EGYPT & TIME

By Malcolm H. Wiener

The papers and subsequent discussions at this fine workshop, while establishing no major breakthroughs in the chronology of Ancient Egypt, succeeded in clarifying a number of major issues while simultaneously illuminating events in the Third Intermediate Period. Indeed, the papers by David A. Aston, Gerard P.F. Broekman, Dan'el Kahn and Kenneth Kitchen concerning the T.I.P. seemed almost a parallel conference that discussed in detail historical and chronological issues within the period, without impacting Egyptian chronology in general since all of the speakers accepted c. 945 B.C. as the time of the accession of Shoshenq I. At the 2003 SCIEM conference, Rolf Krauss set forth a strong case based on lunar observation data for an accession in 943 B.C. (In press. I am grateful to R. KRAUSS for sharing his text).[1] Kenneth Kitchen's paper (presented *in absentia* in final form after the conference) addressed many contentious chronological issues within the T.I.P. and presented his current position with respect to the whole of Egyptian historical chronology, relying largely on texts and "dead reckoning" of reigns. The dates proposed have received widespread general acceptance and are propounded as well in the paper by Manfred Bietak. The paper by Vera Müller presented a general overview of all periods and various approaches, scientific as well as textual, cautioning against placing total reliance on proposed absolute astronomical dates.

THE THIRD INTERMEDIATE PERIOD AND THE TWENTY-FIFTH DYNASTY

The fine papers on the genealogy and history of the Third Intermediate Period and Twenty-fifth Dynasty speak for themselves. The T.I.P–Twenty-fifth Dynasty framework established through the heroic efforts of Ken Kitchen in particular, Morris Bierbrier and others was subject to vigorous challenge on many points of detail. Dan'el Kahn's proposal that Manethonian absolute dates in the period around 700 B.C. are in error by a few years supports the long-held understanding that Manetho's sources were better for some periods than others.

THE NEW KINGDOM

Workshop papers and discussions of the New Kingdom raised two challenges to the current widely accepted absolute chronology placing the accession of Ramses II at 1279 B.C., of Tuthmosis III at 1479 B.C. and of Ahmose I and the beginning of the New Kingdom c. 1539 B.C. The first challenge came in a paper by David Aston, who argued that the reign of Tuthmosis IV should be lengthened considerably beyond the decade (c. 1400–1390 B.C.) now generally allotted because of the number of tomb chapels constructed and officials recorded during his reign, plus the significant change in pottery styles during his reign and the preceding reign of Amenophis II (c. 1427–1400

[1] Egyptian textual evidence (KITCHEN 1986; 1991; 1996) provides a date not later than 941 B.C., and probably a little earlier (KITCHEN, this volume). A major building program in the temple of Karnak at Thebes was begun by Shoshenq I in Year 21 of his reign, according to a rock stele found in the sandstone quarries at Gebel Silsila (CAMINOS 1952; KITCHEN, this volume). The building program, left unfinished presumably because of the death of Shoshenq the following year, included a relief recounting a major campaign in Israel and perhaps in Judah. Correspondingly, the Hebrew Bible in I Kings 14:25 states that Shishak seized the Temple treasure of Jerusalem in the 5th year of the reign of Rehoboam, king of Judah. Correlations with Assyrian annals from the reign of Shalmaneser III establish Hebrew Biblical monarchic dates from the beginning of the Divided Monarchy in c. 931–30 B.C. (see KITCHEN, this volume). Accordingly, if the proposed new lunar observation-based date of 943 B.C. for the accession of Shoshenq I is correct, then either the campaign in Judah occurred in Year 18 rather than Year 20 of his reign, followed by a delay of two years until the inauguration of the building program containing the stele describing the campaign, or the 5th year of Rehoboam should be placed in 923 B.C. rather than 925 B.C. as proposed by THIELE (1951; 1983) and KITCHEN (1986; 1996; this volume) on the basis of Biblical accounts of the lengths of interconnecting reigns in Israel and Judah.

B.C. on the generally accepted chronology). In the discussion following David Aston's paper, I commented that periods of prosperity uninterrupted by war, drought or plague in a land as wealthy as Egypt could have witnessed much building activity and expansion in administration, and that the rate of change in pottery in all societies is irregular and dependent on many factors, including foreign influences, tastes of rulers and users or consumers *versus* the extent to which certain shapes and patterns of decoration came to denote the contents of containers, *i.e.*, as trademarks, thus tending toward stability. The length of the reign of Tuthmosis IV has been the subject of considerable past discussion. Thirty years ago, E. Wente and C. Van Siclen published an important article arguing for a 34-year reign for Tuthmosis IV and a high Egyptian chronology placing the reign of Tuthmosis IV between 1419 and 1386 B.C. and the accession of Tuthmosis III in 1504 rather than 1479 B.C. (Wente and Van Siclen 1976). In 1991 B. Bryan, in the expanded version of her 1980 dissertation on the reign of Tuthmosis IV, argued that while there was abundant evidence for Tuthmosis IV through his 8th year, there was none thereafter, adding that a brief reign was supported by astronomical evidence and the Manetho Kinglist. Bryan concluded that the reign of Tuthmosis IV was unlikely to have gone beyond 12 years at the most. E. Wente then graciously stated that he accepted Bryan's position (pers. comm., for which I am most grateful). A brief reign for Tuthmosis IV is also favored by K.A. Kitchen. Rolf Krauss believes that astronomical sightings in the 23rd and 24th years of Tuthmosis III firmly fix the year of his accession at 1479 B.C. (forthcoming) and hence require a brief reign for Tuthmosis IV. Further astronomical evidence is available in the form of a lunar observation in Year 52 of Ramses II, consistent only with an accession date of 1279 B.C. within the period required both by Near Eastern correlations and by "dead reckoning" via the addition of the regnal years of subsequent rulers (Krauss forthcoming and this volume). Furthermore, Karl Jansen-Winkeln argued in his paper that on the basis of genealogical data regarding average life spans even a date of 1279 B.C. appeared to be earlier than might be anticipated and that accordingly a 25-year increase to the higher lunar cycle date seemed contraindicated. It will be interesting, therefore, to see whether David Aston's contribution to this workshop will change the *communis opinio*.

The second challenge to the now standard chronology of the New Kingdom went to the heart of the issues raised at this workshop. Franz Weninger, Peter Steier and Walter Kutschera in their paper presented radiocarbon dates of seeds collected at Tell el-Dab^ca from early New Kingdom, Second Intermediate Period and Middle Kingdom strata. At Tell el-Dab^ca two determinations from the C/2 stratum of the post-Hatshepsut Tuthmosis III period gave central dates of 1620 B.C. and earlier, far too early on textual, archaeological and astronomical grounds (Bietak, this volume). Moreover, the radiocarbon determinations showed very poor agreement between the originally calibrated and the quasi-Bayesian-sequenced time range in radiocarbon terms (see below). There is an old saying in radiocarbon dating that "one date is no date," reflecting the uncertainty inherent in any single ^{14}C determination. Here perhaps one may say the same of two dates, when they are of this nature. The ^{14}C dates obtained from seeds from the early New Kingdom strata are also far earlier than the dates established through the study of texts and astronomical observations. The absolute dates for these strata and for the New Kingdom in general cannot move very much from those stated above, not only for the reasons previously stated but also because of the correlations with the chronology of the ancient Near East fixed via the correspondence of Amenophis III and Akhenaten with Near Eastern rulers whose dates are known to within about a decade. Confirmation of the firm foundation of Near Eastern chronology was provided recently by the discovery at Assur of correspondence between the twelfth-century B.C. rulers Ninurta-apil-Ekur of Assur and Meli-Shipak of Babylon (Frahm n.d.), thus confirming the overlap of these reigns as required by the independent chronologies of Assur and Babylon set forth over 30 years ago by J. Brinkman (1972, 272–273; 1976, 31–33; 1977).

The work of Brinkman (which of course utilized the records contained in the vast number of fired clay tablets produced in the Near East) took the chronologies of Assyria back to around 1430 B.C. with a possible error range of about a decade. The recent extensive reworking of the evidence by H. Gasche (2003) has reaffirmed Brinkman's conclusions back to the last quarter of the fifteenth century B.C. with only minor variation; for example Brinkman (1977) placed the reign of Enlil-nasir II in c. 1430–25 B.C., whereas Gasche (2003, 210 n. 17) gives regnal dates of

1422–17 B.C. Further discussion of the ^{14}C measurements from New Kingdom strata is contained in the concluding section of this summary dealing with radiocarbon dating problems in general.

The Second Intermediate Period

Apart from radiocarbon dates from the relevant strata, discussions of the Second Intermediate Period are provided by Kim Ryholt and Chris Bennett. Both stress the high degree of chronological uncertainty which prevails. Ryholt's paper reports that the damaged figure in the Hyksos summation in the Turin Kinglist is in fact more compatible with the reading "140 years" than "108 years," although the latter cannot be entirely ruled out. Ryholt further notes that it would be unwise in any event to place much confidence in the Turin Kinglist for the obscure Fifteenth Dynasty, considering that for the better-documented Twelfth Dynasty the Kinglist is hard to reconcile with the contemporary sources of information (Ryholt 2004 and pers. comm. of 5 January 2006). Bennett's paper notes that the surviving portions of the Turin Kinglist covering the late Second Intermediate Period are particularly difficult to reconcile with the Manethonian tradition. The Turin Kinglist, contained on about 300 fragments of papyrus now housed in the Turin Museum, provides what was intended as a complete list of Egyptian kings since the creation beginning with gods and semidivine mythic figures. In its scope and intention, the list is a unique document from the Pharaonic period. The list is written on the reverse of a discarded tax register of the thirteenth century B.C., but whether the list was written in the same century or later is unclear (Ryholt 2004).

Would adding 32 years to the Hyksos in accordance with Ryholt's tentative suggestion raise dates overall or merely reduce the duration of the Fourteenth Dynasty accordingly? Ryholt believes that the Fourteenth Dynasty at Avaris in the Nile Delta begins very soon after the end of the Twelfth Dynasty in Thebes, whereas Manfred Bietak thinks that the Fourteenth Dynasty in the Delta did not begin until the latter part of the Thirteenth Dynasty located in Memphis. Critical evidence strongly favoring the Bietak position is provided by studies of pottery typology and, in particular, scarabs (Allen, Allen and Ben-Tor 1999). Bietak notes among other arguments that major occupation of the Uronarti fort in Nubia during the Thirteenth Dynasty is established by the pottery and by scarabs with close Hyksos parallels, contrary to Ryholt's view that the occupation belongs in the Fourteenth Dynasty.

The duration of the Hyksos period is of interest for Aegean chronology, for interconnections generally, and (at the margin) for the compatibility of ^{14}C determinations with archaeological evidence. As for the Aegean, an alabaster lid with the cartouche of the Hyksos ruler Khyan was found by Sir Arthur Evans at the Palace of Minos at Knossos. Kim Ryholt's work strongly supports the position that Khyan was the fourth of the Hyksos rulers, and not the first, as the late Olga Tufnell thought (Tufnell 1984). Evans believed the alabaster lid came from a secure Middle Minoan IIIA context at Knossos (Evans 1921). Colin Macdonald has suggested in a recent article that the context could be MM IIIB rather than IIIA (Macdonald 2003, 40), whereas Peter Warren believes Evans' case for a IIIA context remains convincing (pers. comm. of 4 February 2005). The Aegean Long Chronology, supported by Sturt Manning and others, requires that Khyan rule during LM IB (accepting that he is the fourth Hyksos and not the first, which would make the discrepancy far worse still). In this case both Evans' description of the findspot and Macdonald's reinterpretation must be completely wrong and/or the lid must have migrated downward as a result of some now unrecognizable LM II rebuilding in the area in which it was found. The Khyan lid is one of countless archaeological contexts (if one considers all of the relevant Cypriot pottery) which would have to move by roughly a century to accommodate a seventeenth-century date for the eruption of Thera as proposed by some (though disputed by others) on the basis of radiocarbon determinations (*pro:* Manning 1999; Bronk Ramsey, Manning and Galimberti 2004; *contra:* Wiener 2003). Raising the date of Khyan even by a generation (made possible if one assumes that most of Ryholt's 32-year addition comes in the last three Hyksos reigns) would do little to resolve this difference. Similarly, the extension of the Hyksos period *in toto* by about 32 years would affect only slightly the absolute dates of the various strata at Dab^{c}a and of the Cypriot pottery they contained, or the dating of Canaanite sites on the basis of interconnections with Dab^{c}a (Bietak 2003; Bietak, Kopetzky and Stager forthcoming. Of course there would be no effect on the dating of Late Bronze Age Cypriot pottery styles including

White Slip I, a piece of which was found in the Volcanic Destruction Level at Thera).

The paper by Chris Bennett presents a probing analysis of the textual evidence for the Second Intermediate Period, to which is added critical evidence gathered from genealogy and prosopography. Bennett has been able to construct a network of family trees centered on the governors of El-Kab that spans the period from the mid-Thirteenth to the early Eighteenth Dynasty and includes synchronisms with several kings in this period. Bennett reports that the evidence so obtained "suggests that the Theban state broke away from the 13th dynasty a few decades before the end of that dynasty, and that the Theban dynasty lasted some decades longer than is usually supposed" (Bennett 2005). Bennett has also explored the implications of a proposed Sothic (rising of Sirius) date for anchoring Dynasty Sixteen and Seventeen, which he considers a single dynasty (Bennett 2002). The date comes from an unusual and surprising source and location – a rock graffito from Djebel Tjauti (Darnell and Darnell 2002, 49–52). Kim Ryholt, however, in his paper to this workshop presented a detailed argument that the graffito did not record a Sothic date at all. Skepticism has also been expressed in this regard by James Allen of the Metropolitan Museum (forthcoming), although no one has yet proposed an alternative reading for the graffito. Sothic date aside, Bennett's conclusions concerning the succession of governors at El-Kab, which require a minimum distance of about ten generations between Sebekhotep IV to Hatshepsut, argue against lowering the dates of the preceding Middle Kingdom, a subject to which we now turn.

The Middle Kingdom, First Intermediate Period and Old Kingdom

The absolute chronology of the Middle Kingdom and hence earlier periods depends largely on Egyptian Sothic and lunar observations and our understanding of them. Written records play an important role within each period. Interconnections with the Near East may provide additional information via connections to cedar- and juniper-based dendrochronology and to increasing numbers of high-precision Near Eastern radiocarbon dates as described by Ezra Marcus in his paper to this workshop.

With respect to Middle Kingdom astronomical dating, this workshop saw the continuation of an ongoing, long-standing debate. The paper by Rolf Krauss refined his lunar-based argument for a low chronology which would place Year 7 of Senwosret III in 1831–30 B.C., consistent with his dating of the Illahun Papyrus Sothic observation, which Krauss believes was recorded at Elephantine in Upper Egypt rather than at Memphis/Illahun as is commonly held, or at Thebes. The fundamental analysis of Parker in 1950 proposed 1872 B.C. for Year 7 of Senwosret III, with subsequent adjustment to 1866 B.C. by Luft (1992, 114 n. 46) and von Beckerath (1997, 45, 132–134). Parker placed the reign of Senwosret III between 1878 and 1843 B.C.; von Beckerath and Kitchen prefer 1872–53/52 B.C. while Luft favors 1873–54 B.C. (von Beckerath 1997; Kitchen 2000). Krauss' reading of the astronomical evidence, on the other hand, leads to proposed regnal dates of 1837–19 B.C. (Krauss forthcoming). The Turin Canon, compiled more than 500 years later, gives thirty-plus years. Luft believes the astronomical evidence for a shortened 19-year reign of Senwosret III is controlling (Luft 1992, 114 n. 46; 2003, 202). Luft in 1992 also cited W.K. Simpson (1984) who argued for shortening the reign of Senwosret III because of the then lack of epigraphical evidence after Year 19, but in the same year Felix Arnold (1992) published a control note from a limestone building block inside the king's pyramid at Dahshur which recorded a Year 30 (see also Dieter Arnold 2002, 59) and in 1996 J. Wegner published control notes on building blocks from the mortuary temple of Senwosret III that continue up to Year 39. Reconciling the foregoing evidence with Illahun Papyrus Berlin 10055 (Kaplony-Heckel 1971), where a "Year 19" is followed with a "Year 1" in the same hand, requires a co-regency of Senwosret III and his successor Amenemhat III of 20 years. (I am most grateful to Dorothea Arnold for reminding me of the history and commentary concerning the control notes and the Illahun Papyrus.)

In contrast to Krauss' paper, Ulrich Luft strongly defends a high Middle Kingdom chronology on astronomical grounds, arguing for the correctness of both the Sothic date for the reign of Senwosret III and the Illahun lunar observations as set forth by Parker (while also contending for a 19-year reign for Senwosret III on the basis of astronomy, as noted above). Andrew Shortland, Christopher Bronk Ramsey and Thomas Higham's paper also contends that the Illahun observations and the generally accepted understanding of them seem well based. Krauss' lunar calculations would result in an end date for the Twelfth Dynasty and the Middle Kingdom in 1760–59 B.C., compared to high chronology dates of 1786 B.C. (Parker 1950, 63–69), 1794/3 B.C. (von Beckerath 1997), 1795 B.C. (Kitchen 2000, 46–47, 49), 1796 B.C. (Luft 1992, 114 n. 46), and 1803 B.C. (Ryholt 1997, 184–197). Bennett's conclusions concerning the Second Intermediate Period mandate a high Middle Kingdom chronology as well (Bennet 2002), and Ryholt's paper points in the same direction in reemphasizing his prior support for the high Middle Kingdom chronology. Apart from the papers at this workshop, Fabian Boudville (The Egyptologists' Electronic Forum: eef@lists.yale.edu, 29 March 2005) has argued that Krauss' date of 1760/59 B.C. for the end of the Middle Kingdom would shorten the Thirteenth Dynasty unreasonably by allowing an average reign of only 2.4 years for the many short-lived but well-attested kings and that an Elephantine locus for the Sothic sightings adopted by Krauss is much less likely than a Thebes or Memphis observation point, either of which would yield a higher date. Gary Greenberg has also supported the standard Middle Kingdom high chronology, with the Twelfth Dynasty beginning in 1991 and ending in 1786 B.C. (Greenberg 2002; 2003–2004, 53. Substituting an Illahun papyrus date of 1866 for 1872 B.C. brings the inception date of the Twelfth Dynasty down to 1985 B.C.). Shortening the reign of Senwosret II to nine years as suggested by the lack of evidence to date for any year beyond Year 8 would result in a beginning year of 1981 B.C., while the Greenberg ending date of 1786 B.C. assumes a 39-year reign for Senwosret III with only a three-year co-regency (Greenberg 2003–2004, 37–40. So brief a co-regency is difficult to reconcile, however, with the other evidence cited). A further indication that the Thirteenth Dynasty covers a substantial period of time rather than the brief period suggested by Krauss is provided by the extended stratified sequence from the Metropolitan Museum excavations at Dahshur conducted by Dieter and Dorothea Arnold (Dorothea Arnold 1982; pers. comm. of 8 February 1996 from Dorothea Arnold, for which I am most grateful). Manfred Bietak notes that a long time span for the Thirteenth plus Fourteenth Dynasties is further suggested by the stratigraphy at Tell el-Dab^{c}a, where strata G/4, G/1–3, F, E/3 and early E/2 fall in this period (I am most grateful to Manfred Bietak for this observation and for other comments on this section of my paper as well). In sum, the weight of scholarly opinion from various directions is heavily against Krauss' low Middle Kingdom chronology.

The radiocarbon dates reported by Weninger, Steier and Kutschera at this workshop, would imply a higher chronology still, since their analysis of the seed measurements from Thirteenth Dynasty strata at Dab^{c}a produced dates similar to the majority view astronomical dates for the Twelfth Dynasty. Questions posed by the Dab^{c}a ^{14}C determinations are considered in the final section of this summary.

With regard to the First Intermediate Period and the Old Kingdom, various radiocarbon determinations have sometimes yielded dates higher than traditional chronologies, as noted in the paper by Hendrik Bruins (see also Bruins and Mook 1989, 1025; Bruins 2001, 1150–1153; van der Plicht and Bruins 2001, taking account as well of Near Eastern radiocarbon dates and Egyptian interconnections). Here, however, traditional Egyptological chronologies clearly lack precision, and indeed appear more fluid than is often acknowledged, with the F.I.P. and the Sixth Dynasty presenting particular difficulties. Adding together the estimated reign lengths of known rulers leaves open the possibility of additional rulers or periods of interregnum. The Turin papyrus is incomplete in the section covering the First Intermediate Period and the Manethonian report of "70 rulers in 70 days" can hardly be taken literally; rather it suggests that 70 names had been recorded with no way of knowing whether some or all were local rulers who overlapped. Analyses of charcoal used in Old Kingdom pyramid construction (Haas *et al.* 1987; Bonani *et al.* 2001; Nakhla *et al.* 1999) produced some radiocarbon determinations with dates centuries earlier than conventional dates, but the presence of old wood is suspected. The Andrew Shortland *et al.* paper noted that the ^{14}C measurements in question produced both dates that were consistent with the standard chronology and dates hundreds of years older perhaps representing old carbon, and contended that the two sets of dates should not have been averaged. (For additional Old Kingdom radiocarbon dates, see Manning 2006) L. Depuydt (2000) has analyzed a papyrus from the Abusir mortuary temple of the Fifth Dynasty king Neferefre as containing a Sothic date which would place his reign more than

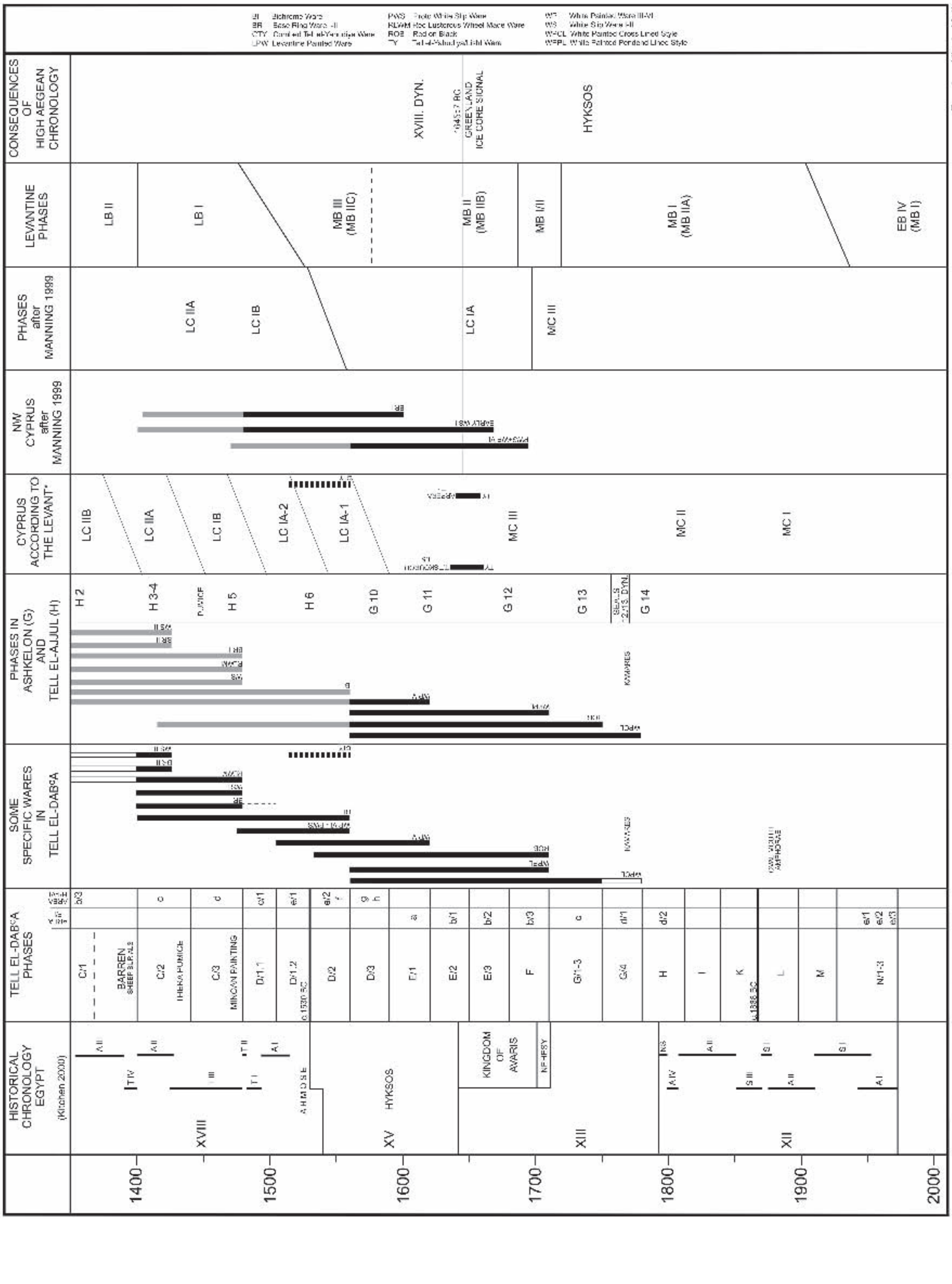

Fig. 1 Comparison of Tell el-Dabᶜa phases to the chronologies of Ashkelon, Tell el-ᶜAjjul, Cyprus and the Levant, including a reference to the 1645 ±7 Greenland ice-core signal (after Bietak 2003, fig. 1)

half a century earlier than conventional dating (KITCHEN 2000, 47–48). Some adjustment of traditional dates for the First Intermediate Period and the Old Kingdom is clearly possible. (Vera Müller's paper entitled "How Fixed is Egyptian Historical Chronology Really?" provides a general overview of this question and many of the problems considered by the workshop.)

THE CHALLENGE OF BAYESIAN-FILTERED RADIOCARBON DATES

A leitmotif of this workshop has been the challenge posed to traditional Egyptological dating by the presentation of radiocarbon dates from Tell el-Dab^ca in the Nile Delta said to be generally 100–150 years older than the dates previously assigned to the contexts in which the dated short-lived samples were found. Fig. 1 (BIETAK 2003) presents the Tell el-Dab^ca archaeological data in detail, together with interconnected archaeological data of chronological significance from Canaan, the Levant, Cyprus and the Aegean. Fig. 2 sets forth the radiocarbon determinations available as of the date of the workshop (I am greatly indebted to Walter Kutschera for allowing me to present his preliminary data here. Additional measurements and analysis will be presented at the 19th International Radiocarbon Conference at Oxford [2006].) In a comment from the floor, Peter Stadler reported that the radiocarbon samples from Miletus on the coast of Anatolia that he was measuring also gave some dates about 100 years too early in comparison with the traditional chronologies. The same shift has been claimed but disputed with regard to Aegean determinations (MANNING 1999; WIENER 2003; WIENER forthcoming). While most participants in the workshop appeared to accept both the existence of the difference and the fact that there was at present no explanation, two members of the workshop, Ezra Marcus and myself, questioned this consensus on the ground that the radiocarbon evidence from Dab^ca appeared unconvincing. The fact that the dates from the seeds recovered from post-Hatshepsut Tuthmosis III strata at Dab^ca were hundreds of years too early for dates which are closely fixed by textual and genealogical data from Egypt and the Near East, and perhaps absolutely fixed by astronomy, has already been noted above, and indeed the radiocarbon analysis indicates that there is very poor agreement between these actual ^{14}C measurements and the dates proposed after Bayesian sequencing, as Walter Kutschera noted. The radiocarbon dates for the early New Kingdom strata are also far too early in terms of well-established New Kingdom dates. No ^{14}C data have been presented to date from phases L or K, which cover the Sothic dates generally accepted for the 7th year of Senwosret III (nor, for that matter for phase I, which would correspond to the Sothic plus lunar date proposed by R. Krauss). One seed measurement for Thirteenth Dynasty level G/4 resulted in a Bayesian-filtered range of dates centering close to the Twelfth Dynasty 1872–66 B.C. span for the 7th year of Senwosret III. Moreover, three seed measurements from later Dab^ca Thirteenth Dynasty phases G/1–3, after Bayesian sequencing, overlap the 1872–66 B.C. range to some extent. Thus the Bayesian-sequenced radiocarbon dates proposed conflict with all views of the astronomical evidence. With respect to some of the other radiocarbon determinations obtained from seed samples at Tell el-Dab^ca, the bottom of the two sigma calibrated range encompasses the dates which would be strongly preferred on textual, genealogical and astronomical evidence in the absence of radiocarbon dates, as noted by Ezra Marcus in the discussion. The incompatibility of the New Kingdom ^{14}C dates proposed with all the other New Kingdom evidence was discussed above.

Accordingly, it is appropriate to review some of the problems inherent in radiocarbon dating, beginning with the process of Bayesian "sequencing." We may begin by noting the improvements in the past few years in the OxCal statistical programs employed by the Oxford Radiocarbon Laboratory. Walter Kutschera described the current OxCal program as the "Mercedes Model" as compared to the "Model-T Ford" of past decades. Of course the statistical model employed is a critical component of precision radiocarbon dating given the amount of raw data generated. The paper presented by Franz Weninger on behalf of himself, Peter Steier and Walter Kutschera noted that 15 samples for each year over 100 years would produce a total number of data points of 10^{30}. Accordingly, statistical methods are employed to create conditional probabilities by taking slices through each dimension of the data, and then examining the density points. Christopher Bronk Ramsey reported that further refinements were forthcoming in the form of a new version of the OxCal program employing Metropolis-Hastings Markov chain Monte Carlo modeling on a Web-based platform, in place of the step functions used previously.

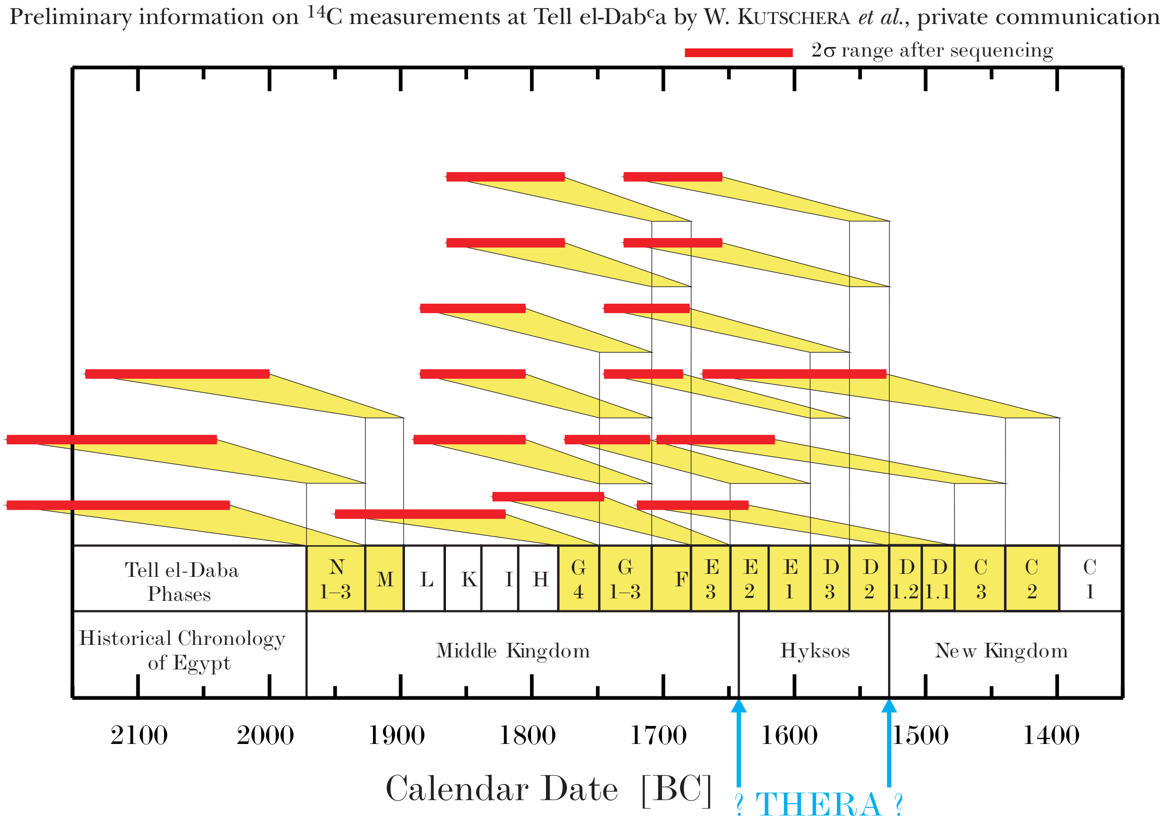

Fig. 2 Comparison of calibrated two sigma ^{14}C ranges with the historical chronology of Egypt and the corresponding Tell el-Dabᶜa phases

Of course no statistical package is bias free, and it may be worthwhile by way of illustration to note one of the difficulties inherent in the model. Suppose that a group of ^{14}C determinations from well-stratified seeds give age ranges before present which intersect an oscillating portion of the calibration curve for two decades in Century I and one decade in Century II. All else being equal, the OxCal program would give a probability of a date in Century I twice that of a date in Century II. In the absence of statistical interpretation, one might simply conclude that dates in both Century I and Century II are consistent with the radiocarbon evidence, and turn to the textual and archaeological evidence, if any. The Bayesian approach makes explicit that there are twice as many radiocarbon-appropriate years in Century I than Century II, and assuming as a Bayesian "prior" that each year is equally likely, gives a "mild weighting" to Century I irrespective of how many or how few samples are measured (Bronk Ramsey, pers. comm. of 19 December 2005, for which I am most grateful. Discussions of various issues arising from the application of Bayesian or quasi-Bayesian Probability Theory to radiocarbon dates may be found in Marcus, this volume; Wiener 2003; Wiener forthcoming; Cavanagh as quoted in Wiener 2003, 391 n. 148; Scott 2000; Whitelaw 1996).

In an ideal world, each seed cluster or other sample measured would be suitable for and subject to either repeated measurements or longer than typical measurement times (depending on the method employed) and also to repetition of pre-treatment on different parts of a sample. In practice, decisions as to duration or repetition of measurements are often made by laboratory technicians in light of the nature of the initial scatter of determinations and the difficulties presented by the sample, subject always to the constraints of available time and cost, which is itself time-dependent. The number of samples tested worldwide is great, with Groningen, for example, processing 4000 samples annually (van der Plicht and Bruins 2005). Between 1994 and 2000, over $1,000,000 was spent by English Heritage alone on radiocarbon dating of samples from the British Isles (Bayliss and Bronk Ramsey 2004, 26–27). The amount spent worldwide on radiocarbon dating today may well exceed

$1,000,000 annually. Submitting samples from excavations for ^{14}C determinations is now de rigueur, but unfortunately many submitted samples are of little value; *e.g.*, pieces of charcoal where there is no indication of the relation of the charcoal to the outer bark of the tree, and/or samples whose context is unclear. More effort devoted to fewer, but well-chosen, samples would seem the better course.

Of course all statements concerning radiocarbon measurements and dates assume the uniform distribution of radiocarbon in the earth's atmosphere at any one time, and hence the absence of distorting regional variation, seasonal variation, or old carbon in the sample measured, as noted below. Such statements assume as well the correctness of the decadal determinations of whichever calibration curve is employed, against which the samples tested are compared. A risk exists that some consumers of radiocarbon data may not realize that a "66.67% probability" in the stylized example given constitutes only a mild preference or that the probabilities stated for radiocarbon determinations do not encompass the probability of non-uniform radiocarbon distribution in the atmosphere nor the possible presence of old carbon in the sample nor the contingent nature of some decades of the calibration curve. Simply put, the probabilities stated for radiocarbon determinations are measurement probabilities, not date probabilities. The opportunity provided by this workshop to clarify such questions through discussion across disciplines was clearly of value.

Certainly the calibration curve, the critical input for the OxCal program, is itself an imperfect construct. The committee of leading ^{14}C authorities charged with producing the INTCAL04 revision of the calibration curve concluded that the previously utilized Gaussian bell-curve distributions were insufficient to capture the inherent uncertainty of ^{14}C determinations of radiocarbon ages, and recommended extending the one sigma range by a factor of 1.3 in presenting ^{14}C ages. The correction reflects only the uncertainties of radiocarbon measurement itself, and does not include the problems posed by calibration curve oscillations, regional variations, some of them episodic, or the potential presence of old carbon in the sample tested, as for example when the burning of a structure containing wood causes old carbon to become mixed with a seed sample.

Moreover, the INTCAL04 committee concluded that the risk of error in the individual decadal or duodecadal radiocarbon determinations comprising the INTCAL98 calibration curve was such that overall reliability would be improved by incorporating information from measurements from the preceding and following three decades of the calibration curve into each decadal segment of the curve. The potential sources of error included the limited amount of measurement of each segment by the Seattle and Belfast laboratories, the small number of samples measured for each decade or duodecade and the fact that modern methods of pre-treatment were not then employed. As a consequence, the ^{14}C determinations of the Seattle and Belfast laboratories produced inconsistent results for certain decades as well as determinations later recognized as faulty. Recent measurements of the data for certain critical decades, including comparisons with measurements of the Gordion sequence of wood of closely known dendrochronological date, have produced significant improvements in the data base. The smoothing of the data as described in the INTCAL04 calibration curve is intended to diminish the risk of major error in the measurement of each specific decade, but it will necessarily introduce some distortion in the decadal data, particularly where information is borrowed from decades where the calibration curve is rapidly changing. Moreover, the smoothing of the data automatically reduces the wiggles on which wiggle-matching depends, and accordingly the INTCAL98 calibration curve, whatever its flaws, will continue in use for certain purposes.

With regard to the radiocarbon measurements from Tell el-Dab^{c}a, the process of Bayesian "sequencing" occupies center stage, with the stratigraphic order in which the measured seed samples appeared providing the sole external data. The statistical process (greatly but not falsely simplified) involves slighting any part of the distribution (date range) from a seed measurement that is inconsistent with the range obtained from the radiocarbon measurement of a seed or seeds higher or lower in the stratigraphic excavation sequence. Unlike ^{14}C determinations from a dendro sequence, when the number of years between decadal tree-ring segments tested is known and the tree rings in any sequence or series of overlapping interconnected sequences do not move in relation to one another, the number of years separating Bronze Age archaeological strata is usually unknown. Furthermore, the seeds recovered from them and measured radiometrically may move between strata as the result of human, animal, plant or geological activity, even as a result of post-depositional earth movement apparent only to micromorphologists. Two seed samples may be separated by a destruction level, so that one sample will appear to be clearly earlier in date than the other, but the number of years separating the samples will not be known. Suppose that the seeds from which the ^{14}C determinations have been taken are in fact close in date, in the same decade or in a relatively flat part of the calibration curve where the actual date difference cannot be accurately determined by radiocarbon dating. Attempting to provide meaning for otherwise somewhat inchoate radiocarbon determinations via sequencing in such circumstances runs major risks. M. SCOTT (2000) summarized the general position as follows: "Bayesian analysis is not a 'cure-all'; it has costs, not least the specification of the prior. This is not easy and even in those situations where we think we are not making any strong assumptions, there may be hidden complications." As Christopher BRONK RAMSEY (2005) has noted, no two practitioners are likely to apply the Bayesian model in the same way to the same data. Of course radiocarbon measurements for the century comprising the decadal measurements between 1625 B.C. and 1535 B.C. – essentially the Hyksos period – must contend with the oscillation of the calibration curve in these years, depicted in Fig. 3.

The foregoing caveats (and to some extent those stated below) to the proposed Dab^ca ^{14}C dates are open to the major objection that to the degree such distorting factors exist, their effects should be random, whereas the results obtained purportedly produce somewhat uniform ranges of dates 100–120 years earlier than generally accepted New Kingdom, Second Intermediate Period and Middle Kingdom dates presented by the other papers in this conference. Such an objection appears at least partly circular, however, inasmuch as the radiocarbon dates prior to Bayesian sequencing are largely lacking in structure (although at their central points tending somewhat earlier than standard dates) as noted above. Moreover, the New Kingdom dates which fall into the same general purported pattern and provide a central date of c. 1620 B.C. for post-Hatshepsut Tuthmoside levels and similarly inappropriate dates for the early New Kingdom cannot be correct in any event and the ^{14}C measurements obtained from seeds from Thirteenth Dynasty phases give dates which overlap the widely accepted astronomical dates for the Twelfth Dynasty (LUFT and SHORTLAND *et al.* in this workshop). Accordingly, the objection posed may be reversed by inquiring whether, given that the radiocarbon dates proposed are putatively 100–150 years too early for the Tuthmoside era, the early New Kingdom and the Thirteenth Dynasty, there may be some systemic factor at work affecting the radiocarbon dates.

Apart from the risk of creating false positives through Bayesian analysis noted by Ezra Marcus in his comment at this workshop and considered above, physical problems arising from the possible presence of old carbon and from regional variation, sometimes exacerbated by climatic conditions, can affect radiocarbon measurements. A theoretical potential problem area for seed measurements from riverine environments reported in the literature should be noted in passing, although the evidence is as yet slight and the significance questionable. Groundwater from rivers and marshes is a recognized source of old carbon. While plants absorb the bulk of their carbon from the atmosphere via their leaves, a small amount comes directly from the soil through their roots (WIENER forthcoming, citing GEISLER 1963; YORGALEVITCH and JANES 1988; STOLWIJK and THIMANN 1957; SKOK, CHORNEY and BROECKER 1962; SPLITTSTOESSER 1966; ARTECA, POOVAIA and SMITH 1979). Whether plants almost totally dependent on Nile waters might be affected is unknown.[2] ^{14}C determinations from Amarna-period seeds have not resulted in dates earlier than those established through non-radiocarbon methodologies.

A more conspicuous problem for radiocarbon dating of Egyptian seed samples is posed by the phenomenon of regional variation in ^{14}C measurements. Regional variation may take two forms:

[2] Another example from a Nilotic environment of radiocarbon determinations inconsistent with perceived stratigraphy for the period 2150–1450 B.C. is provided by a series of thirteen dates at Kerma in Nubia (HONEGGER 2005). The radiocarbon dates from Kerma were obtained from charcoal rather than seeds, however; accordingly, the anomalies noted may have resulted from the presence of old wood.

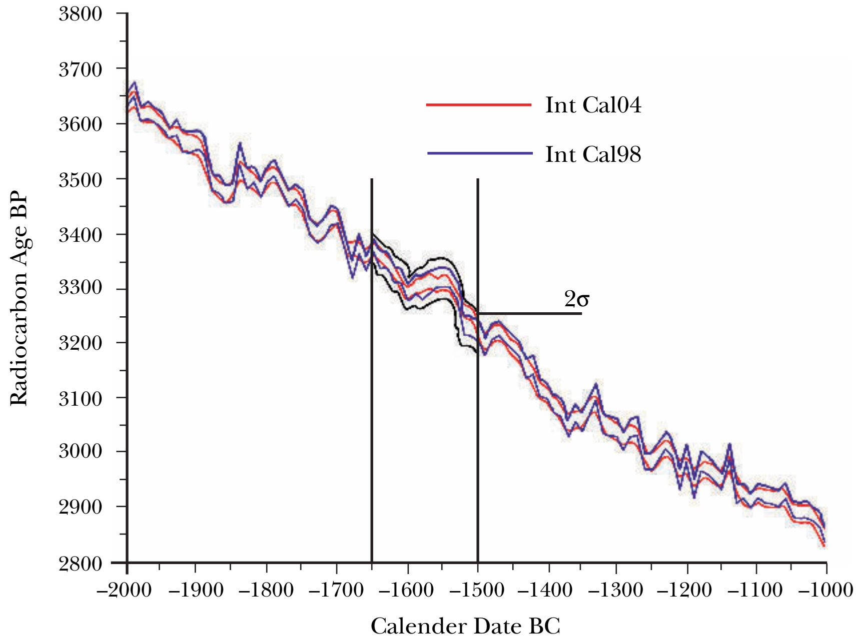

Fig. 3 Comparison of INTCAL98 and INTCAL04 calibration curves, with the addition of a two sigma range in the span between 1500 and 1650 (after S. MANNING in: The Thera (Santorini) Volcanic Eruption and the Absolute Chronology of the Aegean Bronze Age, a companion website to MANNING 1999, http://www.arts.cornell.edu/classics/Faculty/SManning_files/testoftime.pdf)

general differences, as yet inadequately understood, between regions – *e.g.*, Northern *vs.* Southern Hemisphere or (less significantly), Old World *vs.* New World – and variation due to ongoing differences in climate or changes in climate affecting the growing season of plants in relation to the annual carbon cycle.

As to general regional differences, no one can say with confidence why measurements of Southern Hemisphere tree segments of known date are older than Northern Hemisphere tree segments of known date by an average of 41 ±14 years over the last millennium, but with wide differences within the period (MCCORMACK *et al.* 2002; STUIVER *et al.* 1998, 1046) or why bristlecone pine measurements from the western United States of known date show a 37 ±6 year shift from European oak of the same known date (REIMER *et al.* 2004, 1033). Proposed explanations for the Northern *vs.* Southern Hemisphere disparity include 1) the fact that more of the Southern Hemisphere is covered by water; 2) the escape of carbon from a sink of carbon around 17,000 years old in the Weddell Sea in Antarctica; and 3) upwellings of old carbon from El Niño episodes in the Pacific Ocean (LERMAN, MOOK and VOGEL 1970; OLSSON 1979; 1987; KNOX and MCFADGEN 2001; KEENAN 2002). The hypothetical possibility of old carbon from the Mediterranean periodically affecting Egyptian ^{14}C dates has been discussed by D. KEENAN (2002), but no method has been proposed for testing this hypothesis.

As to regional seasonal variation, consider the instructive example of the discrepancy between Anatolian and European radiocarbon determinations from tree-ring segments almost certainly from samples from the same respective decades in the ninth–eighth centuries B.C. KROMER *et al.* (2001) propose that a marked climate change in Anatolia in this period delayed the growing season of the Anatolian trees (see also MANNING *et al.* 2001). P. Reimer, the director of the Belfast Laboratory and lead investigator of the INTCAL04 calibration curve revision, has described succinctly the process at work:

> "^{14}C is primarily produced at high latitudes in the lower stratosphere by the collision of cosmic ray-produced neutrons with nitrogen. During periods of high solar activity, distortion of Earth's geomagnetic field by the solar wind prevents charged particles from entering the atmosphere and little ^{14}C is produced, whereas ^{14}C production peaks during periods of low solar activity (solar minima). The atomic ^{14}C is quickly oxidized to $^{14}CO_2$ and enters the troposphere during the late spring, a period of high stratospheric-tropospheric exchange. By the next spring, the higher ^{14}C concentration

in the atmosphere has been well mixed and diluted by exchange with other carbon reservoirs, particularly the surface ocean. The German trees, which grow mostly in the mid to late summer, take up more $^{14}CO_2$ during photosynthesis than do the Mediterranean trees, which grow in the spring and early summer." (REIMER 2001, 2495).

The growing seasons of Egyptian seeds and the European oak trees which form the basis of the calibration curve are clearly quite different, for almost all Nile plants grow in winter to early spring and the European oaks in mid-spring to early summer. Of course we lack information about climate events, if any, in Egypt between 1900 B.C. and 1450 B.C. which could have had an effect on ^{14}C determinations analogous to the putative cold period in ninth–eighth century B.C. Anatolia. (In the preceding First Intermediate Period, we have harrowing accounts of the suffering caused by the cessation of the Nile floods.)

Unfortunately, it is easier to state the problems inherent in radiocarbon dating than to assess whether, or to what extent, the problems may have affected the radiocarbon dates from any particular site, such as Tell el-Dab^c^a. As the concluding discussion at the workshop made clear, most participants felt that the resolution of the apparent chronological conflict between the radiocarbon measurements from Dab^c^a, on the one hand, and the evidence from astronomy, archaeology and texts on the other must await future developments. A well-known scientific proverb instructs us that "if your data need a heavy dose of statistics to yield results, obtain more data," and accordingly we look forward to results of additional analyses of seed samples from Dab^c^a now underway at the Vienna Environmental Research Accelerator Institute (VERA). Nevertheless, at this fine workshop the productive interaction of radiocarbon physicists and statisticians with experts in Egyptian astronomy, chronological texts and history and with archaeologists working throughout the Near East, in the supportive ambiance of the VERA Institute, promoted interdisciplinary understanding, facilitated probing exchanges and opened important channels of communication. The foundation for future progress across disciplines in Egyptian chronology is now in place.

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