RADIOCARBON DATES FROM IRON AGE GORDION ARE CONFOUNDED

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Abstract

Radiocarbon dates from Iron Age Gordion have been claimed to require a destruction date for the site that is at least a century earlier than the conventionally-accepted date. Herein, it is shown that the radiocarbon dates have severe problems, due to well-known atmospheric variations, and that these problems imply the claim is invalid.

K. DeVries *et al.* recently presented ^{14}C dates from Iron Age Gordion.[1] They claimed that those dates require a destruction date for the site during 827–803 BC (95%-confidence range), which is a century or more earlier than the dates previously proposed. Herein, their claim is examined. (DeVries *et al.* also claimed artefactual support for their earlier date. O. Muscarella, however, has argued that their artefactual interpretation is incorrect and that the previously-proposed dates are valid.[2] The present work provides support for the arguments of Muscarella. It is, though, independent of those arguments.)

DeVries *et al.* presented two suites of ^{14}C dates: one from roof reeds and one from seeds.[3] The roof reeds might have an earlier date than the seeds,[4] perhaps due to reuse or because they predate the seeds, or perhaps because they grew in 'old'[5] water. Herein, I consider only the seeds. The data is reproduced in Table 1.

Table 1. Radiocarbon ages of the five seed samples from the destruction level of Iron Age Gordion.[7]

Seed Sample	^{14}C Age[6]
barley (sample 1)	2678±18
barley (sample 2)	2674±20
flaxseed	2655±19
lentil (sample 1)	2647±32
lentil (sample 2)	2641±25

[1] DeVries *et al.* 2003. (The site of Gordion is in modern Turkey: 39.7 °N, 32.0 °E.)
[2] Muscarella 2003.
[3] DeVries *et al.* 2003, table 1.
[4] The pooled age for the reeds is given as 2692 ± 14 ^{14}C BP (DeVries *et al.* 2003, table 1).
[5] Water sourced from the ground is sometimes ^{14}C-deficient; it (and reeds grown in it) thus appears old when dated by ^{14}C.
[6] The standard deviations might be inaccurate (Scott 2003, section 10.4), but even if they were, that would not affect the statistical analysis presented here.
[7] All data are from DeVries *et al.* 2003, table 1.

DeVries *et al.* obtained their calendar dates from the ^{14}C ages by calibrating via INTCAL98.[8] INTCAL98, though, was constructed from trees that grew in Germany, Ireland, and the USA—not in the region of Gordion. Around 800 BC, the atmosphere at Gordion was experiencing ^{14}C anomalies, which caused Gordion ^{14}C ages to be too early, relative to INTCAL98.[9] DeVries *et al.* must have known about this, because one of the authors (P.I. Kuniholm) is a co-author of all three of the papers that developed the result.[10] (Additionally, the ^{14}C anomalies at Gordion were discovered by the same Heidelberg laboratory that measured the seeds' ^{14}C ages.)

The calibrated dates given by DeVries *et al.* are thus very dubious. Before considering possible remedies, first note the following aspects of the data.

- The two barley ^{14}C ages are almost identical; so they are likely to be quite precise.[11]
- The two lentil ^{14}C ages are almost identical; so they are likely to be quite precise.
- The ^{14}C ages for barley seem greater than the ^{14}C ages for lentil: statistical testing shows that this greaterness is significant at about the 98% confidence level.[12]

All the seeds are from the destruction level. Hence they are likely from the same calendar year (or perhaps a year apart). Why, then, do their ^{14}C ages seem to differ?

The answer probably lies in atmospheric ^{14}C anomalies at Gordion. The annual atmospheric ^{14}C minimum would have occurred in winter/spring and the maximum in summer.[13] Probably, then, the barley seeds grew in early spring (due to early-winter planting) and the lentil seeds grew later on.

So, how large is the error if the seeds are compared to INTCAL98? The growing seasons of the seeds are much shorter than the growing seasons of local trees, which typically extend from the end of winter until the beginning of the summer dry season. If the lentil seeds grew near the middle of the

[8] For INTCAL98, see Stuiver *et al.* 1998.

[9] Kromer *et al.* 2001; Manning *et al.* 2001; 2003.

[10] *Op. cit.*

[11] Here, 'precision' refers to a measurement's empirical reproducibility, not accuracy (which refers to a measurement's conformity with the true value).

[12] To evaluate the significance of the greaterness, the barley means were compared to the lentil means using a one-sided *t*-test (without assuming equality of the two variances—which is conservative). (If the sources of variation in the two populations were uncorrelated, then the confidence level would be 97.0%; a positive correlation, which presumably exists, would raise this level.) Note that the statistical comparison should properly be made on calibrated ^{14}C ages; it is necessary to approximate this, by using uncalibrated ages, because no calibration for the seeds is available—as discussed.

[13] Kromer *et al.* 2001, 2531.

tree growing season, then the lentil ^{14}C ages would be closer than the barley ^{14}C ages to the ^{14}C ages of local tree rings (grown in the same year). So consider the two tree-ring samples from Gordion with ^{14}C ages closest to the ^{14}C ages of the lentil (tree-ring ages 2660 ± 28 and 2608 ± 26 ^{14}C years).[14] These two samples are roughly 75 ^{14}C years too old, relative to INTCAL98.[15] (All this relies on the recently-proposed date for the Anatolian master dendrochronology;[16] if the original date of the Anatolian master were used, the error would be larger.)

The ^{14}C data for both INTCAL98 and Gordion trees have been taken from decadal samples. Decadal sampling attenuates inter-annual ^{14}C variations (as well as hiding intra-annual ^{14}C variations). Hence the error induced by Gordion's ^{14}C anomalies could easily be larger than 75 ^{14}C years. (It is worth noting, too, that inter-annual anomalies likely also occurred during times other than around 800 BC—but are invisible in the decadally-attenuated tree-ring record; such anomalies would affect ^{14}C dates for those times.)

Another possible cause of the difference in the ages of the seeds (besides early-winter planting) is that the barley seeds were from old grain stores. Multi-year grain stores are known to have existed in Anatolia during the 2nd millennium ~~century~~ BC;[17] whether they existed at Gordion prior to the destruction is not known. Given how rapidly the (inter-annual) atmospheric ^{14}C was changing around the time of the destruction, the barley would only need to have been a few years older than the lentil in order for it to have the measured difference in ^{14}C age. If storage were the cause of this difference, then again the lentil ^{14}C age would be the more accurate indicator for the time of the destruction. As above, the lentil ^{14}C ages would be roughly 75 ^{14}C years too old, perhaps more, and again intra/inter-annual variation presents a problem.

To summarise, there are three distinct problems with the work of DeVries *et al.*: first, INTCAL98 was used for calibration, and thus regional ^{14}C variation was ignored; second, intra-annual ^{14}C variation was ignored; and third, inter-annual ^{14}C variation was ignored. These problems must have been known to DeVries *et al.*, whose work was remiss in not properly considering them. If these problems had been addressed, then the calibrated date range would have been centred decades later and would also have been decades wider—although precisely quantifying this seems to be intractable.

Finally, it is clear that similar problems pertain to many samples that grew in the region of the eastern Mediterranean. In particular, intra-annual variation would affect the ^{14}C ages of all land-based plants whose growing sea-

[14] Manning *et al.* 2003, data.
[15] Kromer *et al.* 2001, fig. 3; Manning *et al.* 2003, data.
[16] Kromer *et al.* 2001; Manning *et al.* 2003.
[17] Seeher 2000, 295–99.

sons include winter (because plants absorb carbon during their growing seasons). Such plants comprise most vegetation that grows in the eastern Mediterranean region.[18] The result is that much vegetation growing in the region during ancient times (not just around 800 BC) would measure some ^{14}C decades too old,[19] relative to contemporaneous INTCAL98 trees.

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[18] Plants need moisture to grow, and most of the eastern Mediterranean region—including Cyprus, Syria, Palestine, Iraq, and much of Greece—receives almost all its precipitation in or around winter (at least in modern times—New *et al.* 1999). Additionally, the Nile floods, which occur in summer–autumn, imply that in Egypt almost all growing seasons are outside summer–autumn (i.e. they usually include winter).

[19] This is based on estimates for the difference between the winter/spring ^{14}C minimum and the summer ^{14}C maximum of at least four ^{14}C decades (calculating from Kromer *et al.* 2001, 2531); as discussed, the difference is sometimes double that or more.