

III. 1 RADIOCARBON DATING AND EGYPTIAN CHRONOLOGY*

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1. Introduction: History of Field

In the beginning, the historical chronology of Egypt was held to offer a test for the utility of the radiocarbon dating method; measurements were thus run on several ancient Egyptian samples and the ability to achieve ages relatively close to the historical age demonstrated that radiocarbon dating worked in approximate terms (or was not ‘beyond reasonable credence’).¹ Egyptian samples thus comprised part of the original ‘curve of knowns’ published in Arnold and Libby² to show that the radiocarbon method worked, approximately, over the last several thousand years.

Over the next few decades a number of radiocarbon ages were obtained on Egyptian samples. Egyptian chronology continued to be considered as the known age, and radiocarbon was being compared—tested. Radiocarbon technology through the 1960s was not capable of delivering ages of sufficient accuracy or precision to be of actual utility to Egyptologists.³ In 1970 Säve-Söderbergh and Olsson published a well thought out critical analysis of radiocarbon dates from Egypt.⁴ They highlighted problems of poor association between samples and presumed historical context (or age), of contamination, and of the need

* The final text of this paper was submitted 19 August 2003. The paper employs the *then* standard IntCal98 radiocarbon calibration dataset. A new IntCal04 dataset has since been published in early 2005 (*Radiocarbon* vol. 46(3), 2004). Use of the new dataset would make only small and fairly insignificant changes to the figures and discussions in this paper. For a comparison of the two calibration curves for the period 500–3500 BC, see Figure III. 1.6 at the end of this paper.

¹ W. F. Libby, “Archaeology and radiocarbon dating”, *Radiocarbon* 22 (1980), 1017–1020.

² J. R. Arnold & W. F. Libby, “Age determinations by radiocarbon content: checks with samples of known age”, *Science* 110 (1949), 678–680.

³ H. S. Smith, “Egypt and C14 dating”, *Antiquity* 38 (1964), 32–37.

⁴ T. Säve-Söderbergh & I. U. Olsson, “C14 dating and Egyptian chronology”, in: I. U. Olsson, ed., *Radiocarbon variations and absolute chronology* (Stockholm, 1970), 501–511.

to achieve replication and inter-laboratory checks. But Säve-Söderbergh and Olsson also noted the uncertainties attending the historical dates, especially those prior to the second millennium BC.

Overall, Egyptian chronology contributed positively to the development of radiocarbon dating in the earlier decades: the apparent discrepancies observed between the radiocarbon age of some third millennium BC samples (mainly from Egypt) versus their 'known' age led to focussed interest in the investigation of such anomalies.⁵ Such work, using especially known age tree-rings, led to the realisation that the relationship between radiocarbon and solar (calendar) years was *neither* equivalent nor fixed.⁶ The development of increasingly accurate and precise records of such secular variation in natural radiocarbon levels became the dominant theme in radiocarbon dating for the next generation; already by the late 1960s to early 1970s calibration curves existed to convert radiocarbon years to calendar years back to beyond 5000 BC.⁷

The advent of calibrated radiocarbon dating, which had the effect of making many prehistoric contexts in Europe older than previously believed, had a radical impact in prehistoric archaeology—in particular leading to the replacement of the previous 'diffusionist' models.⁸ Calibration also meant that the radiocarbon ages for Egyptian samples needed reconsideration, and a series of papers quickly addressed the radiocarbon dates from Egypt in the light of the initial proposals for an approximate calibration curve.⁹ However, although the calibrated ages made general sense, the radiocarbon dates continued to be of

⁵ W. F. Libby, "Accuracy of radiocarbon dates", *Antiquity* 37 (1963), 7–12.

⁶ H. deVries, "Variation in the concentration of radiocarbon with time and location on Earth", *Koninklijke Nederlandse Akademie van Wetenschappen* (Series B) 61 (1958), 94–102.—H. E. Suess, "Secular variations of the cosmic-ray-produced carbon 14 in the atmosphere and their interpretations", *Journal of Geophysical Research* 70 (1965), 5937–5952.

⁷ E.g. H. E. Suess, "Bristlecone-pine calibration of radiocarbon time 5200 BC to present", in: Olsson (n. 4), 303–312.

⁸ C. Renfrew, "The tree-ring calibration of radiocarbon: an archaeological evaluation", *PPS* 36 (1970), 280–311.—Idem, *Before civilisation. The radiocarbon revolution and prehistoric Europe* (London, 1973).

⁹ I. E. S. Edwards, "Absolute dating from Egyptian records and comparison with carbon-14 dating", *Philosophical Transactions of the Royal Society of London A* 269 (1970), 11–18.—R. M. Derricourt, "Radiocarbon chronology for Egypt and North Africa", *JNES* 30 (1971), 271–292.—R. M. Clark & C. Renfrew, "Tree-ring calibration of radiocarbon dates and the chronology of ancient Egypt", *Nature* 243 (1973), 265–270.—R. D. Long, "Ancient Egyptian chronology, radiocarbon dating and calibration", *ZÄS* 103 (1976), 30–48.—R. M. Clark, "Bristlecone pine and ancient Egypt: a re-appraisal", *Archaeometry* 20 (1978), 5–17.

neither the accuracy nor precision to be of any real use to Egyptology; furthermore, the routine radiocarbon technology of the time required large sample sizes that were often problematic or impossible in terms of acquisition from archaeological excavations or from monuments or museums.

Over the subsequent quarter of a century radiocarbon dating has dramatically improved in terms of accuracy, precision, and sample size requirements.¹⁰ In tandem, the natural and anthropogenic cycles and variations in atmospheric radiocarbon levels have become quantified in considerable detail.¹¹ The necessity of careful archaeological and other analysis to ascertain the security of association between the sample to be dated and the context for which a date is required is now fully appreciated (seminal paper by Waterbolk 1971).¹² Programmes of inter-laboratory checking have greatly improved general standards in the field.¹³ New technologies like accelerator mass spectrometry (AMS) permit dating of tiny samples,¹⁴ and several routine radiocarbon laboratories refined accuracy and precision to what is termed 'high-precision' level. Today the leading high-precision laboratories can demonstrate both good correspondence between measured ages and known real tree-ring ages, and good agreement between the laboratories, within the presently possible precision margins of c.2‰—that is within c.10–20 radiocarbon years for the periods discussed in this paper.¹⁵ The key

¹⁰ R. E. Taylor, Radiocarbon dating, in: R. E. Taylor & M. J. Aitken, eds., *Chronometric dating in archaeology* (New York, 1997), 65–96.

¹¹ T. F. Braziunas, I. E. Fung & M. Stuiver, "The pre-industrial atmospheric $^{14}\text{CO}_2$ latitudinal gradient as related to exchanges among atmospheric, oceanic, and terrestrial reservoirs", *Global Biochemical Cycles* 9 (1995), 565–584.—M. Stuiver & T. F. Braziunas, "Anthropogenic and solar components of hemispheric ^{14}C ", *GRL* 25 (1998), 329–332.—I. Levin & V. Hesselmer, "Radiocarbon—a unique tracer of global carbon cycle dynamics", *Radiocarbon* 42 (2000), 69–80.

¹² H. T. Waterbolk, "Working with radiocarbon dates", *PPS* 37 (1971), 15–33.

¹³ E.g. International Study Group, "An inter-laboratory comparison of radiocarbon measurements in tree-rings", *Nature* 298 (1982), 619–623.—E. M. Scott, A. Long & R. S. Kra, eds., "Proceedings of the international workshop on intercomparison of radiocarbon laboratories", *Radiocarbon* 32(3) (1990), 253–397. And further international inter-comparison exercises since.

¹⁴ H. E. Gove, "The history of AMS, its advantages over decay counting: applications and prospects", in: R. E. Taylor, A. Long & R. S. Kra, eds., *Radiocarbon after four decades: an interdisciplinary perspective* (New York, 1992), 214–229.

¹⁵ E.g. M. Stuiver, P. J. Reimer, E. Bard, J. W. Beck, G. S. Burr, K. A. Hughen, B. Kromer, G. McCormac, J. van der Plicht & M. Spurk, "INTCAL98 radiocarbon age calibration, 24,000–0 cal BP", *Radiocarbon* 40 (1998), 1041–1083.—B. Kromer, S. W. Manning, P. I. Kuniholm, M. W. Newton, M. Spurk & I. Levin, "Regional $^{14}\text{CO}_2$ offsets in the troposphere: magnitude, mechanisms, and consequences", *Science* 294

outcome of the latter development was the creation in the mid-1980s of a high-precision calibration of the radiocarbon timescale for the BC period.¹⁶

Shaw¹⁷ quickly tried out high-precision calibration for existing Egyptian samples using the Irish Oak data of Pearson *et al.*¹⁸ He found the calibrated ages to be in general agreement with the historical chronology, but did not see them as able to offer a useful alternative. Shaw was uncomfortable with the ‘wiggles’ in the calibration curve, and the situation where a given radiocarbon age could yield two or more calendar age ranges. It was Hassan and Robinson¹⁹ who finally brought methodological sophistication and chronometric hygiene to bear for Egyptian radiocarbon dates. They reanalysed the corpus of radiocarbon data from Egypt against the 1986 high-precision calibration curve. They found that with suitable samples radiocarbon often could yield results compatible with the historical chronology,²⁰ and they highlighted the ability of radiocarbon to date directly a whole range of Egyptian contexts not closely tied into written records and the chronology of the pharaohs—a hint of the future real relevance of radiocarbon to (especially non-élite) Egyptian archaeology and its chronology. But they also concluded that the existing corpus of radiocarbon data as of 1987 was not, with a few exceptions, fully satisfactory—they instead looked forward to better measurements in the future and *then* the fulfilment of the promise of radiocarbon dating.²¹

(2001), 2529–2532.—F. G. McCormac, A. G. Hogg, T. G. F. Higham, J. Lynch-Stieglitz, W. S. Broecker, M. G. L. Baillie, J. Palmer, L. Xiong, J. R. Pilcher, D. Brown & S. T. Hoper, “Temporal variation in the interhemispheric ^{13}C offset”, *GRL* 25 (1998), 1321–1324.

¹⁶ G. W. Pearson, J. R. Pilcher & M. G. L. Baillie, “High precision ^{14}C measurements of Irish oaks to show the natural ^{14}C variations from 200BC to 4000BC”, *Radiocarbon* 25 (1983), 179–186.—G. W. Pearson, & M. Stuiver, “High-precision calibration of the radiocarbon time scale”, 500–2500 BC, *Radiocarbon* 28 (1986), 839–862.—M. Stuiver & G. W. Pearson, “High-precision calibration of the radiocarbon time scale, AD 1950–500 BC”, *Radiocarbon* 28 (1986), 805–838.

¹⁷ I. M. Shaw, “Egyptian chronology and the Irish Oak calibration”, *JNES* 44 (1985), 295–317.

¹⁸ Pearson *et al.* (n. 16).

¹⁹ F. A. Hassan & S. W. Robinson, “High Precision radiocarbon chronometry of ancient Egypt, and comparisons with Nubia, Palestine and Mesopotamia”, *Antiquity* 61 (1987), 119–135.

²⁰ See also B. Weninger, “Theoretical radiocarbon discrepancies”, in: D. A. Hardy & A. C. Renfrew, eds., *Thera and the Aegean world III. 3: Chronology* (London, 1990), 216–231.—B. Weninger, *Studien zur dendrochronologischen Kalibration von archäologischen ^{14}C -Daten* (Bonn, 1997).

²¹ Cf. (n. 19) at p. 129.

But sadly there have been at best limited attempts to provide such better quality radiocarbon data for the periods after the Archaic—where increasingly good data exist.²² Instead, publications by leading Egyptian chronological specialists concerned with the 3rd through earlier 1st millennia BC in the late 1990s through 2003 largely dismissed or ignored radiocarbon evidence;²³ with Kitchen stating that “‘science’ cannot solve the intricate problems of detailed Egyptian successions, and the cross-links with the neighbouring Near East; texts alone can do that”.²⁴ Such scholars cannot see any use for radiocarbon dating versus the believed-in dating accuracy and precision available from textual evidence. Ironically, the potential modern relevance of radiocarbon to Egyptology has been brought to the fore by a set of publications in the 1990s, which sought to question and reject the standard chronological synthesis and instead to propose a radically different (lower) Egyptian chronology for the second and earlier first millennia BC.²⁵ These writers appreciated that radiocarbon dating offered an independent check on their claims—they thus sought to dismiss or downplay radiocarbon dating evidence.²⁶ In reality, however, radiocarbon evidence from the east Mediterranean indicated the reverse: that the range of the standard chronology was correct.²⁷ Radiocarbon perhaps had a use after all for Egyptian chronology.

²² J. Görsdorf, G. Dreyer & U. Hartung, “¹⁴C dating results of the Archaic Royal Necropolis Umm el-Qaab at Abydos”, *MDAIK* 54 (1998), 169–175.—S. H. Savage, “AMS ¹⁴Carbon Dates from the Predynastic Egyptian Cemetery, N7000, at Naga-ed-Dêr”, *JAS* 25 (1998), 235–249. Cf. A. R. Millard & T. A. H. Wilkinson, “Comment on ‘AMS radiocarbon dates from the Predynastic Egyptian Cemetery, N7000, at Naga-ed-Dêr’ by S. H. Savage”, *JAS* 26 (1999), 339–341.—S. H. Savage, “Towards an AMS radiocarbon chronology of Predynastic Egyptian ceramics”, *Radiocarbon* 43 (2001), 1255–1277.

²³ E.g. Beckerath, *Chronologie*, 55–56.

²⁴ K. A. Kitchen, “Ancient Egyptian chronology for Aegeanists”, *Mediterranean Archaeology and Archaeometry* 2.2 (2002), 5–12 at p. 11.

²⁵ P. James, I. J. Thorpe, N. Kokkinos, R. Morkot & J. Frankish, *Centuries of darkness* (London, 1991).—D. M. Rohl, *A test of time. 1: The Bible—from myth to History* (London, 1995).

²⁶ James *et al.* (n. 25), 321–325.—P. James, N. Kokkinos & I. J. Thorpe, “Mediterranean chronology in crisis”, in: M. S. Balmuth & R. H. Tykot, *Sardinian and Aegean chronology: towards the resolution of relative and absolute dating in the Mediterranean* (Oxford: Studies in Sardinian Archaeology V, 1998), 29–43.—Rohl (n. 25), 384–387.

²⁷ E.g. S. W. Manning & B. Weninger, “A light in the dark: archaeological wiggle matching and the absolute chronology of the close of the Aegean Late Bronze Age”, *Antiquity* 66 (1992), 636–663.—S. W. Manning, B. Weninger, A. K. South, B. Kling, P. I. Kuniholm, J. D. Muhly, S. Hadjisavvas, D. A. Sewell & G. Cadogan, “Absolute age range of the Late Cypriot IIIC period on Cyprus”, *Antiquity* 75 (2001), 328–340.

2. Radiocarbon Dating and the Historical Timescale

The problem, historically, is that earlier radiocarbon dating offered at best large possible date ranges for any given measurement and these dates thus seemed an order of magnitude less accurate or precise than those available from the historical chronology of Egypt (the point made by von Beckerath).²⁸ And, as the review of Weinstein showed,²⁹ up until the early 1980s it is true that radiocarbon simply lacked the ability to supply the precision required in calendar years to be relevant to the existing, quite refined, historical chronology for the ancient Near East. But the advent of high-precision calibration curves from the mid-1980s, and increased accuracy and precision for standard radiocarbon dates, dramatically changed the situation. It was now possible to approach the precision of the historical chronology, and radiocarbon dating could thus offer an independent chronology free from the assumptions and step-wise logic transfers inherent in the existing chronological synthesis for Egypt and, there from, for the whole east Mediterranean.³⁰

Recent developments emphasise this position. Following the first internationally recommended high-precision calibration curves of 1986, a second internationally recommended extension, refinement, and revision was made available in 1998³¹—and another (IntCal04) has been published while this text was in press.³² Radiocarbon calibration datasets from tree-ring records from the east Mediterranean³³ have confirmed the local relevance of the standard northern hemisphere calibration for most periods (such work has in addition identified some intervals of possible regional/temporal variations for further study linked to key periods of short-term solar irradiance minima and climate change issues).³⁴ The

²⁸ Beckerath, *Chronologie*, 56.

²⁹ J. M. Weinstein, "Radiocarbon dating in the southern Levant", *Radiocarbon* 26 (1984), 297–366.

³⁰ H. J. Bruins & W. G. Mook, "The need for a calibrated radiocarbon chronology of Near Eastern archaeology", *Radiocarbon* 31 (1989), 1019–1029.

³¹ Stuiver *et al.* (n. 15).

³² P. J. Reimer *et al.*, "Radiocarbon calibration from 0–26 cal kyr BP", *Radiocarbon* 46, 3 (2004), 1029–1058.

³³ Kromer *et al.* (n. 15).—S. W. Manning, B. Kromer, P. I. Kuniholm & M. W. Newton, "Anatolian tree-rings and a new chronology for the east Mediterranean Bronze-Iron Ages", *Science* 294 (2001), 2532–2535.—S. W. Manning, M. Barbetti, B. Kromer, P. I. Kuniholm, I. Levin, M. W. Newton & P. J. Reimer, "No systematic early bias to Mediterranean ¹⁴C ages: radiocarbon measurements from tree-ring and air samples provide tight limits to age offsets", *Radiocarbon* 44(3) (2002), 739–754.

³⁴ See B. Kromer, M. Korfmann & P. Jablonka, "Heidelberg radiocarbon dates for

development and application of stratified archaeological ‘wiggle-matching’ techniques have in turn allowed the exploitation of both (i) refined archaeological knowledge (stratigraphy) and (ii) the now refined and specific history of past natural atmospheric levels of radiocarbon entailed in these calibration curves in order to yield accurate and highly precise calendar age ranges for sets of seriated samples.³⁵ Radiocarbon dating has thus moved from a resolution of century-scale at best, to now being capable of decadal scale resolution. Radiocarbon can thus now have relevance at the ‘historical’ timescale.

This does not mean that everything is now simple and clear; there remains plenty of scope for ambiguities and inconsistencies—as illustrated in several of the papers in the recent Bruins *et al.* volume in *Radiocarbon*.³⁶ In particular, without selection of directly relevant samples from primary contexts (e.g. short- to shorter-lived samples from secure and specific archaeological contexts relevant to the archaeological event/phase for which a date is sought), and then proper pre-treatment, and accurate and precise measurement in the laboratory, nothing useful will be gained. Old wood is clearly a major problem with some Egyptian samples³⁷ (see Section 4 below). The need for quality control at radiocarbon laboratories in terms of known-age blind checks is widely appreciated these days. Attention is increasingly moving now to the consideration of the integrity of the sample itself as offering only the

Troia I to VIII and Kumtepe”, in: G. A. Wagner, E. Pernicka & H.-P. Uerpmann, eds., *Troia and the Troad: scientific approaches* (Berlin, 2003), 52–53.

³⁵ E.g. Manning and Weninger (n. 27).—C. E. Buck, J. A. Christen & G. N. James, “BCal: an on-line Bayesian radiocarbon calibration tool”, *Internet Archaeology* 7 (1999), [<http://intarch.ac.uk/journal/issue7/buck/>]—C. E. Buck, C. D. Litton & S. J. Shennan, “A case study in combining radiocarbon and archaeological information: the early Bronze-Age settlement of St. Veit-Klinglberg, Land Salzburg, Austria”, *Germania* 72 (1994), 427–447.—B. Weninger, “Stratified ¹⁴C dates and ceramic chronologies: case studies for the Early Bronze Age at Troy (Turkey) and Ezero (Bulgaria)”, *Radiocarbon* 37 (1995), 443–456.—C. Bronk Ramsey, “Radiocarbon calibration and analysis of stratigraphy: the OxCal program”, *Radiocarbon* 37 (1995), 425–430.—J. A. Christen & C. D. Litton, “A Bayesian approach to wiggle-matching”, *JAS* 22 (1995), 719–725.—J. A. Zeidler, C. E. Buck & C. D. Litton, “The integration of archaeological phase information and radiocarbon results from the Jama River Valley, Ecuador: a Bayesian approach”, *Latin American Antiquity* 9 (1998), 160–179.—C. Bronk Ramsey, J. van der Plicht & B. Weninger, “‘Wiggle matching’ radiocarbon dates”, *Radiocarbon* 43 (2001), 381–389.

³⁶ H. J. Bruins *et al.*, “Near East Chronology: archaeology and environment”, *Radiocarbon* 43 (2001), 1147–1390.

³⁷ M. Lehner, S. Nakhla, Z. Hawass, G. Bonani, W. Wölfli, H. Haas, R. Wenke, J. Nolan, W. Wetterstrom, “Dating the pyramids”, *Archaeology* 52(5) (1999), 26–33.

age of interest. Thus does the sample remain intact with only the radiocarbon age from the time the sample was exchanging with the atmosphere, or have contaminating materials become included? And have there been processes of post-depositional diagenesis at work which are relevant? The need to investigate bone samples to ensure good collagen preservation is already appreciated and various strategies have been adopted.³⁸ Although typically not likely to be a significant issue in general, the need to confirm removal of potentially contaminating humic material from archaeological wood/charcoal/seed samples should be a focus of further work.³⁹

3. Radiocarbon and Egypt: An Example of Historically Relevant Data

Integrated archaeological and radiocarbon analyses in other parts of the world carried out over the last decade have shown that, with high quality sampling and analysis, it is possible and practical to resolve chronology accurately and precisely down to the near-historical timescale. Although there has not yet been a significant body of work for Egypt after the Archaic period (e.g. refs. Section 1 above), it is important to appreciate that radiocarbon is now capable of offering relevant and *independent* dating for the OK through TIP. What is needed are modern research programmes. To demonstrate that radiocarbon can potentially provide useful data which can either confirm and test historical chronology (where available), or can provide near-historical level dating for those many other archaeological contexts in Egypt for which secure historical dates are not available, I review one example. The lack of my ability to note several good examples reflects the history of the field (cf. previous sections), and the failure so far to exploit radiocarbon where it could be most useful.

³⁸ R. E. M. Hedges, "Bone diagenesis: an overview of processes", *Archaeometry* 44 (2002), 319–328.—G. J. Van Klinken, "Bone collagen quality indicators for palaeodietary and radiocarbon measurements", *JAS* 26 (1999), 687–695.

³⁹ See already D. Alon, G. Mintz, I. Cohen, S. Weiner & E. Boaretto, "The use of Raman spectroscopy to monitor the removal of humic substances from charcoal: quality control for ¹⁴C dating of charcoal", *Radiocarbon* 44 (2002), 1–11.

Tell el-Amarna

Among existing radiocarbon dates from Egypt, one suite demands attention.⁴⁰ These are five dates on a range of materials (bone, horn, skin, wood and charcoal) collected specifically and carefully for a high-quality programme of radiocarbon dating⁴¹ from modern excavations at Tell el-Amarna, the short-lived capital of Egypt for most of Akhenaten's reign, founded in his 5th regnal year or ca. 1350/1346 BC.⁴² The city's relative chronology is based on seventeen successive vintages documented in its epigraphical record, fourteen of Akhenaten himself (years 4 to 17), and three belonging to his successors.⁴³ The city was deserted before the delivery of an eighteenth vintage. The specific context of the samples taken for radiocarbon analysis was a midden probably deposited early within the site's history and thus it would date during the 13 years of Akhenaten's reign at the site.⁴⁴ Hence the historical date range might be narrowed to between c.1350/1346 BC to 1338/1334 BC.

The Amarna radiocarbon ages on both known shorter-lived samples (skins, bone and horn) and on the potentially longer-lived wood and charcoal samples, offer a tight and coherent set of results entirely consistent with the historical dates and disprove any radically different chronology: Figure III. 1.1. We can see that the final interpretation of the radiocarbon data is very much determined by the shape of the radiocarbon calibration curve in the 14th–13th centuries BC: see Figure III. 1.2. There is a sharp 'wiggle' upwards centred 1325 BC (confirmed for the east Mediterranean from Anatolian trees).⁴⁵ The Amarna data (bone sample Q-2505 perhaps apart) clearly do not match the peak of the wiggle, and thus could lie on either side. At 2σ (95.4%) confidence, we see almost equal probability for either 1389–1329 BC or 1323–1260 BC. The former range (and especially the most likely sub-range at 1σ confidence of 1373–1338 BC) matches the historical age estimate very closely. In support, we might note what seems to be an anomaly in the five-date set. The wood sample Q-2401 yields the second youngest (i.e. second most recent) radiocarbon age, and the animal bone sample

⁴⁰ Also Hassan & Robinson (n. 19), 123.

⁴¹ V. R. Switsur in: Kemp, *Amarna Reports I* (1984), 178–188.

⁴² Murnane & Van Siclen, *Stelae*, 73–86; Kitchen, "Chronology I", 39–52.—Kitchen (n. 24).

⁴³ Cf. above; Chapter II. 8.

⁴⁴ Cf. Switsur (n. 41), 181–182.

⁴⁵ Cf. n. 33.

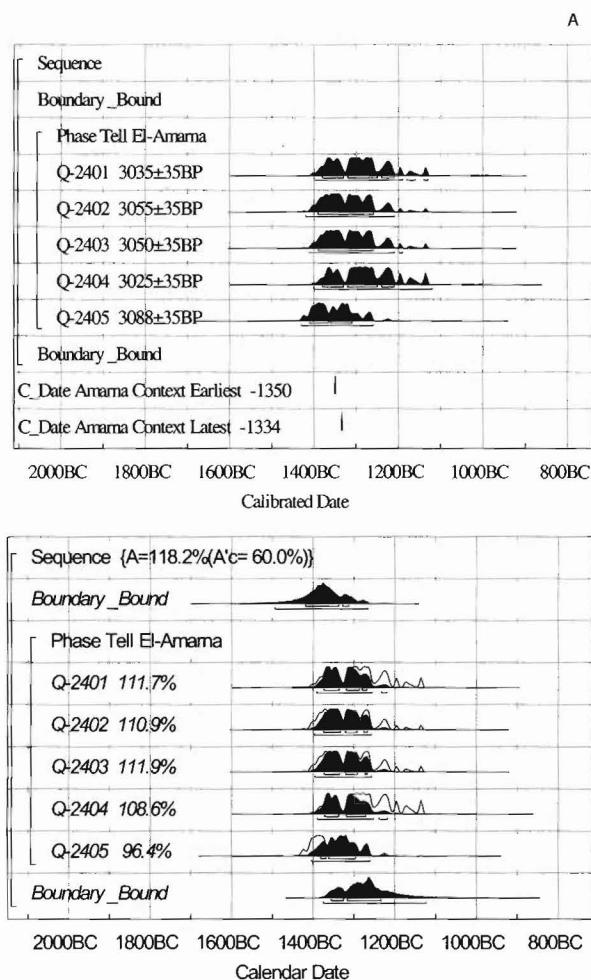


Figure III. 1.1.A. Calibrated calendar ages for the radiocarbon data reported from Tell el-Amarna, Egypt (Switsur, n. 41, 178–188) compared to the historical date for the context (see text). The upper and lower lines under each histogram indicate respectively the 1σ (68.2%) and 2σ (95.4%) calibrated age ranges. B. Sequence analysis (solid histograms) of the Amarna data (with the individual probabilities from A. indicated by the hollow histograms) as a phase within calculated boundaries. The Amarna data are entirely consistent with the historical age estimate for the context. Calibration and analysis employing OxCal 3.9 (Bronk Ramsey, n. 35 and later versions, with curve resolution set at 4) and INTCAL98 (n. 15). Q-2401, wood; Q-2402, charcoal; Q-2403, skin; Q-2404, horn; Q-2505, bone. Weighted average of all five data: 3050 ± 16 BP (1), weighted average of just the three definitely shorter-lived samples 3054 ± 20 BP (2). 2σ (95.4%) confidence calibrated ranges respectively (1) 1388–1331 BC (46.6%), 1322–1260 BC (48.8%), and (2) 1393–1260 BC (94%), 1228–1222 BC (1.4%).

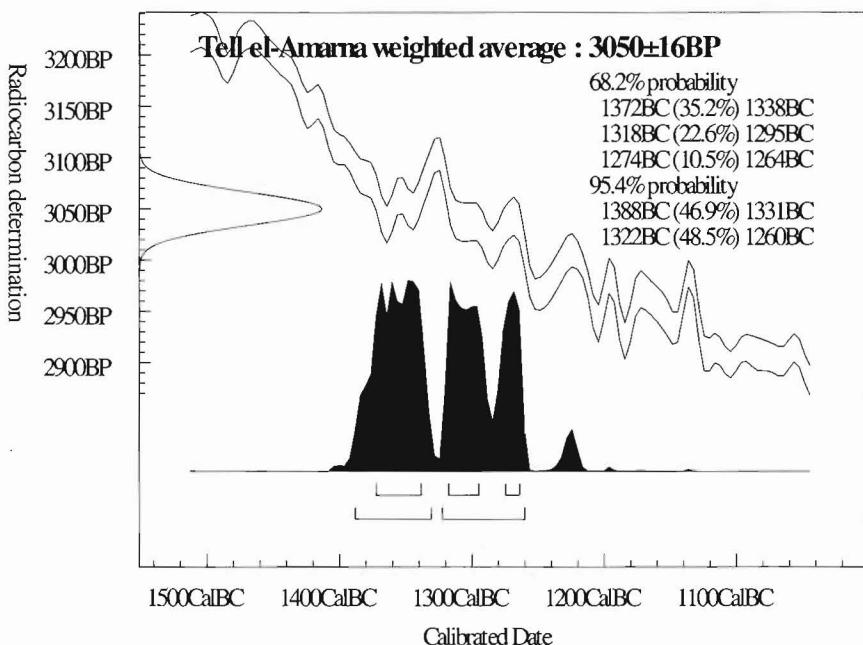


Figure III. 1.2. Calibrated probability distribution for the weighted average radiocarbon age from the five measurements on samples at Tell el-Amarna reported by Switsur, n. 41). For discussion, see text. Calibration and analysis employing OxCal 3.9 (Bronk Ramsey, n. 35 and later versions, with curve resolution set at 4) and INTCAL98 (n. 15).

Q-2405 yields the oldest age, and, in general, the average age of the likely longer-lived samples (wood and charcoal) at 3045 ± 25 BP, is (just) younger than the average age of the shorter-lived samples (animal skin, horn and bone) at 3054 ± 20 BP. Yet one would expect the wood sample to be older in real calendar terms than the animal bone sample (by a few years or even a few decades or more). Out of the dating possibilities for each sample, the only way for this likely correct sample relationship to occur is for the wood sample to date around the earliest of its three potential intercept ranges with the calibration curve at c.1368–1360 BC (and *not* c.1315–1289 BC or c.1280–1262 BC), and for the animal bone sample to date around the later of its two possible intercept ranges at c.1336–1320 BC (and *not* c.1394–1375 BC). And, plausibly, for the other three samples to date around or in between these preferred ranges. In turn, the mid to later 14th century BC date range is most likely for the Amarna samples. This is exactly compatible with, and in support of, the standard Egyptian chronology, and, via

the cuneiform text linkages attested at Amarna,⁴⁶ this finding in turn supports and requires the standard Assyrian-Babylonian chronological range for this period.⁴⁷ Hence again radiocarbon provides useful independent support to Egyptian and ancient Near Eastern chronology, and disproves attempts to install radical chronological alternatives.

4. Past Radiocarbon Fluctuations (the Shape of the Calibration Curve), the Old Wood Problem, and Egyptian OK Radiocarbon Dates

A study by Haas *et al.*,⁴⁸ which indicated radiocarbon ages for various OK monuments several centuries earlier than expected, was widely seen as both a problem,⁴⁹ and by some as a good reason to avoid radiocarbon dating in Egyptology. The Haas *et al.* finding was largely repeated in the followup study by Bonani *et al.*⁵⁰ But it is not at all clear that there is any unknown 'problem'. A key issue is the history of past natural radiocarbon levels; there was in effect a plateau in radiocarbon levels in the period 2900–2500 BC. This means that radiocarbon ages for the period 2900–2500 BC typically could intercept at several places with the radiocarbon calibration curve (i.e. several calendar periods have similar radiocarbon ages). For example, if we consider the OK monuments thought to be constructed c.2600–2500 BC, then the wood employed will, at the latest, have its outermost ring dating then, and the rest of the relevant tree will be progressively older. Depending on species and source of the wood, one might expect an average offset of several decades to a century, give or take a range, for an average wood sample (e.g. compare the $+50 \pm 50$ old wood adjustment estimated by Vogel *et al.*).⁵¹ Thus the 'average' wood used in a monument

⁴⁶ Summary in Beckerath, *Chronologie NR*, 23–24; cf. above, Chapter II. 13.

⁴⁷ J. A. Brinkman, *Materials and studies for Kassite History* (Chicago, 1976).

⁴⁸ H. Haas, J. Devine, R. Wenke, M. Lehner, W. Wölfli & G. Bonani, "Radiocarbon chronology and the historical calendar in Egypt", in: O. Aurenche, J. Evin & F. Hours, eds., *Chronologies du Proche Orient/Chronologies in the Near East. Relative chronologies and absolute chronology 16,000–4,000 B.P.* (Oxford: BAR Int. Ser. 379, 1987), 585–606.

⁴⁹ Hassan & Robinson (n. 19), 129.

⁵⁰ G. Bonani, H. Haas, Z. Hawass, M. Lehner, S. Nakhla, J. Nolan, R. Wenke, W. Wölfli, "Radiocarbon dates of Old and Middle Kingdom monuments in Egypt", *Radiocarbon* 43 (2001), 1297–1320.

⁵¹ J. S. Vogel, W. Cornell, D. E. Nelson & J. R. Sounthor, "Vesuvius/Avellino, one possible source of seventeenth century BC climatic disturbances", *Nature* 344 (1990), 534–537.

built in the reign of Cheops in the mid or third quarter of the 26th century BC (conventional date ranges) likely dates during the first quarter of the 26th century BC give or take about 50 years—let us say 2587 ± 50 BC in broad terms. If we simulate the radiocarbon age, and its calibration, for 2587 ± 50 BC, we get a result like that shown in Figure III. 1.3. And what we find is that the shape of the calibration curve (which represents the history of past natural variations in atmospheric radiocarbon levels) yields a calibrated age that seems 100–300 years too old in the main and only just includes the real date at the very end of the calibrated range at 95.4% probability. But we calibrated the ‘correct’ radiocarbon age! The point is that radiocarbon dating of single context events in this period is problematic because of the history of natural radiocarbon variations. Only use of another approach (like wiggle-matching)⁵² can overcome this limitation.

We can in fact generalise the *potential* and problems of OK radiocarbon dating by simulating radiocarbon ages for calendar years across this period. Figure III. 1.4 shows two runs of simulated dates at ± 50 years dating precision for the period 2750–2300 BC at 25 year intervals and including also the weighted average radiocarbon ages determined and used for calibration by Bonani *et al.*⁵³ for the Pyramid of Snofru at Maidum and the Pyramids of Cheops, Khephren and Mycerinus at Giza. Each run of a simulation produces different data from within the possible range. Thus note how the calibrated age for 2525 BC at ± 50 precision can vary quite a bit from a ‘low’ date range in Figure III. 1.4.A to a ‘high’ date range in Figure III. 1.4.B. Samples near a slope in the calibration curve have more such potential for movement; other samples are much more stable. What we see is that the four sets of Dyn. 4 pyramid data lie entirely within the expected calibrated range for real dates from c.2750 BC to 2600 BC; they could be consistent with data from as late as c.2475 BC, but clearly prefer a date range starting around 2600 BC and older (compare also Figure III. 1.3 where the data want to lie on the plateau 2850–2600 BC and not so much on the slope following c.2600 BC). Such an outcome seems entirely plausible for the non-specific wood/charcoal samples (including ‘flecks

⁵² For examples at this time period, see e.g. B. Weninger, “Die Radiocarbondaten”, in: M. Korfmann, ed., *Demircihüyük: Die Ergebnisse der Ausgrabungen 1975–78. II. Naturwissenschaftliche Untersuchungen* (Mainz, 1987), 4–13.—Weninger (n. 35).

⁵³ Cf. n. 50.

of carbon in mortar' such as from the Cheops pyramid shown in Lehner *et al.*⁵⁴ from the Cheops, Khephren and Mycerinus monuments built in the 26th to early 25th century BC where average sample age is probably of the order of $c.50 \pm 50$ years at the time of inclusion into the monument. (We therefore see that the radiocarbon 'dates' thus can be valid/correct—but they date the 'old' wood (etc). and not the cultural/historical target date wanted: the building of the pyramid monument).

The Pyramid of Snofru at Maidum⁵⁵ provided data where six of the seven dates are closely comparable—SMU-1412 on a 'log' is either aberrant or very old wood notwithstanding the stated dating of its 'outer rings'—and five of the determinations are stated to date outer rings from wood from the burial chamber (see Lehner *et al.*)⁵⁶ or shaft thereto. Thus these samples might be expected to derive from closer to the construction period of the monument (with this period usually assumed to start at year 2 of the reign, onwards). Following the 'historical' chronology, work on this monument began c.2600 BC (Stadelmann)⁵⁷ or 2638/2588 BC (Beckerath),⁵⁸ 2616 BC (Kitchen)⁵⁹ or 2574 BC (Baines & Málek).⁶⁰ The calibrated age range of the average of these six similar ^{14}C ages given by Bonani *et al.*⁶¹ (2855–2583 BC at 1σ , and 2860–2579 BC at 2σ) is entirely compatible at the end of its range (for why it will be just the end, see Figure III. 1.3 above) with the 'historical' age estimates (and especially not the lowest of these). The calibrated probability distribution is entirely similar with a real age of c.2600 BC (see Figure III. 1.4). One may therefore conclude that the radiocarbon ages are approximately valid.

The plateau in radiocarbon levels clearly creates difficulties for narrow dating for OK samples. However, we may make some progress with current debates. For example, Spence proposed a rather lower OK chronology based on a hypothetical stellar alignment used by the pyramid builders.⁶² She proposed dates of 2526 ± 7 BC for the start of

⁵⁴ Lehner *et al.* (n. 37), 31 bottom left illustration

⁵⁵ Bonani (n. 50), 1304.

⁵⁶ Lehner *et al.* (n. 37), 31 top right illustration

⁵⁷ R. Stadelmann, "Beiträge zur Geschichte des Alten Reiches. Die Länge der Regierung des Snofru", *MDAIK* 43 (1986), 229–240.—R. Stadelmann, *Die Großen Pyramiden von Giza* (Graz, 1990).

⁵⁸ Beckerath, *Chronologie*.

⁵⁹ Kitchen (n. 43).

⁶⁰ J. Baines & J. Malek, *Atlas of ancient Egypt* (Oxford, 1980).

⁶¹ Bonani (n. 50).

⁶² K. Spence, "Ancient Egyptian chronology and the astronomical orientation of

work at the Snofru pyramid at Maidum, 2480 ± 5 BC for the Cheops pyramid, 2448 ± 5 BC for the Khephren pyramid and 2415 ± 10 BC for the Mycerinus pyramid. However, if one examines Figure III. 1.4, it is evident that the radiocarbon data from these monuments are less consistent with such a very low chronology unless very, very old wood is always assumed. The range of simulated calibrated ages for samples dating 2450–2400 BC are not at all similar with the radiocarbon ages obtained from the Khephren and Mycerinus samples. The latter clearly date much older wood, wood preferably 100–150 years older. The more traditional range of ‘historical’ chronology estimates provides more suitable dates (allowing for a plausible average old wood factor where relevant; cf. also below, Chapter III. 4).

Apart from the general calibration issue discussed above, some other issues may also be noted with regard to the Bonani *et al.* data sets.⁶³ This team has published an enormous number of radiocarbon dates from OK and MK monuments. There are wide spreads of ages in several of the sets—suggested by the team involved themselves to be partly if not largely accounted for by an ‘old wood’ issue, as all available trees in the region, of widely varying ages, were consumed by the pyramid builders and as older settlement debris was recycled in fires.⁶⁴ While this is plausible in many cases, nonetheless, some samples are clearly aberrant for unspecified reasons. It is undoubtedly the case that the association of measured age for the sample (biological age unless other contaminating processes were involved) versus the date for monument construction is not demonstrated or clear in a number of instances (e.g. ‘charcoal’ from mudbricks or from mortar—see Bonani *et al.*⁶⁵—may easily represent ‘old’ or re-used tree-rings). The limestone and mortar associated with a number of samples may also provide a source of old carbon—for example with reference to samples from ‘flecks of carbon in mortar’ such as from the Cheops pyramid.⁶⁶ It is certainly interesting that the two secure datasets from early second millennium BC MK monuments (Pyramid of Senwosret II at Illahun and Pyramid of Amenemhet III at Dahshur), a new phase of pyramid building after a significant interval, yielded calibrated ages compatible with historical

pyramids”, *Nature* 408 (2000), 320–324. Cf. D. Rawlins, K. Pickering and K. Spence, “Astronomical orientation of the pyramids”, *Nature* 412 (2001), 699–700.

⁶³ Cf. n. 50.

⁶⁴ Lehner *et al.* (n. 37), 33.

⁶⁵ Cf. n. 50, 1297–1298.

⁶⁶ Lehner *et al.* (n. 37), 31 bottom left illustration.

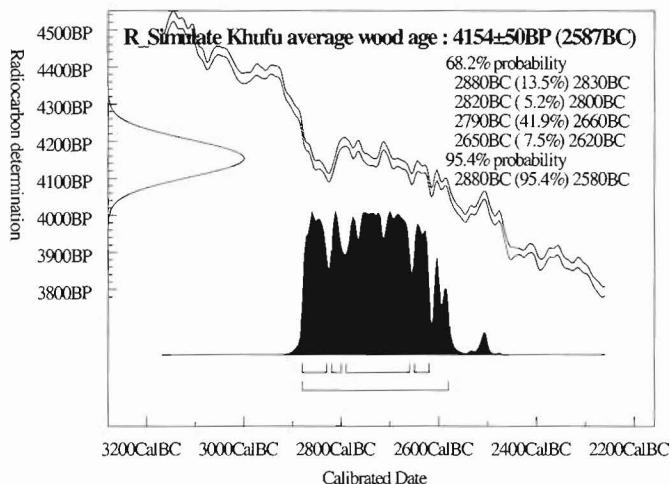


Figure III. 1.3. Simulated radiocarbon age for a calendar date of 2587 ± 50 BC using OxCal 3.9 (Bronk Ramsey, n. 35 and later versions with curve resolution set at 4) and INTCAL98 (n. 15). Note: every simulation run produces a slightly different outcome—this is a ‘typical’ output based on a number of runs. This simulated calendar age is an example of possible typical age of ‘average’ wood from a monument built in the reign of Cheops (reign starts 2604/2593/2554/2551 BC and ends 2581/2570/2531/2528 BC; Beckerath, *Chronologie*; Kitchen n. 43; Baines & Málek, n. 60), given a typical ± 50 year ‘old wood’ adjustment. The calibrated radiocarbon age intersects with the c.2900–2500 BC plateau in the radiocarbon calibration curve, and offers several σ ranges within a large 2σ range c.2880–2580 BC. We thus see as a function of the natural history of radiocarbon fluctuations that real dates in the early 26th century BC yield calibrated radiocarbon ranges mainly apparently too early, with the real date just creeping into the last few years of the calibrated age range. It is noteworthy that the average radiocarbon age from the 45 samples used for the Pyramid of Cheops at Giza is in fact 4147 ± 10 BP (Bonani *et al.*, n. 50, 1315)—almost exactly the 4154 BP radiocarbon age derived by the simulation of a calendar date of 2587 ± 50 BC, as shown above. Thus it appears that the Cheops data do, on average, yield a plausible age for wood used in his reign (with this average wood typically ± 50 or so years in age, give or take a range, versus the actual use date—and the large range within the Cheops data, see below, indicates such a range, or more, in the real wood ages, apart from any contaminating factors from associated mortar/limestone). Because of the history of radiocarbon variations (the 2900–2500 BC plateau), only the very last part of the calibrated range indicates the real age. These data, and the other similar OK data in Bonani *et al.* (n. 50) where the ‘real’ age at best creeps into the end of the calibrated age range, or lies shortly afterwards, therefore do not provide evidence of any additional offset beyond old wood and the calibration outcomes given the history of natural radiocarbon levels c.2900–2500 BC. They provide no evidence at all for claims of hypothetical 100–300 years too early offsets in Mediterranean radiocarbon ages based on claims of putative upwelling of old carbon (Keenan)⁶⁷—something for which there is no positive evidence within an order of magnitude (Manning *et al.* 2002, n. 33).

⁶⁷ D. J. Keenan, “Why early-historical radiocarbon dates downwind from the Mediterranean are too early”, *Radiocarbon* 44(1), (2002), 225–237.

estimates.⁶⁸ The data from Archaic contexts also yielded radiocarbon ages largely in keeping with approximate 'historical' estimates⁶⁹—as have other recent studies.⁷⁰ These periods both have helpful, non-plateau, radiocarbon calibration curve shapes, and may also plausibly have had less of an exhausted natural supply of wood—contrast the peak OK period of pyramid construction which probably forced much recycling of old material.⁷¹

For the third millennium BC, Bonani *et al.* report 17 date sets of the OK as older than their stated historical estimate, 6 as compatible, and 4 as more recent than the historical estimate. This clearly 'seems' to be a problem. But, apart from noting that the historical age estimate is commonly regarded as ± 100 years for this period, the interpretation of Bonani *et al.* is based on two inappropriate starting points. First, there is no allowance for likely average sample age at time of use (i.e. 'old-wood' age for random wood/charcoal samples not known to be outer tree-rings), and second Bonani *et al.* use average values for the radiocarbon age of sample sets which contain significant internal variation, and this is thus potentially misleading (probably less so as set size increases). To illustrate: examination of Bonani *et al.* (n. 50, Fig. 1) shows the Cheops Pyramid (object number 13) to yield one of the apparently tighter calibrated age ranges and to be some two centuries older than the estimated historical age.⁷² And this despite 46 radiocarbon dates being reported for the monument.⁷³ But examination of the 46 radiocarbon data reveals ages varying by 1210 radiocarbon years!—and even excluding the two gross outliers in the set,⁷⁴ the age range left in the set is still 513 ^{14}C years! As shown in Figure III. 1.5, just over one-third of the individual samples—the younger ages—do in fact offer calibrated ages more or less compatible with the estimated historical age of 2589–2566 BC,⁷⁵ and most of the remainder offer

⁶⁸ Bonani (n. 50), Fig. 1 and p. 1320.

⁶⁹ Bonani (n. 50), Fig. 1 object numbers 1–5.

⁷⁰ E.g. Görsdorf *et al.* (n. 22).

⁷¹ Lehner *et al.* (n. 37).

⁷² Bonani *et al.* (n. 50), 1315 use the historical range of 2589–2566 BC—other standard sources suggest c.2593–2570 BC: Kitchen (n. 43), 48; around 2604/2554 BC to 2581/2531 BC: Beckerath, *Chronologie*, 188, or 2551–2528 BC: M. Lehner, *The complete pyramids* (London, 1997), 8.

⁷³ Bonani (n. 50), 1305.

⁷⁴ Marked by the * and + signs by Bonani (n. 50), 1305.

⁷⁵ Bonani (n. 50), 1316.

A

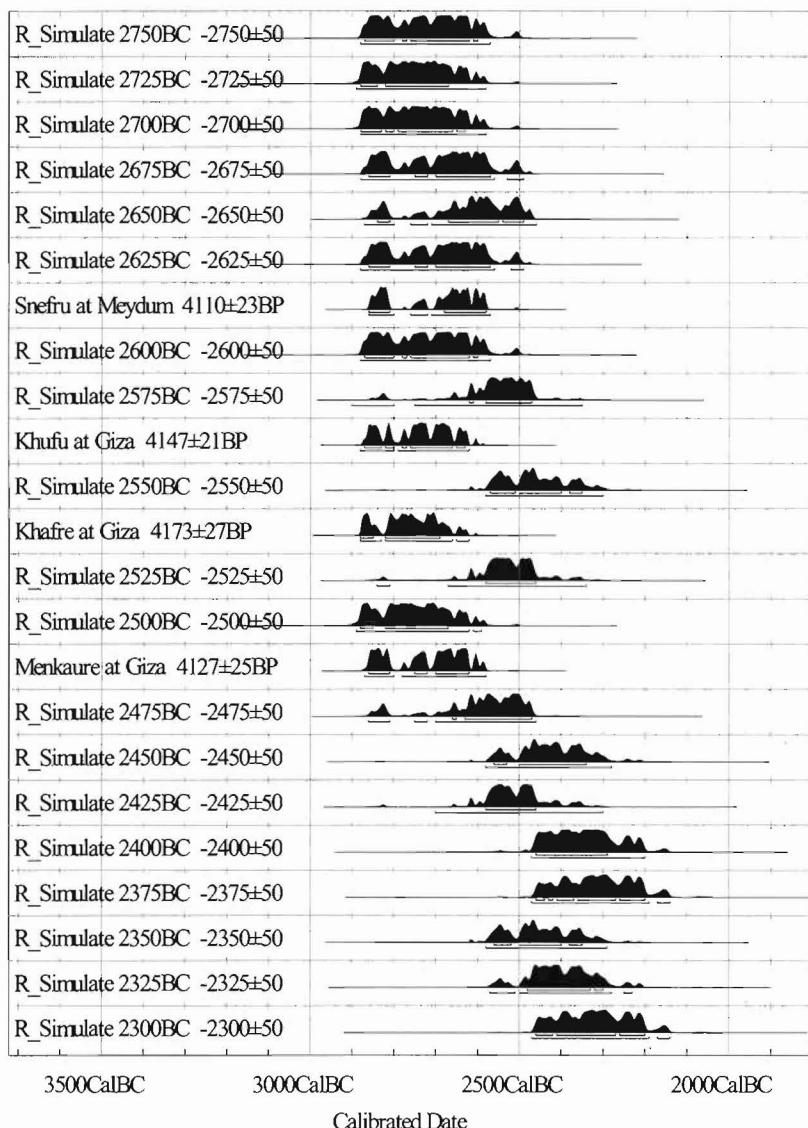
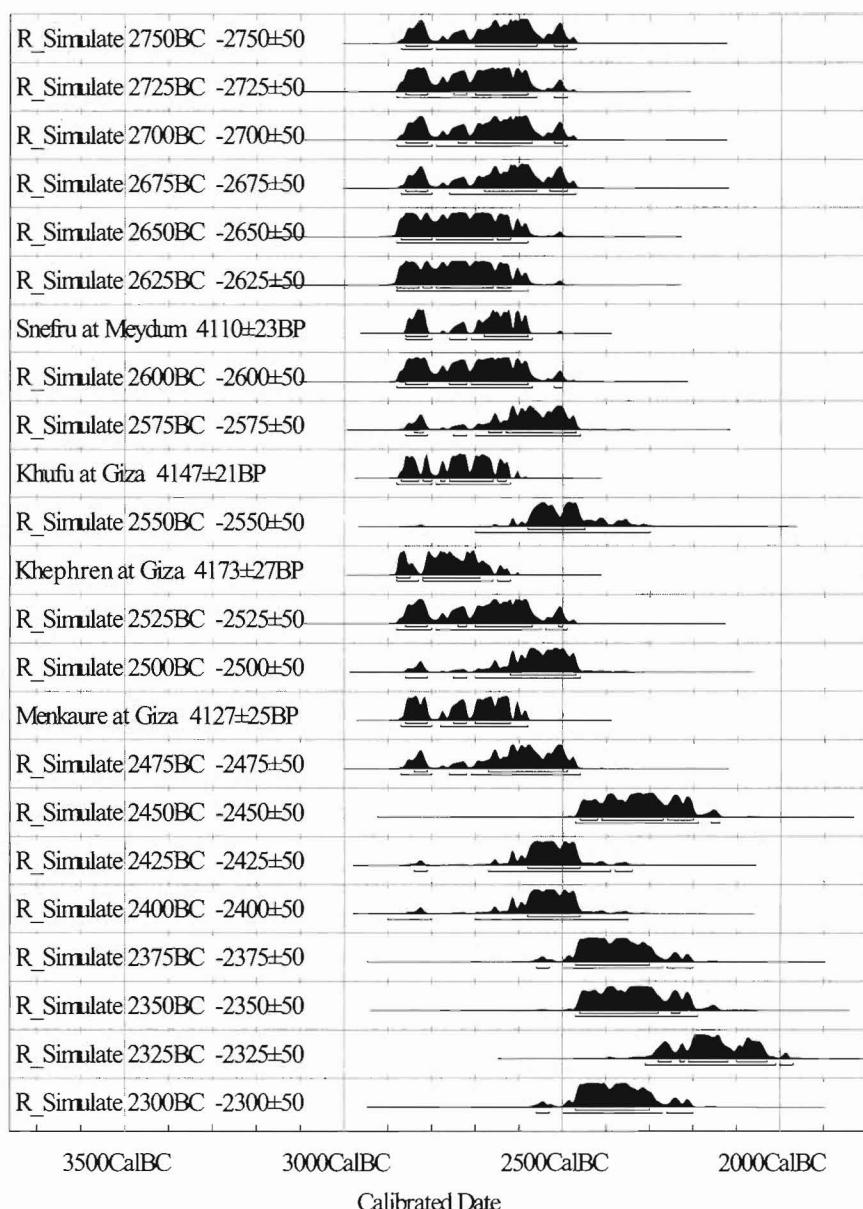


Figure III. 1.4 (A and B). Two outputs of simulations of calibrated radiocarbon ages for calendar years 2750–2300 BC at ± 50 dating precision and at 25 calendar year intervals (data from OxCal 3.9 with curve resolution set at 4, Bronk Ramsey, n. 35 and INTCAL98, n. 15). Included also are the weighted average radiocarbon ages used for calibration by Bonani *et al.*, n. 50, 1314–1316) for the Pyramid of Snofru at Maidum, the Pyramid of Cheops at Giza, the Pyramid of Khephren at Giza and the Pyramid of Mycerinus at Giza. For discussion, see text.

B



variously a little to quite a bit older ages—‘old wood’⁷⁶—would appear the obvious first hypothesis.⁷⁷ Such a pattern: younger ages corresponding to, or close to, context date and older ages reflecting old wood is quite common and expected when dealing with wood/charcoal samples.⁷⁸ Similar observations may be made about the data sets for: Step Pyramid of Djoser at Saqqara, Temple Complex associated with the Step Pyramid, Pyramid of Sekhem-khet at Saqqara,⁷⁹ Pyramid of Khephren at Giza, Pyramid of Ra‘djedef at Abu Rawash, Sphinx Temple of Khephren at Giza (n. 50, 1306), Pyramid of Mycerinus at Giza, Mortuary Temple of Shepseskaf at South Saqqara (n. 50, 1307), Mortuary Temple and Pyramid of Sahure at Abusir (n. 50, 1309) and Pyramid of Teti at Saqqara (n. 50, 1310). In contrast, it is notable that the radiocarbon ages from a modern excavation at the Royal Production Centre at Giza offer both a reasonably consistent set, and calibrated ages more recent than the surrounding OK datasets from the monuments.⁸⁰

We have already noted the case of the Pyramid of Snofru at Maidum, where six of the determinations date outer rings from wood from the burial chamber or shaft thereto. And thus the usual old-wood effect is likely minimised. The calibrated age range of the average of these six similar ¹⁴C ages given by Bonani *et al.* (2855–2583 BC at 1σ , and 2860–2579 BC at 2σ) is entirely compatible at the end of its range (for why it will be just the end, see Figure III. 1.3 above) with the ‘historical’ age estimate employed by Bonani *et al.* (n. 50, 1314) or those estimated by Kitchen (n. 43) or Beckerath, *Chronologie*, (higher range), and also overlaps with the date for the accession of Snofru c.2600 BC and his earlier reign, and thus the construction of this Snofru’s first (of three) pyramids, given by Stadelmann (n. 57). One may observe that the stated calibrated range ends +8/+4 years from the start of the lower ‘historical’ age estimate for Snofru by Lehner from Baines & Málek (n. 60);⁸¹ this is hardly a significant difference, and the wood in

⁷⁶ M. B. Schiffer, “Radiocarbon dating and the ‘old wood’ problem: the case of the Hohokam chronology”, *JAS* 13 (1986), 13–30.

⁷⁷ See Lehner (n. 37), esp. 31–33.

⁷⁸ For an example from Troy II, see Kromer *et al.* (n. 34), 48 and Fig. 4.

⁷⁹ Bonani (n. 50), 1303.

⁸⁰ Bonani (n. 50), Fig. 1 object 12, contrasted with other objects 10–19. One might speculate that the samples from this context, which are not from major architecture/monuments and their creation industries, do not therefore suffer so much from an average old wood problem.

⁸¹ Lehner (n. 72).

question could easily have been cut a few years earlier than the start of Snofru's reign if the lower dates are to be preferred, just as it could have been cut during his reign if the slightly higher dates are preferred. We have already seen how even the correct radiocarbon age for a date around the early 26th century BC only includes the real calendar age within the very end of the calibrated range, as much of the dating probability ends up on the plateau in the radiocarbon curve over the preceding couple of centuries (compare Figure III. 1.3 above). Thus these dates for the Pyramid of Snofru at Maidum are entirely consistent with the estimated 'historical' age.

In sum, these OK radiocarbon dates do not in fact indicate any problem with radiocarbon dating and Egyptian chronology; instead they nicely illustrate the importance and impact of the shape of the calibration curve in dating, and they highlight the need to obtain organic samples directly associated with, and relevant to, the human context for which a date is sought. Wood and charcoal samples especially can easily be older, or even much older, than their final deposition context depending on tree species and the uses and perhaps re-uses of the wood. Add in calibration taphonomy and correct radiocarbon ages for organic materials can appear to yield dates that are centuries too old for their historical/archaeological context (see Figure III. 1.3). Aquatic samples, which may include a water/marine reservoir radiocarbon age (versus solely the normal atmospheric reservoir radiocarbon age represented in normal terrestrial plants, and animals eating these), must also be treated with care and caution—again this may explain some of the apparently aberrant radiocarbon ages obtained on 'reed' samples in Egypt.

As evident from the Amarna example in Section 3, and other studies cited in Sections 1 and 2, or other studies in the literature,⁸² in appropriate circumstances high-quality radiocarbon data from Egypt and the east Mediterranean region can provide accurate and precise dates.⁸³ When issues occur, such as the completeness of removal of age contamination by humic material,⁸⁴ or the old wood offsets evident in the extensive OK radiocarbon measurements published by Bonani *et al.*

⁸² M. Lange, "Wadi Shaw 82/52: ^{14}C dates from a peridynastic site in northwest Sudan, supporting the Egyptian historical chronology", *Radiocarbon* 40 (1998), 687–692.

⁸³ See also Manning *et al.* (2002, n. 33).

⁸⁴ Alon *et al.* (n. 39).

A

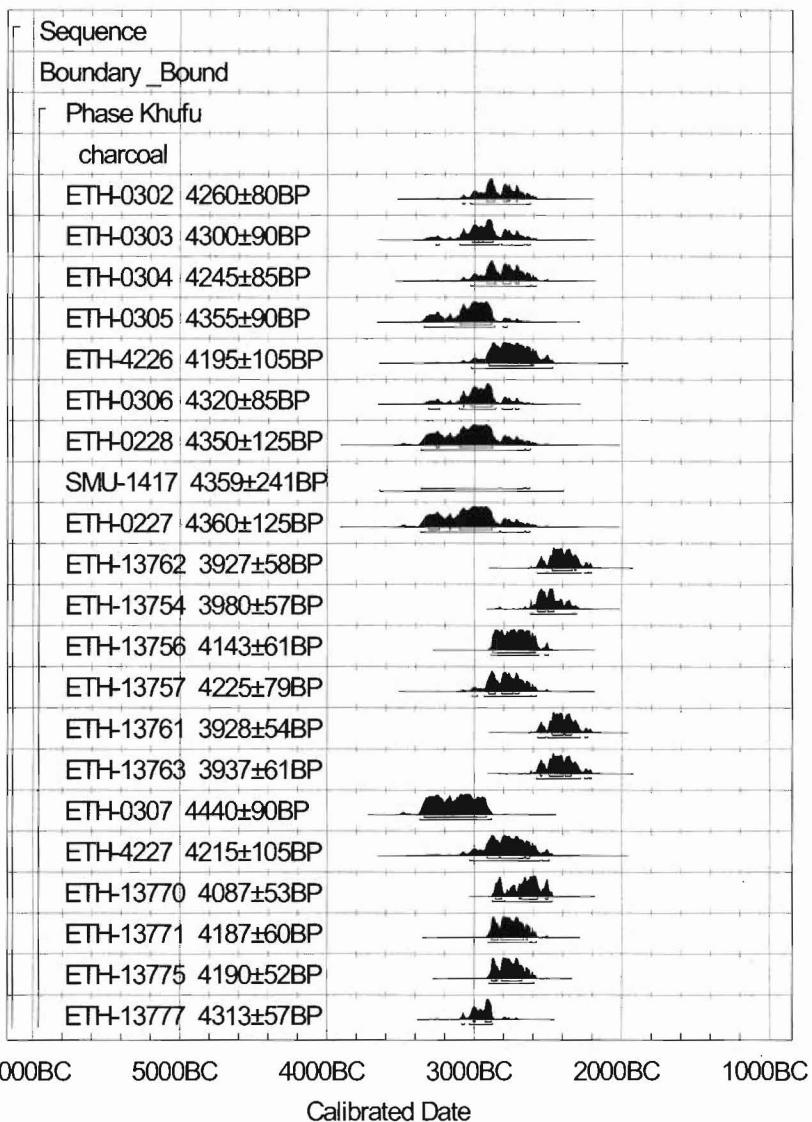
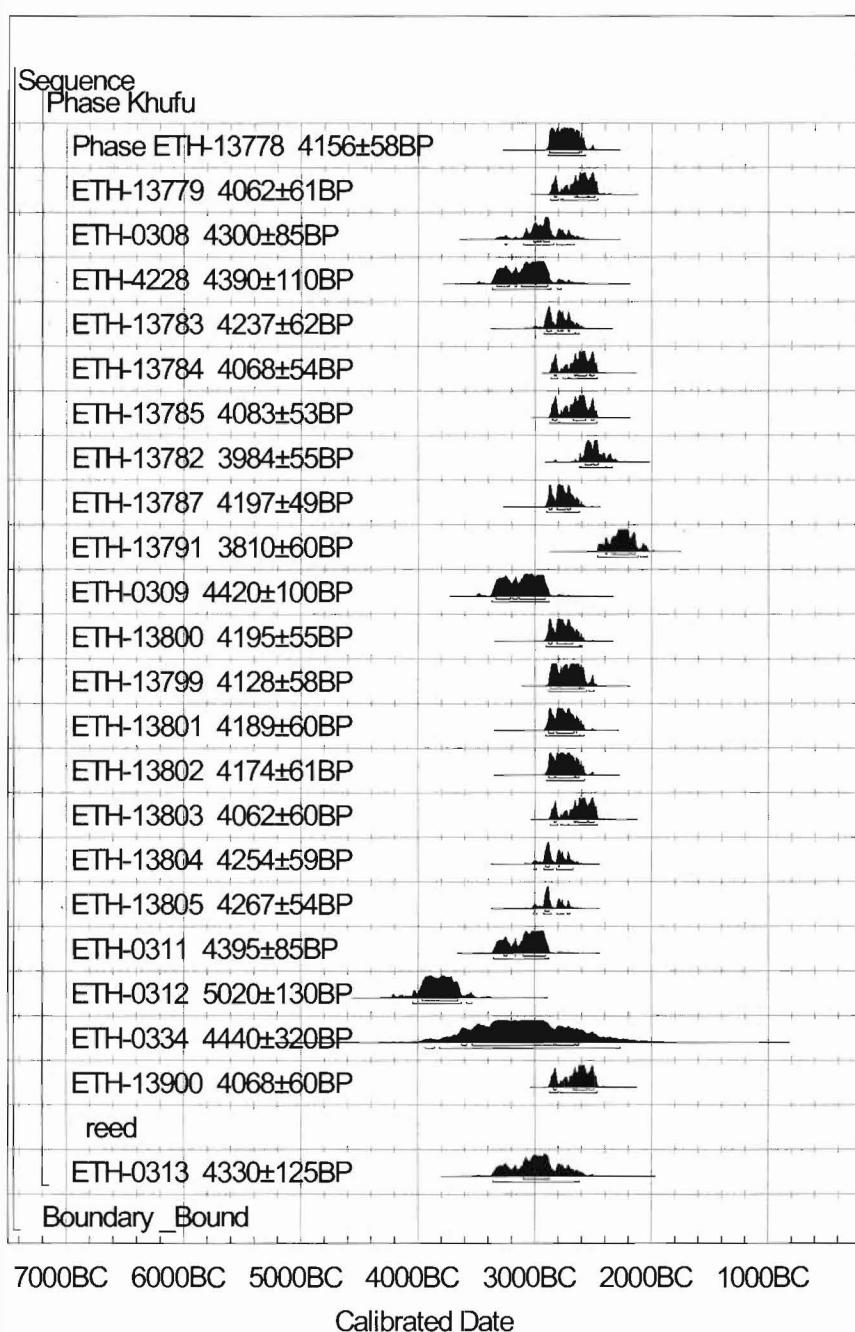


Figure III. 1.5 (A and B). Calibrated calendar ages for the 46 radiocarbon data reported from the Pyramid of Cheops at Giza (data from Bonani *et al.* n. 50, 1305). The estimated historical age employed by Bonani *et al.* (n. 50, 1315) is 2589–2566 BC. The upper and lower lines under each histogram indicate respectively the 1σ (68.2%) and 2σ (95.4%) calibrated age ranges. Calibration employing OxCal 3.9 (Bronk Ramsey, n. 35 and later versions, with curve resolution set at 4) and INTCAL98 (n. 15). For discussion, see text.

B



(n. 50), they in fact lead us to consider important topics concerning taphonomy, sample diagenesis, social history, economic processes, and the environment. As Lehner *et al.* conclude with regard to the OK issue:⁸⁵

If the fair agreement of our 1995 results with historical dates and previous radiocarbon dates for the Archaic period and with the historical dates for the MK hold, the problematic OK dates are boxed in. And therein may lie a hint of multifaceted old wood effects for a period, especially from Djoser to Mycerinus, when any and all wood resources may have been consumed at a whole other order of magnitude than before or after the giant pyramid-building projects . . . our project . . . now has us thinking about forest ecologies, site formation processes, and ancient industry and its environmental impact . . .

5. Caution: *The Need to Make Only Secure Historical Associations is Paramount*

Radiocarbon dating determines the age of an organic sample. The association of such a sample and its radiocarbon age with history/archaeology is the task of the archaeologist. And one has to be careful and rigorous. Associations must be demonstrated, not casually assumed. A recent example illustrates the potential problems and the need to be even more careful as better precision becomes available in modern radiocarbon dating.

Shoshenq I and Radiocarbon?

A key synchronism for the standard chronology of Egypt (and wider Near Eastern history) concerns the identification of the important Egyptian pharaoh Shoshenq I with the Shishak attested in the Bible (I Kings 14:25–26; II Chronicles 12:3–4) as invading Judah and Israel in the 5th year of Rehabeam.⁸⁶ Rehabeam year 5 is in turn dated c.926/925 BC by linking the attested names and reign lengths of the 10th–9th century BC kings of Israel and Judah with recorded synchronisms in the 9th century BC between the Israelite kings Ahab and Jehu and the

⁸⁵ Lehner (n. 37), 33.

⁸⁶ Kitchen, *TIP*, esp. xlv, 72–76, 287–302; Kitchen (n. 24), 7–8; Beckerath, *Chronologie NR*, 30–34; idem, *Chronologie*, 68–70.

Assyrian king Shalmaneser III. Since the chronology of the Assyrian kings is effectively absolute back to the 10th century BC, this enables precise calendar dates to be applied (of respectively c.853 BC for the last year of Ahab's reign and c.841 BC for the first year of Jehu's reign).

In an important and controversial paper, Bruins *et al.* (2003) recently reported sets of high-precision radiocarbon dates, allied with an interpretative stratified archaeological wiggle-matching analysis, from the site of Tel Rehov in Israel.⁸⁷ These samples, on high-quality short-lived samples, provide the basis for a high-resolution chronology for the site in the 12th through 9th centuries BC. But Bruins *et al.* also suggested that the date for the destruction of Stratum V at Tel Rehov could be associated with the campaign of Shoshenq I and thus their date for this stratum—c.940–900 BC—was argued to support this proposed identification, and in turn the standard Egyptian chronology or one very close to it (with the Shoshenq I invasion dated c.926/925 BC—see above, or various slight alternative calculations, such as the 918 BC of Miller and Hayes,⁸⁸ cited by Bruins *et al.* (n. 35) 317, or 927 BC in Barnes⁸⁹ or 922–921 BC in Hayes and Hooker.⁹⁰

However, the critical logical step was missing. There is no evidence at all that the Stratum V destruction links with Shoshenq I—this is merely an unproven and (unnecessary) assumption incorporated into the Bruins *et al.* paper and its dating model (and so leads to a circular argument). The dating of the site and the dating of Shoshenq I are separate until and unless clear evidence can be produced to show that Shoshenq I caused the specific Stratum V destruction horizon dated by the radiocarbon measurements. Archaeologists must always be aware that non-rigorous and specific (i.e. documented) assumptions that try to bring archaeological and historical evidence together (the event-historical model) are often inherently problematic because the respective evidence types represent fundamentally different facets of

⁸⁷ Bruins *et al.* n. 35.

⁸⁸ M. Miller & Hayes, *A history of ancient Israel and Judah* (Philadelphia, 1986).

⁸⁹ W. H. Barnes, *Studies in the chronology of the divided monarchy of Israel* (Cambridge, Mass., 1991).

⁹⁰ J. H. Hayes & P. K. Hooker, *A new chronology for the kings of Israel and Judah and its implications for Biblical history and literature* (Atlanta, 1988).

historical reality.⁹¹ In the Shoshenq I case, it is fair to note that much is less than certain and very different narratives are possible based on the same limited and likely non-contemporary ‘historical’ evidence/tradition.⁹²

This example highlights the need to delineate clearly what is the target date and how and why the relevant organic samples do (or do not) provide associated dating evidence when radiocarbon dated. Without such chronometric care results are not credible, and conclusions may turn out to rest on foundations of sand.

6. Conclusions

High quality radiocarbon dating offers an important but as yet not fully exploited resource for Egyptology. It provides an increasingly accurate and precise test for the historical chronology and can actively inform and resolve disputes in less certain or ambiguous periods. Available dating accuracy and precision from radiocarbon should in principle—i.e. on suitable short-lived samples from primary contexts dated at good precision—offer a chronological precision for the third millennium BC of the order of, or better than, the historical age estimates—which, for this period, are often regarded as having a significant error margin of up to a century. It could test and resolve claims for significantly differing

⁹¹ A. M. Snodgrass, “Archaeology”, in: M. Crawford, ed., *Sources for ancient history* (Cambridge, 1983), 137–184.—Idem, *An archaeology of Greece: the present state and future scope of a discipline* (Berkeley, 1987), 37–66.

⁹² I. Finkelstein, “The campaign of Shoshenq I to Palestine: a guide to the 10th century BCE polity”, *ZDPV* 118 (2002), 109–135.

Postscript. Since the present text was submitted in August 2003, there have been several further publications (and much discussion) taking this topic now well beyond the initial publication of Bruins *et al.* (2003) cited above. However, the logic/methodology point noted in the text remains relevant as outlined (and has since been accepted by the Bruins *et al.* authorship—I wish to thank Hendrik Bruins and Amihai Mazar for friendly, constructive, and productive discussion). For the latest (AD 2005) situation on the analysis of the important Tel Rehov datasets, see now (i) Mazar, A. *et al.* “Ladder of Time at Tel Rehov: Stratigraphy, Archaeological Context, Pottery and Radiocarbon Dates”, and (ii) Bruins, H. J. *et al.* “The Groningen Radiocarbon Series from Tel Rehov: OxCal Bayesian Computations for the Iron IB-IIA Boundary and Iron IIA Destruction Events”, both papers in *Radiocarbon Dating and the Iron Age of the Southern Levant—the Bible and Archaeology Today*, edited by Thomas Levy and Thomas Higham, Equinox Publishing, Ltd., London (2005), 193–255, and 271–293 respectively.

dates, such as those suggested from speculative astronomical conjecture by Spence (n. 62).

For the second millennium BC radiocarbon may also be able to assist. For many non-elite contexts it may offer the best means of dating. For the chronology of the pharaohs it will be of less need, as the dates in the second millennium BC are relatively accurately and precisely determined from a combination of so-called ‘dead-reckoning’ (the compilation of documented names of Egyptian kings and various other persons and attested years of reign/office backwards from an agreed starting point fixed against the Greco-Roman timescale)⁹³ and analysis of some records of astronomical observations (e.g. Krauss;⁹⁴ Beckerath).⁹⁵ Recent scepticism, and claims to reject for example all lunar data (Wells⁹⁶—approvingly cited by e.g. Kitchen),⁹⁷ have been shown to be based on incorrect or partial understanding of the data and their analysis.⁹⁸

The leading scholars immersed in the details argue that this combination of historical data and astronomical evidence forms a closely dated chronological system for the second millennium BC, with only at most a few years to a decade or so error range, and with several likely absolute placements therein, such as the accession of Tuthmosis III in 1479 BC.⁹⁹ Nonetheless, one role for radiocarbon will be to offer an independent check and verification of these chronologies. Without this, complete certainty will never be possible given that there are gaps and uncertainties/ambiguities in the evidence (textual or astronomical), and key assumptions/interpretations have been made by modern scholars. Radiocarbon dating is direct and independent, and can cut through circular debates and assumptions.

⁹³ Kitchen, *TIP*; idem, “Chronology I”; idem n. 24.

⁹⁴ Krauss, *Sothis*.

⁹⁵ Beckerath, *Chronologie*, 41–51.

⁹⁶ R. A. Wells, “The role of astronomical techniques in ancient Egyptian chronology: the use of lunar month lengths in absolute dating”, in: J. M. Steele & A. Imhausen, eds., *Under one sky: astronomy and mathematics in the ancient Near East* (Münster, 2002), 459–472.

⁹⁷ Kitchen, n. 24 at p. 11.

⁹⁸ R. Krauss, “Ronald A. Wells on astronomical techniques in Ancient Egyptian Chronology”, *DE* 57 (2003), 51–56.

⁹⁹ Kitchen, *TIP*, n. 43; n. 24; Beckerath, *Chronologie NR*, 1997; cf. below, Chapter III. 8.

High-quality radiocarbon dating also offers the independent means to test and reject the several publications of the last decade which have argued that conventional Egyptian (and wider ancient Near Eastern) historical chronology is incorrect.¹⁰⁰

Radiocarbon dating should become the friend of Egyptologists. Whereas in its origins Egyptology helped to test radiocarbon dating and to expose the need for calibration, modern radiocarbon dating now offers the means to test, support, extend, and even to refine Egyptian chronology. Certain periods like the OK will be problematic if samples or contexts are dated in isolation thanks to the unhelpful plateau in the calibration curve (see Figure III. 1.3 above); but by exploiting techniques like seriated archaeological wiggle-matching (ideally of short-lived samples tied securely to the context for which a date is sought), even this time period can be made to yield an accurate and precise calibrated radiocarbon chronology by taking advantage of the shape of the calibration curve.¹⁰¹ Radiocarbon dating also offers the route to engage with all those many Egyptian archaeological contexts not specifically linked with the (largely elite centred) textual record (compare the similar but still largely unfulfilled hope expressed twenty years ago by O'Connor).¹⁰² The entirety of Egyptian archaeology can then be integrated into an accurate and precise near-historical level timeframe.

¹⁰⁰ E.g. J. Goldberg, "Centuries of darkness and Egyptian chronology: another look", *DE* 33 (1995), 11–32.—G. Hagens, "A critical review of dead-reckoning from the 21st Dynasty", *JARCE* 33 (1996), 153–163.—James *et al.* (n. 25), (n. 26).—Rohl n. 25.—P. Van der Veen & W. Zerbst, *Biblische Archäologie am Scheideweg?* (Holzgerlingen, 2002).

¹⁰¹ See e.g. Weninger (n. 52); Weninger (n. 35).

¹⁰² D. O'Connor, "New Kingdom and Third Intermediate Period", in: B. G. Trigger, B. J. Kemp, D. O'Connor & A. B. Lloyd, *Ancient Egypt: a social history* (Cambridge, 1983), 183–278, esp. 185.

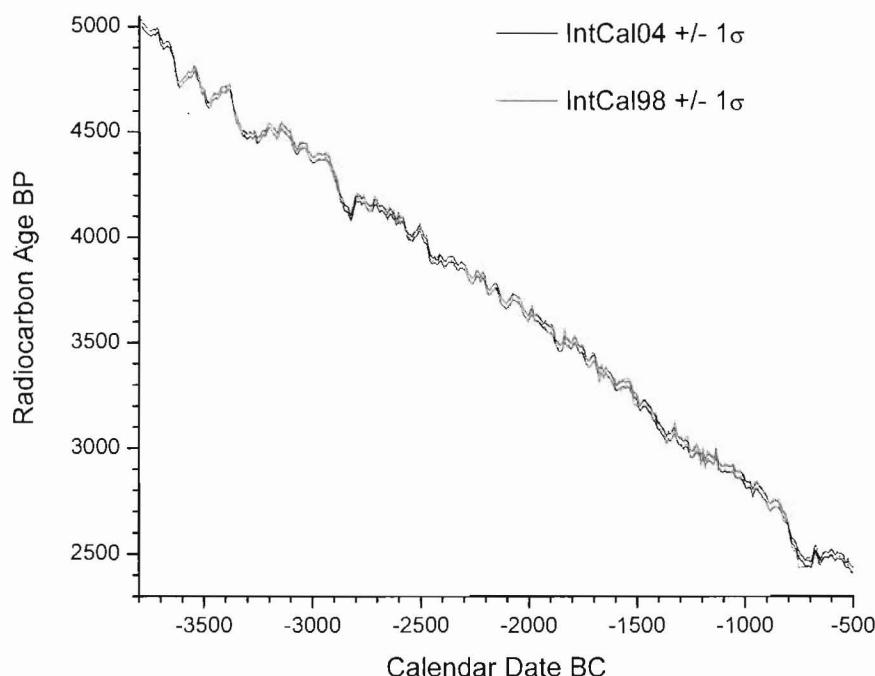
Appendix

Figure III. 1.6. The new (AD 2005) IntCal04 radiocarbon calibration curve (black) at 1σ for period 500 BC to 3500 BC, compared to the previous IntCal98 curve (grey) as used in this paper. There is little significant difference—the main change is that the IntCal04 curve is a little more smoothed. Data from Reimer *et al.* (n. 32) and Stuiver *et al.* (n. 15).