocarbon dating of collagen in fossil bone (bone that is older than 10,000 years). One such factor is the presence of glue. The great fragility of most fossil bone necessitates the addition of glue to the bone during excavation. The excavator uncovers a few square inches of bone, pours glue onto it, waits for the glue to soak in, then repeats the process, a few square inches at a time. Naturally, this makes fossil excavation a very time-consuming process for large skeletons, and a large fossil skeleton may take multiple field seasons to excavate.

When one separates the mineral fraction from the collagen fraction of bone, to subject the latter to radiocarbon dating, the so-called collagen fraction is actually the entire organic fraction of the bone. In fossil bone, that fraction includes substantial amounts of glue. In the case of younger, nonfossil bone, for which the addition of glue during excavation is not necessary, this is not a problem for radiocarbon dating. But fossil bone requires copious amounts of glue, and the new radiocarbon in the glue yields a falsely young "date" for the "collagen" fraction (Nalawade-Chavan et al., 2014).

Another complicating factor is cross-linking. For nonfossil bone, a decontamination technique called ABA (treatment of the sample with an acid, then a base, then an acid again) is used for bone collagen. However, over time, the collagen in buried bone forms cross-links with younger organic contaminants from the surrounding humus (van Klinken & Hedges, 1995), which then cannot be separated from the collagen by ABA or even by stronger techniques such as ultrafiltration (Higham et al., 2009; Higham, 2011; Marom et al., 2012, 2013; Nalawade-Chavan et al., 2014; Deviése et al., 2017, 2018; Spindler et al., 2021). As a result, the "collagen" fraction of fossil bone consistently yields a falsely young radiocarbon "date," due to cross-linkages and the presence of glue.

Until recently, the glue dilemma and the cross-linking dilemma have posed serious obstacles for the use of radiocarbon to obtain reliable dates for late Pleistocene fossil bone collagen, and researchers have preferred other dating methods for late Pleistocene fossils. However, in recent years, researchers on Pleistocene fossils have figured out a solution to the problems of glue and cross-linking. One can sidestep both problems altogether if one extracts the part of the "collagen" fraction that is specific to collagen (leaving the glue and other organic contaminants behind) and subjects only that part to radiocarbon dating. Like any other protein, collagen is made of amino acids. The amino acid hydroxyproline is very abundant in collagen, and not much else. So if one subjects only the hydroxyproline fraction to radiocarbon dating, then one avoids accidentally dating glue (unless the glue is collagen-based) and other organic contaminants. This method, abbreviated HYP (for hydroxyproline), yields reliable dates for late Pleistocene fossil bones that are too old for ABA, ultrafiltration, and other decontamination techniques (Marom et al., 2012, 2013; Nalawade-Chavan et al., 2014; Deviése et al. 2017, 2018; Spindler et al., 2021). For samples older than the radiocarbon dating limit, the date that one finds after treatment with the HYP method is "greater than x" (e.g., greater than 43,000 years, greater than 45,000 years, etc.), in other words, too old to date with radiocarbon. When the same fossil specimens are treated only with ABA, ultrafiltration, or some other decontamination technique, they yield falsely young "dates" of a few thousand to a few tens of thousands of years (Higham et al., 2009; Higham, 2011; Marom et al., 2012, 2013; Nalawade-Chavan et al., 2014; Deviése et al., 2017, 2018; Spindler et al., 2021).

This is where the recent study of a YEC team comes in. Miller and colleagues (2019) subjected the "collagen" fraction of a series of Mesozoic dinosaur bones to radiocarbon dating, after using ABA for decontamination. The team did not use the HYP method. The "collagen" fraction yielded "dates" that fell between 22,000 and 42,000 years. When the HYP method is used, radiocarbon dates are significantly older (and more reliable) than when HYP is not used, even in samples as young as 11,000 years (Deviése et al., 2018). Because the bones used in the study by Miller and colleagues (2019) are far older than that—as demonstrated by their own reported radiocarbon "dates" of > 22,000 years—and because the team did not use the HYP method, the radiocarbon "dates" of the dinosaur bones in their report must be falsely young.

**Conclusion**

The recent "finding" by YEC researchers that "collagen" in Mesozoic dinosaur bones is only thousands of years old is unreliable. That is because the researchers did not use the HYP method. Instead, they used a decontamination method (ABA) that is inadequate for samples older than a few thousand years, which left their results marred by the date-skewing influence of glue and cross-linked organic contaminants.

**Further Comments**

The radiocarbon "dates" that Miller and colleagues (2019) and previous YEC researchers (Dahmer et al., 1990; Fields et al., 1990; Helfinstine & Roth, 2007; Thomas & Nelson, 2015) found for Mesozoic dinosaur bones are far older than 6000 years, the approximate age of the Earth according to the YEC view. Nevertheless, such researchers point out that such dates are closer to the YEC view than to the view of mainstream science that the fossils are millions of years old, and from that they conclude that the YEC view fits the data better than does the view of mainstream science. That conclusion fails to take into account a very important fact: the curve that expresses the ratio between a sample's actual age and the falsely young radiocarbon "date" that contamination causes flattens at less than 50,000 years of actual age (e.g., Figure 3 in Wood, 2015). This means that whether a fossil sample is 50,000 or 50 million years old, a given level of contamination will yield the same falsely young "date" of < 50,000 years. One therefore expects false radiocarbon "dates" of a few tens of thousands of years for old Pleistocene bone, older Cenozoic bone, older Mesozoic bone, and Paleozoic bone. The only way to avoid getting the falsely young "date" for fossil bone is to use the HYP method. For Mesozoic bone, that method will, of course, yield a date of "older than x" (i.e., too old to date). YEC arguments that are based on the radiocarbon dating of Mesozoic fossil bone that has not been treated with the HYP method are therefore incorrect and misleading.

Teachers who encounter students who have been misled by such YEC arguments are encouraged to direct such students to the information presented here and to other recent investigations of dinosaur-themed YEC misinformation (Table 1). YEC publications
have also generated a plethora of other anti-evolution arguments, all of which are based on fallacies or misinformation. Most of those arguments have been refuted in four recent books: Isaak (2007), Prothero (2007), Kane et al. (2016), and Senter (2019a). Additionally, the YouTube video series Grumpy Old Grouch Explains Things refutes several of the most often cited of these claims that are dinosaur-themed. Such resources could be useful to educate both teachers and students and to inoculate students against future exposure to YEC arguments.

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PHILIP J. SENTER (psenter@uncfsu.edu) is a professor in the Department of Biological and Forensic Sciences at Fayetteville State University, 1200 Murchison Road, Fayetteville, NC 28301.

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