

CHARCOAL RADIOCARBON DATES OF TELL EL-DAB^a

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INTRODUCTION

Tell el-Dab^a, situated in the north-eastern Nile Delta, occupies a crucial position in the study of both Egyptian and regional chronologies in the 2nd millennium BCE (BIETAK, 1991, 1997, 2003). As the ancient capital of the Hyksos – Avaris – the site provides key archaeological information about the Second Intermediate Period and the transition to the 18th Dynasty. The stratified archaeological remains of Tell el-Dab^a facilitate essential associations with Egyptian literary sources and their unique historical chronological information.

How can we know that these historical data and the related chronological interpretations are correct? How can we verify the “Egyptian Calendar”, which forms the *de facto* absolute chronological basis for archaeology in the entire Eastern Mediterranean Region, including the Aegean and the Levant? Such verification, which is a legitimate scientific request, must come from an independent outside source in order to avoid circular reasoning. Radiocarbon dating is the most obvious basis for verification and even for possible modification of the “Egyptian Calendar” (HASSAN and ROBINSON, 1987; BRUINS and MOOK, 1989; VAN DER PLICHT and BRUINS, 2001). However, hardly any ¹⁴C dating of 2nd millennium Egypt has been carried out (BRUINS and VAN DER PLICHT, 2003).

The chronological controversy concerning the date of the Minoan Thera eruption (MANNING, 1999; MANNING and BRONK RAMSEY, 2003; HAMMER *et al.*, 2003; BIETAK, 2003; WIENER, 2003) is a serious problem. The archaeological interconnections between various sites in the Eastern Mediterranean region form a material cultural network with intrinsic chronological significance. The pinning down of this network to calendar years should not be based solely on Egyptian literary sources. Radiocarbon dating of stratigraphic sequences of key sites throughout the region may provide the chronological linchpin to solve the problem.

This article presents and evaluates a series of 16 radiocarbon dates of Tell el-Dab^a, which were measured in 1987–1988 by Dr. Edwin Pak at the Institut für Radiumforschung und Kernphysik (University of Vienna). All samples consisted of charcoal, mainly from Acacia trees, which was used as fire wood in the different strata at Tell el-Dab^a (Bietak, personal communication). At first face the results looked rather inconsistent and were, therefore, never published.

However, statistical options available in the OxCal program (BRONK RAMSEY, 1995, 2001, 2003) enable verification (ranking) of individual dating results through Markov Chain Monte Carlo (MCMC) sequencing analysis within the constraints of stratigraphic models. Since the Tell el-Dab^a charcoal dates can be related to each other, according to the detailed stratigraphy of the site (BIETAK, 1991, 1997), such evaluation is possible and worthwhile. A new series of radiocarbon dates based on short-lived samples from Tell el-Dab^a, measured by AMS (VERA Laboratory, University of Vienna), will soon be published (KUTSCHERA, in preparation). These dates are undoubtedly of a better quality. Nevertheless, it is important to have an account also of the series of 16 multi-year charcoal dating results.

Some background comments made by Dr. Edwin Pak (letter 23-02-1988) concerning the 16 charcoal dates are quoted: “Konventionsgemäß sind die Daten auf das Jahr 1950 bezogen und unter Zugrundelegung der seinerzeit von Libby angenommenen ¹⁴C-Halbwertszeit von 5568 Jahren berechnet. Die statistische Unsicherheit des Alterswertes ist als (einfache) Standard-abweichung angegeben ... Jedes Zitieren der Datierung sollte immer samt der statistischen Unsicherheit und der VRI-Nummer erfolgen”. This basic information concerning the meaning of BP in radiocarbon dating and the half-time used in the calculation of the age values, though a more precise value exists, as well as the convention about citation of ¹⁴C dates, are concisely explained in the monograph by MOOK and WATERBOLK (1985).

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SIXTEEN ^{14}C CHARCOAL DATES OF TELL EL-DAB^a: STRATIGRAPHIC EVALUATION

Most charcoal samples were derived from strata in Area F (the new centre of the Middle Bronze Age population), except for one sample (#38, VRI-942) coming from Area A (the eastern town) (BIETAK 1991, 1997). The radiocarbon dating results are summarised in Table 1 in stratigraphic order, putting the youngest layer on top. The calibrated dates, using the OxCal program (BRONK RAMSEY, 1995, 2001, 2003), appear in Column 10. The next column, 11, shows the mid-probability point (50% p), besides the 16% p and 84% p values, calculated with the Cal25 program (VAN DER PLICHT, 1993). The rather large σ of the individual ^{14}C dates in BP years results in a roughly Gaussian calibrated age, which justifies the use in this case of the mid-probability point as an approximation of the highest relative probability. The last column shows the narrower ranges of calibrated dates, selected by Markov Chain Monte Carlo (MCMC) sampling (GILKS *et al.*, 1996; BRONK RAMSEY, 2003) within the constraints of a stratigraphic model, explained below.

Figure 1 shows the series of 16 normally calibrated dates in stratigraphic order, using the OxCal program. The results of alternating old and young dates appear at first face to carry no sensible pattern of useful information. Should these 16 dates be simply rejected as a non-coherent series?

The acceptability of the dates within the constraints of the stratigraphic order can be tested by statistical analysis. Figure 1 shows the make-up of the sequence model for analysis with MCMC sampling in the OxCal program. The propositions put into the model are entirely based on the Tell el-Dab^a stratigraphy (BIETAK, 1991, 1997). The dates are organized in stratigraphic phases separated by boundaries. Two hiatus intervals (BIETAK, 1991, 1997) are also included. Neither historical dates nor historical information have been put into the model. The MCMC sampling method generates probabilities for the ^{14}C dates within the constraints of the stratigraphic propositions and also evaluates the agreement of individual dates within the model, as well as the overall agreement. Statistical background information for these procedures can be found in the OxCal manual (BRONK RAMSEY, 2003) and other publications (BUCK *et al.*, 1992; GILKS *et al.*, 1996; BRONK RAMSEY 2001; STEIER *et al.*, 2001).

The sequencing results of all dates, according to this model, are graphically displayed in Figure 2. The overall agreement is poor, only 31.3%, which is well below the critical value of 60% (OxCal manual,

BRONK RAMSEY, 2003). Looking at each individual date within the sequence, it appears that this is caused by 4 dates that show poor agreement lower than 60%: #36 VRI-940, #119 VRI-951, #34 VRI-938, and #120 VRI-952. Removing these 4 radiocarbon measurements results in a series of 12 remaining dates, which appear to be reasonably coherent (Figure 3). Two dates with a very large σ (#44 VRI-948 and #50 VRI-949) are a bit problematic but are kept in the stratigraphic sequence as both received MCMC agreement above 60% (Figure 2).

Running the sequence model with MCMC sampling analysis – without the four “bad” dates – gives a dramatic improvement of the overall agreement, which is now 136% (Figure 4). All individual dates show agreement above 60%. The selected calibrated age ranges generated by MCMC sampling within the constraints of the model are numerically presented in Table 1, column 12. A more detailed description and evaluation of the results in comparison with archaeological-historical age assessments follows in stratigraphic chronological order, beginning with the oldest layer and going successively to younger strata.

Stratum e

The earliest known town at Tell el-Dab^a is purely Egyptian in character, composed of a royal domain and an orthogonally planned settlement further to the south, represented by Stratum e. The latter settlement belongs, according to ceramic studies, to the beginning of the 12th Dynasty (ca 1963–1934 BCE), to the period of Amenemhat I and Sesostri I (CZERNY, 1999; BIETAK, 1997). There is one charcoal sample (#43) from stratum e, which yielded a radiocarbon date of 3760 ± 130 BP (VRI-947). This is indeed the oldest ^{14}C date obtained in the entire series (Table 1), thus fitting well with the stratigraphic sequence. The large standard deviation (σ) of 130 results in a very wide calibrated age range covering the 1 σ period of 2400–1979 BCE. This result is older than the archaeological-historical date of 1963–1934 BCE. The even wider 2 σ calibrated age range of 2563–1812 does accommodate the historical date in its younger margin. However, the midpoint of the calibrated date (50% probability), 2072 BCE (Table 1, column 11), is more than a century older than the historical date, according to the Cal25 program (VAN DER PLICHT, 1993). The 1 σ MCMC sampling calibrated age range, according to the above stratigraphic model, is 2233–1978 BCE (Table 1, column 12), which is also older than the historical age. This MCMC date is narrower – more precise – and somewhat younger than the regular 1 σ calibrated

# No	Stratum	Area	Charac- teristics	Culture	Dynasty	Archaeo- Historical Age	Lab No	¹⁴ C Date (yr BP)	Calibrated Date BCE OxCal 3.9 r-2 1) Standard Calibration	Calibrated Date BCE Cal25 2) Mid-(50%) probability	Calibrated Date BCE OxCal 3.9 r-2 3) Sequencing 12 agreeable results with MCMC sampling
120	b/1-2	F	b/1 is Hyksos	MB IIB	Late 13 to 15	1680-1620	VRI-952	3680 ± 130	1σ: 2278-2252 (3.8%) 2230-2220 (1.5%) 2206-1883 (62.9%) 2σ: 2458-2416 (2.2%) 2408-1742 (93.2%)	16%p: 2263 50%p: 2072 84%p: 1898	
38	F (~b/3)	A	Kingdom of Nehesy	MB IIA-IIB	13	1710-1680	VRI-942	3420 ± 110	1σ: 1880-1839 (9.9%) 1830-1603 (56.4%) 1552-1547 (1.0%) 1542-1538 (0.9%) 2σ: 2016-1997 (1.0%) 1980-1490 (92.9%) 1479-1451 (1.5%)	16%p: 1868 50%p: 1727 84%p: 1587	1σ: 1745-1613 (68.2%) 2σ: 1781-1522 (95.4%) Agreement 116.9%
32	b/3	F	Kingdom of Nehesy	MB IIA-IIB	13	1710-1680	VRI-936	3280 ± 120	1σ: 1728-1723 (0.8%) 1688-1429 (67.4%) 2σ: 1879-1839 (2.8%) 1829-1366 (88.6%) 1363-1295 (4.0%)	16%p: 1707 50%p: 1570 84%p: 1442	1σ: 1742-1607 (68.2%) 2σ: 1783-1506 (94.2%) Agreement 102.5%
33	c/1 b/3	F	Mass burials	MB IIA	13	ca. 1710			1σ: 1879-1840 (8.7%) 1828-1791 (7.6%) 1783-1600 (44.8%) 1566-1529 (7.2%) 2σ: 2024-1996 (1.5%) 1980-1434 (93.9%)	16%p: 1869 50%p: 1717 84%p: 1568	1σ: 1784-1679 (68.2%) 2σ: 1832-1608 (95.4%) Agreement 126.0%
39	c/1 b/3	F	Mass burials	MB IIA	13	ca. 1710	VRI-943	3560 ± 170	1σ: 2138-2075 (8.2%) 2072-1688 (60.0%) 2σ: 2352-1513 (95.4%)	16%p: 2147 50%p: 1916 84%p: 1703	1σ: 1787-1684 (68.2%) 2σ: 1836-1614 (95.4%) Agreement 105.7%
34	c	F	Canaanite settlement	MB IIA	13	1740-1710	VRI-938	3310 ± 110	1σ: 1736-1714 (4.9%) 1691-1492 (58.0%) 1478-1454 (5.3%) 2σ: 1881-1837 (3.8%) 1832-1383 (91.6%)	16%p: 1728 50%p: 1600 84%p: 1478	
40	c	F	Canaanite settlement	MB IIA	13	1740-1710	VRI-944	3560 ± 120	1σ: 2115-2099 (2.5%) 2037-1740 (65.7%) 2σ: 2204-1603 (95.4%)	16%p: 2081 50%p: 1907 84%p: 1754	1σ: 1834-1741 (68.2%) 2σ: 1888-1684 (95.4%) Agreement 112.1%
42	c	F	Canaanite settlement	MB IIA	13	1740-1710	VRI-946	3560 ± 130	1σ: 2124-2097 (4.1%) 2090-2084 (0.7%) 2039-1738 (61.4%) 1708-1694 (2.0%) 2σ: 2283-2250 (1.4%) 2208-1600 (92.4%) 1570-1528 (1.6%)	16%p: 2095 50%p: 1908 84%p: 1745	1σ: 1834-1740 (68.2%) 2σ: 1888-1684 (95.4%) Agreement 115.3%

#No = archaeological sample number; VRI = ¹⁴C Lab acronym of the Institut für Radiumforschung und Kernphysik (University of Vienna); 1) Individual calibration of each date with the OxCal v3.9 program, using a resolution of 2 (BRONK RAMSEY, 2003); 2) Mid-point probability of the calibrated date (50% p), as well as (16% p and 84% p) with the Cal25 calibration program (VAN DER PLICHT, 1993); 3) Sequence MCMC analysis of all 12 agreeable radiocarbon results, without VRI-938, VRI-940, VRI-951, VRI-952, according to the stratigraphic model with phase boundaries and two hiatus intervals, based on the stratigraphy of Area F (BIETAK, 1991, 1997). The MCMC analysis used 908,693 iterations. Overall Agreement is 135.9%, which is well above the minimum standard of 60.0%

Table 1 Charcoal radiocarbon dates of Tell el-Dab^{ca}, their stratigraphic relations, archaeo-historical age assessment, and ¹⁴C calibrated age ranges

# No	Stratum	Area	Charac- teristics	Culture	Dynasty	Archaeo- Historical Age	Lab No	¹⁴ C Date (yr BP)	Calibrated Date BCE OxCal 3.9 r:2 1) Standard Calibration	Calibrated Date BCE Cal25 2) Mid-(50%) probability	Calibrated Date BCE OxCal 3.9 r:2 3) Sequencing 12 agreeable results with MCMC sampling
44	d/1	F	Egyptian palace	MB IIA	Early 13	1780–1750	VR1-948	3270 ± 250	1σ: 1882–1836 (4.1%) 1833–1295 (63.0%) 1232–1217 (1.1%) 2σ: 2146– 914 (95.4%)	16%p: 1870 50%p: 1557 84%p: 1237	1σ: 1912–1808 (68.2%) 2σ: 1978–1753 (95.4%) Agreement 88.5%
50	d/1	F	Egyptian palace	MB IIA	Early 13	1780–1750	VR1-949	3270 ± 220	1σ: 1877–1841 (3.4%) 1814–1797 (1.6%) 1779–1294 (62.2%) 1275–1264 (1.0%) 2σ: 2135–2079 (1.4%) 2060– 997 (94.0%)	16%p: 1833 50%p: 1556 84%p: 1276	1σ: 1911–1808 (68.2%) 2σ: 1977–1755 (95.4%) Agreement 77.5%
119	d/1	F	Egyptian palace	MB IIA	Early 13	1780–1750	VR1-951	3740 ± 120	1σ: 2330–2323 (1.0%) 2308–2008 (60.5%) 2003–1974 (4.7%) 1971–1957 (1.9%) 2σ: 2472–1874 (94.0%) 1842–1810 (1.4%)	16%p: 2333 50%p: 2154 84%p: 1986	
122	d/1	F	Egyptian palace	MB IIA	Early 13	1780–1750	VR1-953	3500 ± 110	1σ: 2008–2003 (0.9%) 1957–1685 (67.3%) 2σ: 2135–2080 (3.7%) 2049–1597 (87.7%) 1591–1525 (4.1%)	16%p: 1971 50%p: 1826 84%p: 1694	1σ: 1914–1812 (68.2%) 2σ: 1976–1758 (95.4%) Agreement 127.4%
51	d/1–2	F		MB IIA	Late 12 – Early 13	1800–1760	VR1-950	3520 ± 130	1σ: 2029–1992 (6.1%) 1982–1686 (62.1%) 2σ: 2199–2159 (1.9%) 2148–1521 (93.5%)	16%p: 2029 50%p: 1855 84%p: 1696	1σ: 1976–1857 (68.2%) 2σ: 2048–1792 (95.4%) Agreement 120.5%
36	d/2	F	Canaanite settlement	MB IIA	Late 12	1830–1780	VR1-940	3290 ± 120	1σ: 1731–1721 (1.9%) 1689–1434 (66.3%) 2σ: 1882–1836 (3.4%) 1833–1366 (89.0%) 1363–1308 (3.0%)	16%p: 1719 50%p: 1580 84%p: 1452	
37	d/2	F	Canaanite settlement	MB IIA	Late 12	1830–1780	VR1-941	3680 ± 120	1σ: 2271–2257 (2.1%) 2203–1885 (66.1%) 2σ: 2404–2362 (2.4%) 2353–1744 (93.0%)	16%p: 2250 50%p: 2071 84%p: 1910	1σ: 2050–1892 (68.2%) 2σ: 2179–1858 (95.4%) Agreement 118.5%
43	e	F	Planned orthogonal settlement, Egyptian culture	MB I	12	1980–1920	VR1-947	3760 ± 130	1σ: 2400–2380 (2.9%) 2348–2013 (62.4%) 1998–1979 (2.9%) 2σ: 2563–2522 (1.5%) 2497–1876 (92.8%) 1841–1812 (1.1%)	16%p: 2377 50%p: 2182 84%p: 1998	1σ: 2233–1978 (68.2%) 2σ: 2402–1907 (95.4%) Agreement 112.4%

#No = archaeological sample number; VR1 = ¹⁴C Lab acronym of the Institut für Radiumforschung und Kernphysik (University of Vienna); 1) Individual calibration of each date with the OxCal v3.9 program, using a resolution of 2 (Bronk Ramsey, 2003); 2) Mid-point probability of the calibrated date (50% p), as well as (16% p and 84% p) with the Cal25 calibration program (VAN DER PLICHT, 1993); 3) Sequence MCMC analysis of all 12 agreeable radiocarbon results, without VR1-938, VR1-940, VR1-951, VR1-952, according to the stratigraphic model with phase boundaries and two hiatus intervals, based on the stratigraphy of Area F (BIETAK, 1991, 1997). The MCMC analysis used 908,693 iterations. Overall Agreement is 135.9%, which is well above the minimum standard of 60.0%

Table 1 continued Charcoal radiocarbon dates of Tell el-Dab'a, their stratigraphic relations, archaeo-historical age assessment, and ¹⁴C calibrated age ranges

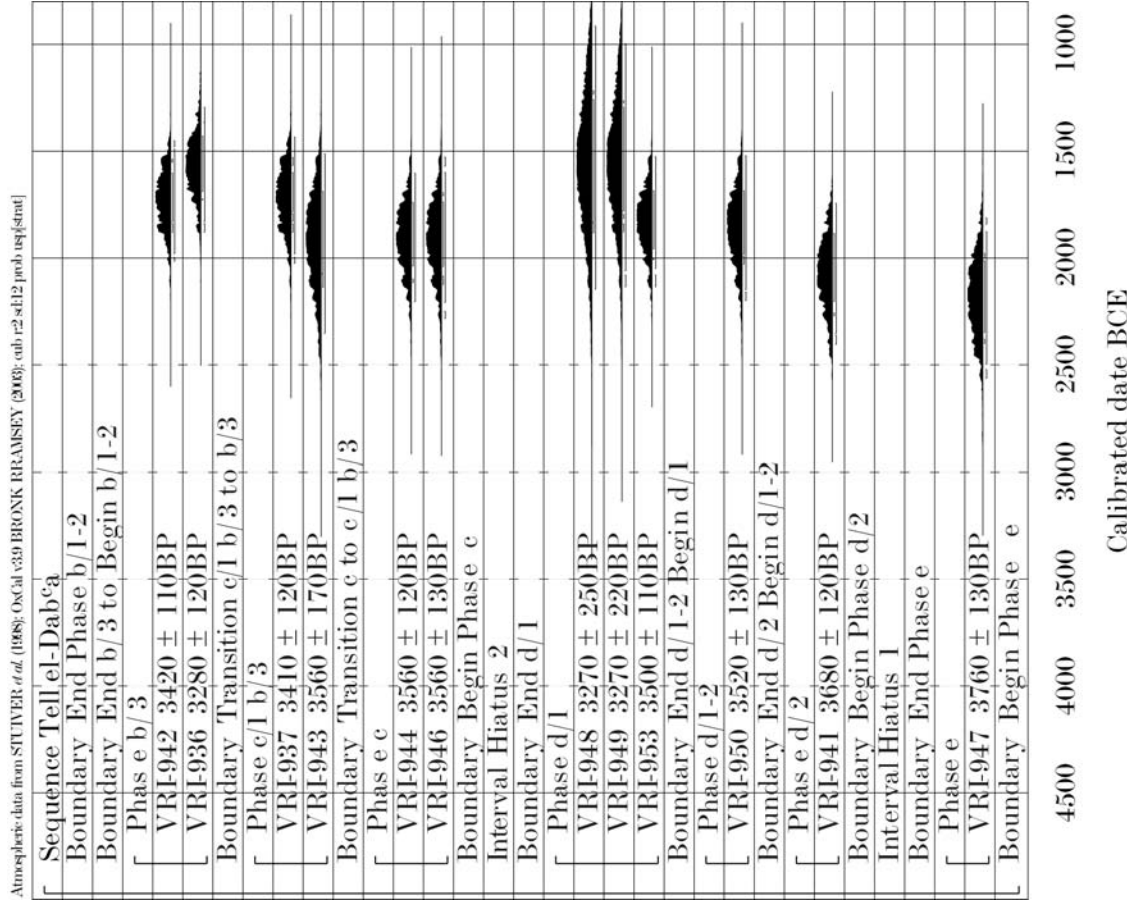


Fig. 3 The 12 agreeable dates in the Tell el-Dab'a series in stratigraphic order show a reasonably consistent pattern. The comparatively young dates VRI-948 and VRI-949 are somewhat problematic but nevertheless agreeable in the sequence due to their large σ

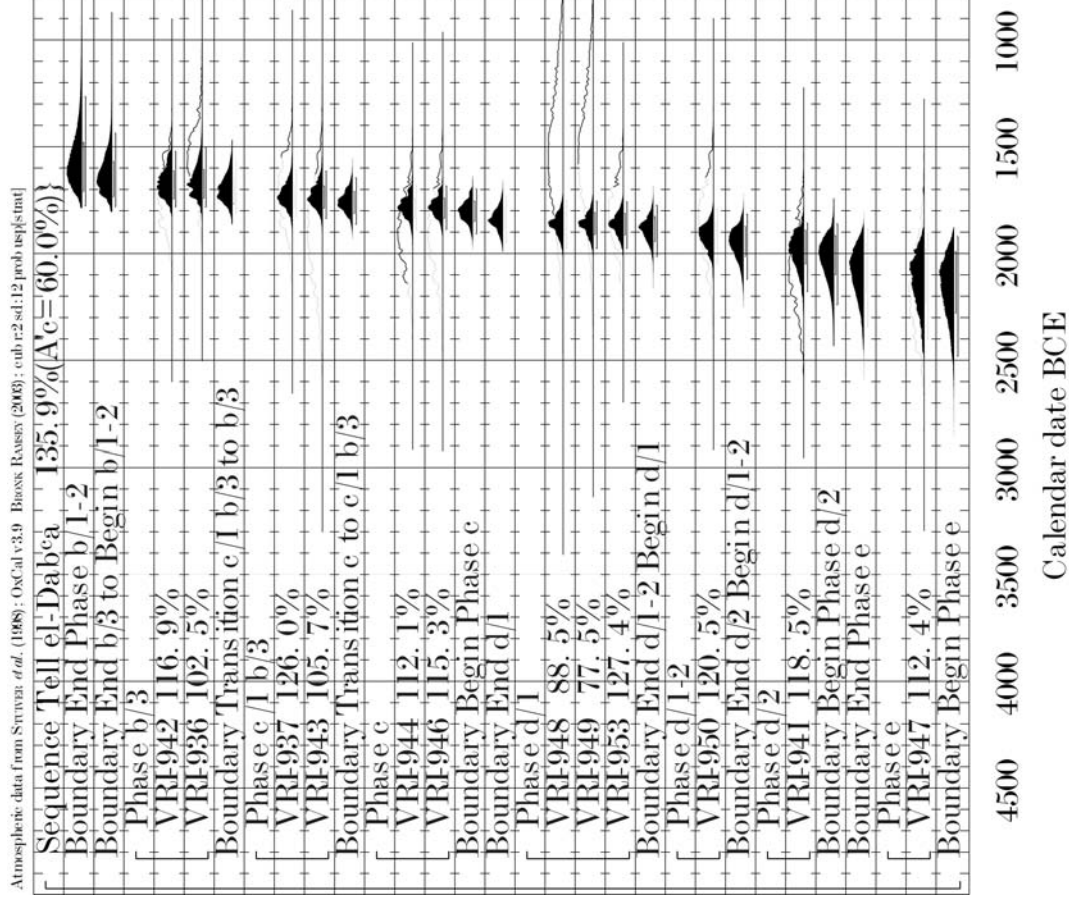


Fig. 4 Sequencing of the remaining 12 radiocarbon dates with Bayesian statistics using Markov Chain Monte Carlo (MCMC) sampling. The sequence model now has a good overall agreement (135.9%), well above the minimum required 60%

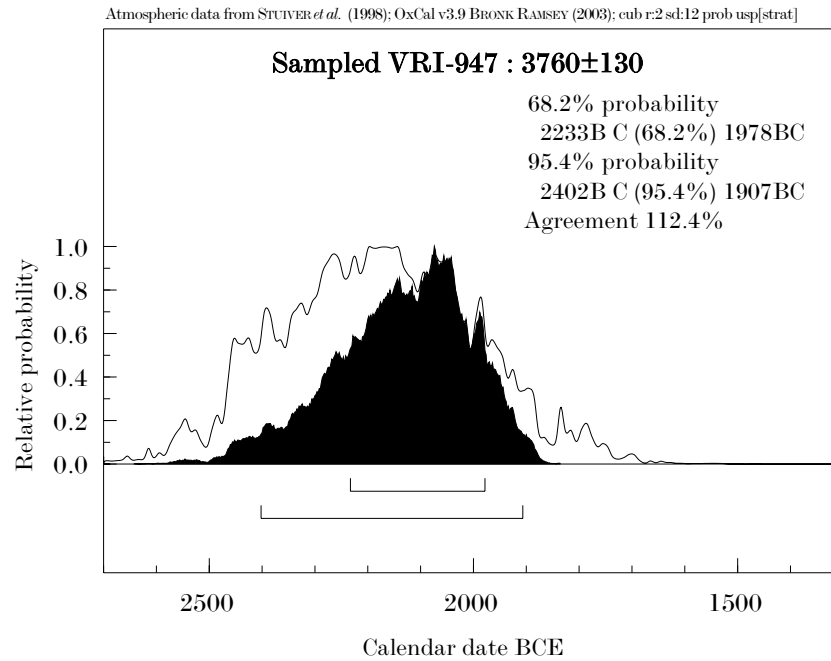


Fig. 5 Selected date by MCMC sampling (solid black) of Stratum e, being somewhat younger and narrower than the regular calibrated date (area below irregular black line)

range, modified by the stratigraphic sequence constraints, as shown graphically in Figures 4 and 5. However, as the internal age of the charcoal (old-wood effect) is unknown, no firm conclusions may be drawn until results of short-lived samples from Stratum e may be available.

Hiatus 1

MCMC sampling also gives an indication for the duration of the Hiatus interval between Strata e and d/2. The 1σ sampled duration of the interval is 0–79 years (Figure 6), which seems to fit well with

the archaeological-historical assessment of about 90 years (BIETAK, 1991, 1997).

Stratum d/2

A Canaanite settlement with *Mittelsaal* house type characterises Stratum d/2 (BIETAK, 1997). Though most pottery is composed of Egyptian types, about 20% is Levantine Middle Bronze Age in style. The settlement is dated on archaeological-historical grounds, based on the seriation of Egyptian ceramics, to the end of the 12th Dynasty, approximately 1830–1780 BCE (BIETAK, 1997).

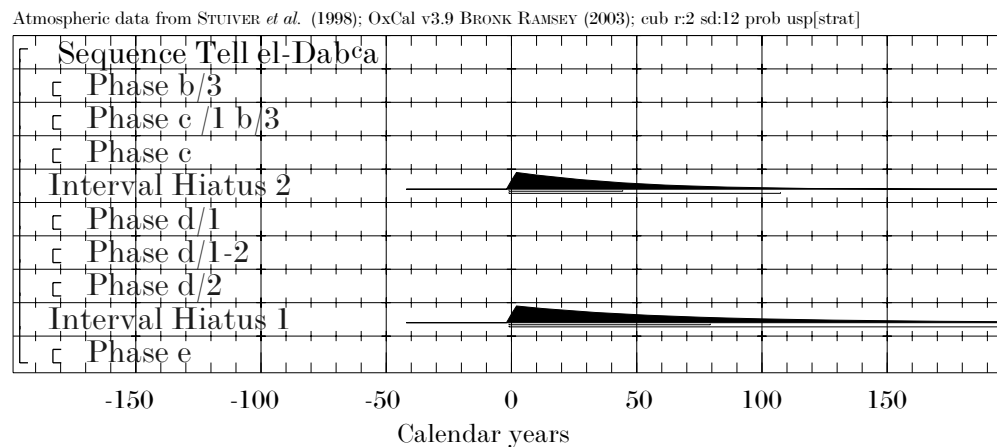


Fig. 6 MCMC sampled duration of the two hiatus intervals in the stratigraphic sequence. The upper line beneath and part of the solid black graphics of Hiatus 1 and Hiatus 2 indicates the 1σ range and the lower line the 2σ range

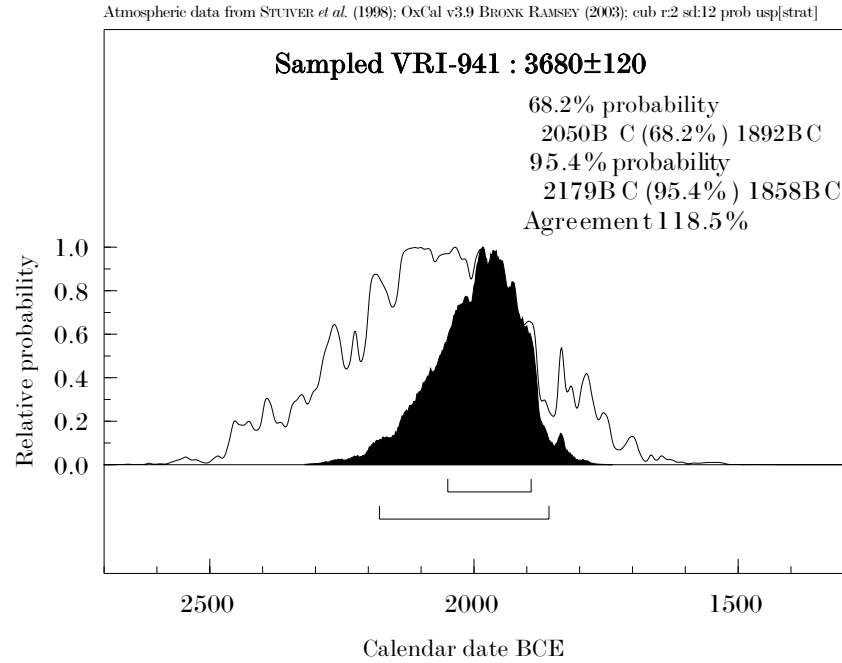


Fig. 7 MCMC sampling selects a narrower and somewhat younger part of the full calibrated age range for Stratum d/2, according to the stratigraphic model

There are two ^{14}C dates for Stratum e, which differ considerably in age: 3290 ± 120 BP (VRI-940) and 3680 ± 120 BP (VRI-941). It is statistically not correct in this case to calculate a weighted average, because the chi-squared test is not passed: $T=5.3$ (5% 3.8). The sequence analysis of all ^{14}C dates with MCMC sampling, using a stratigraphic model (Figure 2), rejects the young date (VRI-940). Its poor agree-

ment of only 15.5% within the sequence is well below the acceptable limit of 60%. The agreeable older date has a 1σ calibrated age of 2271–1885 BCE, which is older than the historical age. Likewise, the mid-probability point of 2071 BCE is considerably older by more than 200 years. The selected narrower age range following MCMC sampling (Figure 7) is 2050–1892 BCE, also older than the historical date (Table 1).

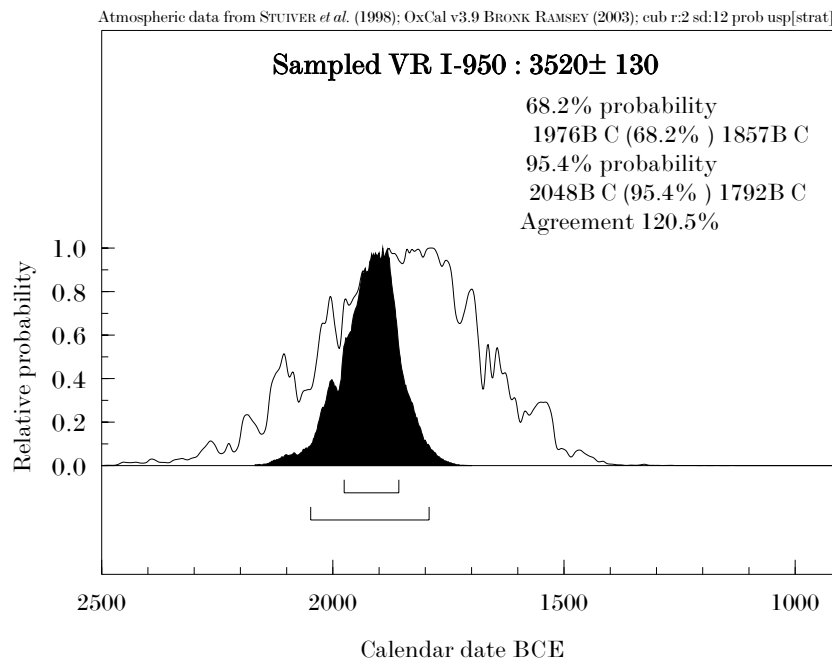


Fig. 8 MCMC sampling selects a narrower and somewhat older part of the full calibrated age range for Stratum d/1-2, according to the stratigraphic model

Stratum d/1–2

The dated sample (VRI-950, 3520 ± 130 BP) is from a layer transitional between d/2 and d/1. The latter Stratum is characterised by an Egyptian palace of the 13th Dynasty and associated tombs. Stratum d/1 is archaeologically-historically dated to the period of about 1780–1750 BCE (BIETAK, 1997, Figure 4.3). The acceptable ^{14}C dates for Strata e, d/2 and d/1–2 show a coherent relationship, becoming gradually younger (Table 1). The 1σ calibrated date of Stratum d/1–2 (VRI-950) is 2029–1686 BCE with a mid-probability point of 1855 BCE (Table 1). The younger part of the calibrated age range includes the archaeological-historical date around 1780 BCE. However, the MCMC selected 1σ age range, 1976–1857 BCE, is clearly older, and also the 2σ MCMC age of 2048–1792 BCE.

Stratum d/1

The 13th Dynasty Stratum d/1 of the Egyptian palace was the source of four charcoal samples. The ^{14}C results vary considerably (Table 1, Fig. 1). The oldest result (VRI-951, 3740 ± 120 BP) is rejected by MCMC sampling (Fig. 1), showing poor agreement (33.3%) in the sequence. The weighted average of the three remaining dates is 3549 ± 73 BP, passing the chi-squared test: $T=5.5$ (5% 7.8). The detailed calibrated 1σ age of the average is 2010–2001 (2.4%), 1976–1857 (40.1%), 1845–1770 (25.7%) BCE. This result is basically older than the archaeological-historical date of 1780–1750 BCE (BIETAK, 1997, fig. 4.3), although there is minimal overlap at the youngest margin. The calibrated 2σ age range {2128–2083 (3.4%), 2041–1730 (88.7%), 1722–1689 (3.3%)} does include the historical date in its younger part. However, the narrower calibrated age range of 1914–1808 BCE, obtained with MCMC sampling for the three agreeable dates of Stratum d/1 (Table 1, column 12), according to the stratigraphic model, is substantially older than the historical age.

Hiatus 2

A hiatus interval of about 10 years duration is indicated by BIETAK (1997, fig. 4.3) in Area F after the end of Stratum d/1 and before the beginning of Stratum c. This hiatus interval was placed into the stratigraphic model (Figure 3 and 6), but without any indication of its time duration. MCMC sampling of the model suggests a 1σ duration of 0–44 years (Fig. 6). Hence the suggested 10 year hiatus is certainly probable within this range.

Stratum c

On the ruins of the Egyptian palace of Stratum d/1

a new Canaanite settlement was built by an Asian population during the 13th Dynasty. Stratum c exhibits an increase in Middle Bronze Age ceramics (40%), as compared to the two previous strata (20%), which might indicate a new wave of immigration from Canaan. The indicated archaeological-historical date for Stratum c is 1740–1710 BCE (BIETAK, 1997).

Three radiocarbon dates are available for Stratum c (VRI-938, 3310 ± 110 BP; VRI-944, 3560 ± 120 BP; and VRI-946, 3560 ± 130 BP). The two latter dates are almost exactly the same, while the young outlier is rejected by MCMC sampling (Fig. 2), showing poor agreement (48.5%) within the full sequence. Combining the two similar dates gives a weighted average of 3560 ± 88 BP for Stratum c. The 1σ calibrated age of the average is 2026–1995 (7.8%), 1980–1856 (37.7%), 1846–1769 (21.5%), 1757–1752 (1.1%) BCE. The 2σ calibrated age is 2141–1684 BCE. The highest relative probability is for the age range of 1980–1856 BCE.

MCMC sampling of the stratigraphic model selects a somewhat younger part of the calibrated range (Figure 9): a 1σ age range of 1834–1741 BCE and a 2σ range of 1888–1684 BCE. The historical age assessment would fit the youngest part of the 2σ MCMC selection, but the section with the highest relative probability (1σ range) is older

Stratum c/1 b/3

The end of Stratum c is characterised by mass graves, often shallow, perhaps related to an epidemic, dated to about 1710 BCE on archaeological-historical assessment (BIETAK, 1997). There are two radiocarbon dates of this phase. One date (VRI-943, 3560 ± 170 BP) is very similar as two previous dates of Stratum c. The other date (VRI-937, 3410 ± 120) is somewhat younger.

Both dates are acceptable within the sequence of the stratigraphic model, according to the MCMC sampling analysis, receiving agreement of 115.6% and 122.5%, respectively. Combining both samples is allowed with respect to the chi-squared test: $T=0.5$ (5% 3.8). The resulting weighted average is 3461 ± 98 BP, giving a 1σ calibrated age of 1915–1901 (2.5%), 1890–1680 (60.3%), 1670–1658 (2.5%), 1651–1637 (2.9%) BCE and a 2σ age range of 2027–1994 (2.4%), 1981–1522 (93.0%) BCE. The MCMC sampling analysis, considering both radiocarbon dates, selects a narrower range of 1787–1679 BCE within the constraints of the stratigraphic model. The archaeological-historical date of about 1710 BCE fits well in this case with the radiocarbon

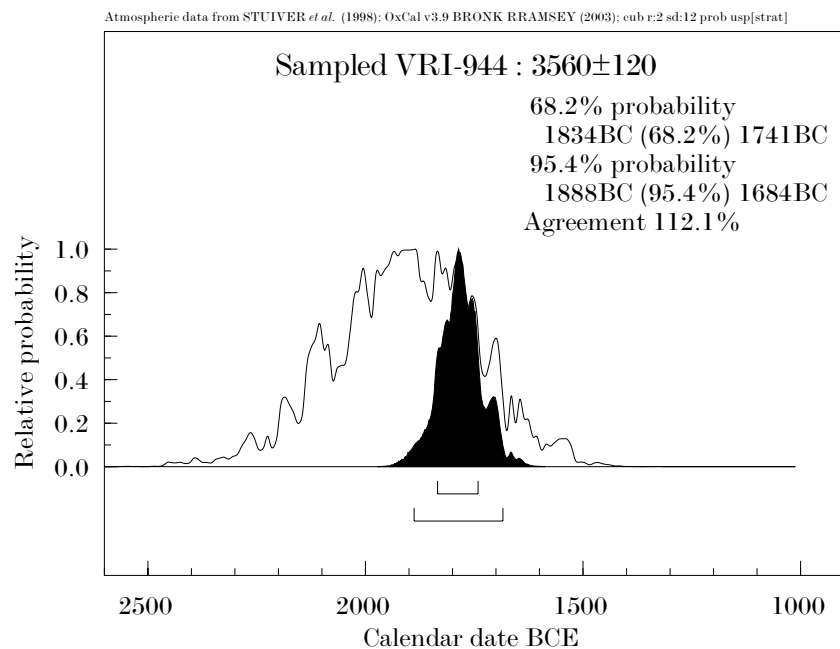


Fig. 9 MCMC sampling selects a narrower and somewhat younger part of the full calibrated age range for Stratum c, according to the stratigraphic model

age evaluations, particularly for sample VRI-937 (Fig. 10).

Stratum b/3

During this phase, the site of Tell el-Dab^a had become the capital of the kingdom of Avaris, established by Nehesy. The archaeological-historical date

for Stratum b/3 is ca 1710–1680 BCE (BIETAK, 1997). There are two ¹⁴C dates for this phase: 3280 ± 120 BP (VRI-936) derived from Stratum b/3 in Area F, and 3420 ± 110 BP (VRI-942) derived from the similar Stratum F in the eastern town of Area A. Both dates are acceptable in terms of MCMC sampling analysis within the constraints of the stratigraphic model,

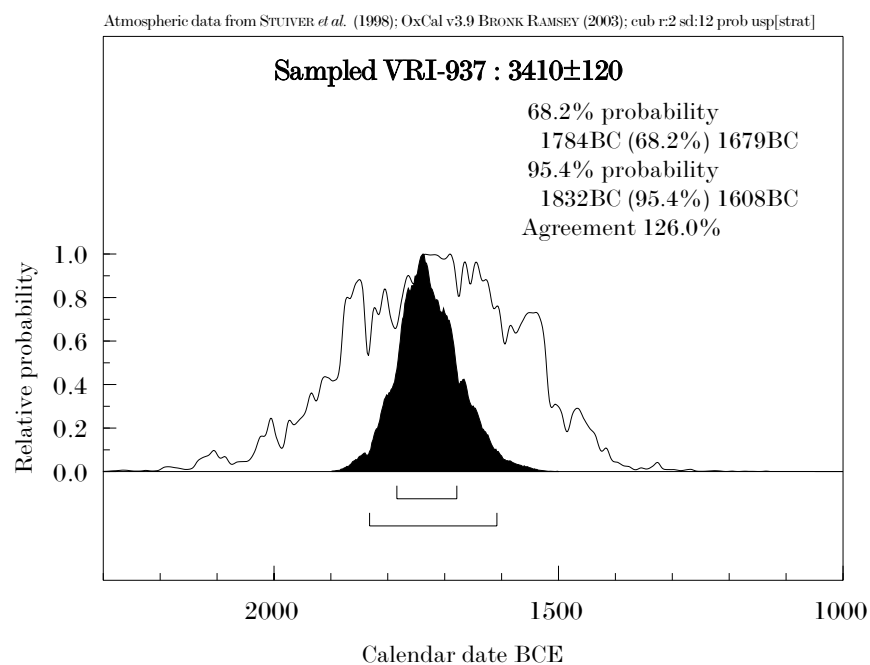


Fig. 10 MCMC sampling shows how well this date (VRI-937) of Stratum c/1 b/3 fits with the stratigraphic model and the historical age of ca 1710 BCE

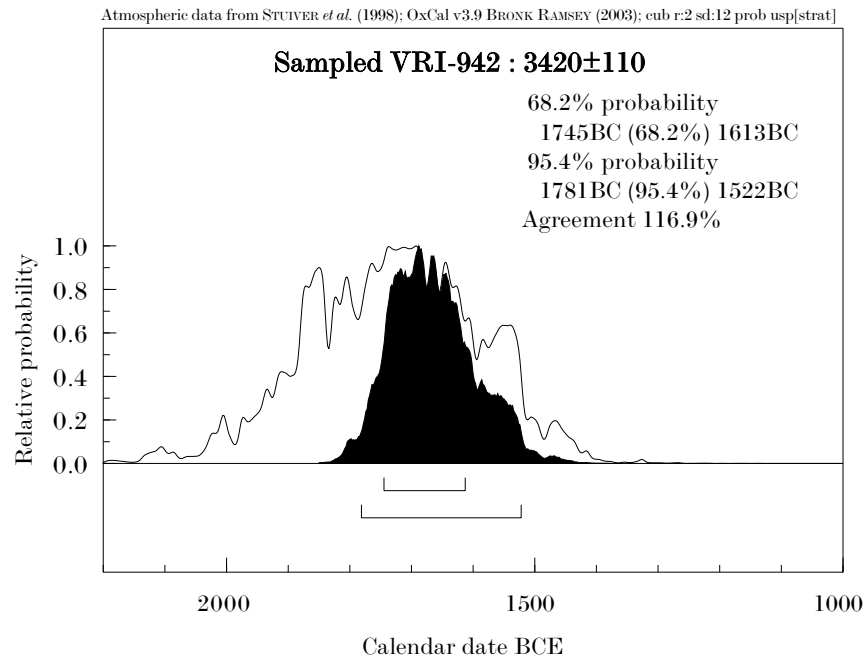


Fig. 11 MCMC sampling selects a narrower and somewhat younger part of the full calibrated age range for Stratum b/3, according to the stratigraphic model

MB Phases	Archaeo-Historical Date Year BCE	Egypt Relative Chronology	New Center Area F	Calibrated Date BCE Sequence MCMC sampling
LB I	1530–1410	XVIII		
MB II C	1580–1530	Hyksos	Denuded	
MB II B	1600–1580	XV	a / 2	
	1650–1600		b / 1	
	1680–1650		b / 2	
MB II A–B	1710–1680	XIV		
MB II A	1740–1710		Burials c/1 b/3 c	1787–1679 1834–1740
	1750–1740		Hiatus	
	1780–1750		d / 1	1912–1808
	1830–1780	XII	d/1–2 d / 2	1976–1857 2050–1892
	1920–1830		Hiatus	
MB I	1940–1920		e / 1	2233–1978
	1970–1940		e / 2–3	
	1970–2050+	XI X		

Fig. 12 Calibrated radiocarbon dating results with MCMC sampling according to the stratigraphic model in relation to archaeological and historical age assessments (BIETAK, 1991, 1997)

showing agreement of 103% and 117%, respectively. On an individual basis, the older date (VRI-942) fits well with the archaeological-historical age assessment. The highest relative probability of VRI-942 in the 1σ range is 1830–1603 (56.4%) BCE. The sampled MCMC 1σ selection is the calibrated period 1745–1613 BCE (Fig. 11), also fitting well with the historical date of 1710–1680 BCE (Table 1).

Stratum b/1–2

The radiocarbon date for this phase, which represents the beginning of the Hyksos period, is clearly too old: 3680 ± 130 BP (VRI-952). The date is rejected by MCMC sampling analysis within the constraints of the stratigraphic model, receiving a poor agreement of 21% (Fig. 2).

CONCLUSIONS

This evaluation should only be regarded as preliminary, because the data-series involved has its distinct limitations: 1) Multi-year charcoal samples, 2) Not enough samples per individual stratum to test the

repeatability and reliability of the radiocarbon measurements, 3) No ^{14}C dates of the younger phases in the stratigraphic sequence that cover the Hyksos period and the beginning of the 18th Dynasty.

The evaluation indicates that the radiocarbon dates for the older strata (e, d/2, d/1) are older by 100 to 200 years than the archaeological-historical age assessment. The radiocarbon results for stratum c are also considerably older, but slight overlap exists between the youngest part of the ^{14}C dates and the historical age assessment.

Radiocarbon dates for the transition towards the Nehehy Kingdom of Avaris (Stratum c/1 b/3) and the first part of this kingdom (Stratum b/3) match very well with archaeological-historical dates.

An overview of the principal results of MCMC sampling of this charcoal radiocarbon series of Tell el-Dab^a, according to the stratigraphic model, is presented in Figure 12 in relation to Middle Bronze Age archaeological cultural periods, Egyptian historical periods and their age assessments, based on BIETAK (1991, 1997).

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