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Review

Standard evaluations of bomb curves and age calibrations along with consideration of environmental and biological variability show the rigor of phytolith dates on modern neotropical plants: Review of comment by Santos, Alexandre, and Prior

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ABSTRACT

Santos et al. claim that a recent phytolith ^{14}C study by Piperno of Neotropical plants that grew during the post-bomb era provided anomalously old ages due to ^{14}C depletion. They argue the depletion source is likely old carbon in soils transported into plants via root uptake. Here I show: 1) their claims for anomalous ^{14}C depletions in phytoliths are unfounded because they fail to consider uncertainties created in the bomb curve from local and regional environmental variability and other factors shown to lead to bomb curve offsets in post-bomb ^{14}C study, 2) they error by not calibrating the phytolith dates, a standard procedure with post-bomb ^{14}C determinations, 3) they inexplicably consider an ancient (1640 ^{14}Cyr B.P) age for one of the dated samples to be accurate when (a) it is known the sample was treated with substances made from fossil fuels that were not removed with the extraction process, and (b) the amount of radiocarbon dead carbon required to generate the ancient age from SOM is unreasonable, and 4) their theory that old soil carbon from root uptake is sequestered in phytoliths causing significant skews to phytolith ages is not supported by accumulated evidence from ancient, and now modern Neotropical contexts.

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1. Introduction

Piperno (2015) reported post-bomb phytolith ages from a variety of modern Neotropical plants, an expected result that was

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consistent with their collection dates after 1950. Santos et al. (2015; e.g., pg. 7) claim that "widespread and anomalous ^{14}C depletions" occur in the dates that call into question phytolith dating accuracy, and that one of the samples contained an extraneous source of modern carbon adversely affecting its age. As background to this discussion, the atmospheric bomb testing that occurred during the 1950s and early 60s resulted in a large increase in ^{14}C in air as bioavailable $^{14}CO_2$ that reached a peak in about 1963 after the Test Ban Treaty was signed, and then started to decline. Plants growing after 1955, therefore, have elevated ^{14}C signatures, reflected in percent modern carbon (pMC) values greater than 100. Santos et al. (2015) (hereafter Santos et al.) draw their claims of ^{14}C depletions in the dated phytoliths from plotting the percent modern carbon (pMC) values of the specimens against what is called the ^{14}C bomb curve that displays changes in atmospheric ^{14}C over the post-bomb period (Fig. 1). Santos et al. further argue for what they consider to be problematical phytolith dates by calculating a total age offset in years (the Age offset column in their Table 1) through multiplying the difference between the phytolith pMC and the predicted bomb curve pMC for that collection year by a 1% ^{14}Cfree to 80 yr. relationship.

As will be shown here, evaluating the post-bomb ^{14}C ages in these ways is inappropriate for a number of reasons. Santos et al. take available bomb curve data as "absolute", disregarding internal error within the data itself and localized and regional variability (Darden Hood, Beta Analytic Inc., pers. comm. 2015). Furthermore, the 1% 14Cfree to 80 yr relationship, based strictly on using the Libby half-life to calculate radiocarbon ages, assumes that amounts of fully radiocarbon-dead carbon have contaminated samples and is potentially applicable to pre-bomb but not these post-bomb results in part because ^{14}C years and calendar years while comparable for pre-bomb dating, are significantly different for the post-bomb interval (Darden Hood pers. comm. 2015 and further explanation below). Santos et al. also problematically failed to use a standard approach for assessing a specimen's pMC vis a vis its collection date, through calibration of the specimen's age using its pMC with established calibration tools for post-bomb ages (e.g., Reimer et al., 2004).

Here I: 1) discuss in more detail the pMC values of the phytoliths in Piperno (2015) and compare them with values from other plant materials, including leaves and tree rings, in routine post-bomb analyses of other investigators, 2) provide calibrated ages for the phytoliths, showing they routinely produce reasonable ages and results consistent within the error limitations one can expect from bomb carbon prediction data, 3) provide additional details of the environmental contexts and biological characteristics of the plants studied, showing these were not given the attention by Santos et al. that was warranted, and 4) discuss how the Santos et al. theory of old carbon uptake and subsequent segregation in phytoliths from the Neotropics and perhaps other regions is currently poorly supported by a number of different lines of evidence.

2. Bomb curve use, environmental differences, and the samples studied

It is well known in radiocarbon study that bomb curves are generalized per very large global regions (atmospheric CO_2 and ^{14}C concentrations are sub-hemispheric averages and only latitude confined), and subjective with regard to any single sample. Therefore, perfection should not be expected when attempting to correlate a post-bomb age to a year of collection; inherent local and regional variations are likely to exist anywhere and it's entirely reasonable to assume at the outset a 1–2 pMC offset either way in any location (Darden Hood, pers. comm. 2015). It is well-documented that measureable pMC depletion occurs in urban areas due to fossil fuel emissions from various sources (e.g., Hseuh et al., 2007; Pataki et al., 2010). Both living corn in areas of China and living grasses along busy streets in Japan have been measured with a 5 pMC depletion, and in northern California annual forest fires also produce significant amounts of older carbon from the internal rings of trees (Darden Hood, pers. comm. 2015). Areas near volcanoes are known to have depleted atmospheres (e.g., Chatters et al., 1969; Cook et al., 2001; Evans et al., 2010). There is currently no universally accepted correction for inherent local variability in bomb curve data as there is, for example, for the marine reservoir effect (Darden Hood, pers. comm. 2015).

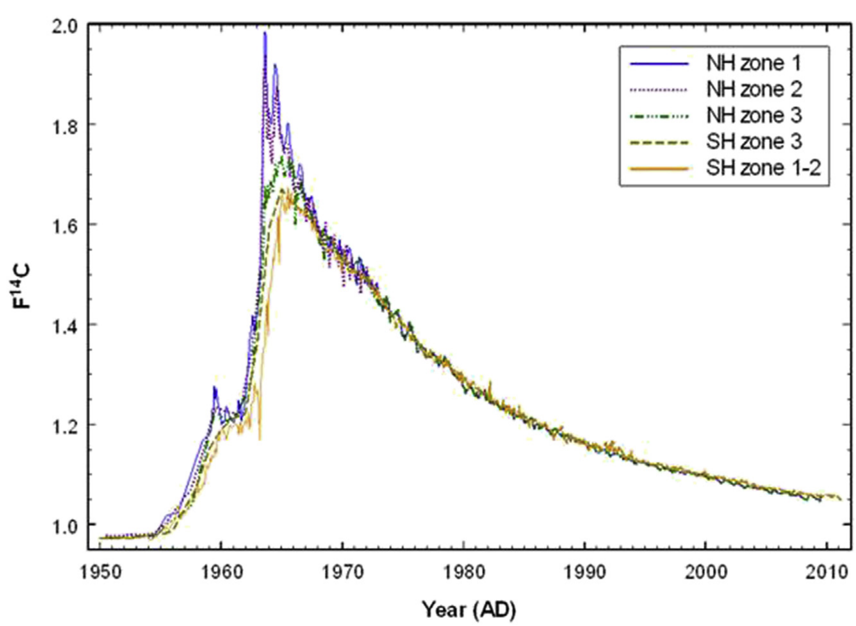

Fig. 1. The bomb curve showing changes in the levels of atmospheric 13C since 1950 due to atmospheric bomb testing. The figure is from Hua et al., 2013. F14C units are converted to pMC by multiplying by 100. See http://calib.qub.ac.uk/CALIBomb/ for the designated boundaries of distribution zones associated with the different plots on the graph and Table 1 notes for more explanation.

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