RADIOCARBON DATES OF OLD AND MIDDLE KINGDOM MONUMENTS IN EGYPT

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ABSTRACT. Between 1984 and 1995 over 450 organic samples were collected from monuments built during the Old and Middle Kingdoms. The most suitable samples were selected for dating. The purpose was to establish a radiocarbon chronology with samples from secure context and collected with the careful techniques required for ^{14}C samples. This chronology is compared to the historical chronology established by reconstructing written documentation.

INTRODUCTION

Sample Collection

Radiocarbon dating of dynastic monuments in Egypt goes back to the very beginning of this dating method. W F Libby included three Old and Middle Kingdom samples in his initial set of known-age samples as a test of the method (Arnold and Libby 1949). In the following twenty years, numerous laboratories have followed Libby's lead and analyzed similar samples. From the published results it became apparent that close agreement with the historical chronology was often lacking. A closer study of this disagreement was needed. The American Research Center in Egypt (ARCE) undertook in 1984 the first of the two projects reported here with financial support from the Edgar Cayce Foundation. The Foundation's interest in the project rested on a hypothesis offered by Cayce that the Giza pyramids dated to 10,500 BC.

The Giza pyramids are memorials to 4th Dynasty rulers whose reigns are placed by egyptologists around 2500 BC. Our project, therefore, concentrated mostly on the Old Kingdom. The results confirmed the sequence of the monuments and their ages as they were established by historians, but the match between ^{14}C and historic dates was only approximate and left open the possibility of a difference between the two chronologies. These results were reported in Haas et al. 1987. More data was needed, thus, a second project was begun in 1995. It was designed for confirming, adjusting, or retracting the difference between the two chronologies. Support for this second project was provided by David H Koch who established the Pyramids Radiocarbon Dating Project.

In the field we looked for organic materials that were clearly linked to the construction of the monuments. Temples and pyramids built from mud bricks yielded grass, straw, and reed fragments, which were mixed into the clay and soil before shaping the bricks. Finding suitable materials in stone monuments was a greater challenge. In most of these monuments the stone building blocks were leveled and secured in place with mortar that was manufactured locally. This required massive fires to heat gypsum or limestone. The roasted minerals and the ashes from the fires were added to the mortar mix, along with remaining charcoal fragments. The usually very small fragments (1–

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2 mm) constituted the datable material. While searching the monuments, we examined seams between stone blocks for mortar filling and for black specks of charcoal inside the mortar.

Detailed records were established during both sampling projects and photographs were taken from most sampling locations. In 1984 a provenience data sheet was filled out for every sample. The samples were given a sequential three-digit number preceded by the code ARCE (American Research Center in Egypt, which provided logistic support to the project). In 1995 detailed observations on the sample and its location were entered in a field book. The samples were given three-digit numbers without a prefix. In the date list each sample can be tied to the particular project by these two distinct numbering systems, shown in column "field nr.". The samples were packaged in the field and not reopened until they arrived at the dating laboratories. Loose charcoal fragments were sealed in film cans or plastic vials. Mortar pieces and mud brick fragments were wrapped in aluminum foil (or plastic wrap) and put inside a plastic bag. Labels with full provenience data were attached to each sample package.

Robert Wenke and Mark Lehner collected 76 samples in 1984. The field season began 12 December 1983 and ended 22 March 1984. Provenance details on these samples are given in Haas et al. (1987). In 1995, Robert Wenke, John Nolan, Mark Lehner, and Herbert Haas participated in the sampling effort that lasted from 26 December, 1994 until 27 February, 1995. A digest on this field season is reported in Lehner et al. (1999).

Sample Pretreatment

In spring 1984 all samples were shipped to the Southern Methodist University (SMU) ^{14}C laboratory in Dallas, Texas. During summer and fall, 64 samples were selected for dating. Pretreatment of these samples was carried out at SMU. Charcoal and fibrous samples (grass, straw, and reed) were given the usual acid-base-acid treatment. Earlier Egyptian dating projects on similar sample materials demonstrated that the integrity of charcoal was strongly degraded by all but the weakest concentrations of chemical reagents. To preserve as much sample material as possible, the treatment with base was performed with weak solutions of sodium hydroxide (0.05 or 0.1%). Usually, three to five such applications were made in succession until the typical brown humic acid reactions were no longer observed. Dissolving mud brick samples in distilled water and wet sieving of the slurry allowed extraction of the fibrous content. Mortar fragments were dissolved in dilute hydrochloric acid—a gradual process lasting several days. At frequent intervals the residue—sand, silt, and rare charcoal fragments—was removed and the charcoal floated off. Thirty-four samples were large enough for conventional dating (larger than 0.8 g of pretreated organic material) and were dated at the SMU laboratory. Thirty samples weighing 2–400 mg were sent to the ETH laboratory for AMS dating.

There the pre-treated material was pyrolysed at about 800 °C in a pure N_2 atmosphere. The pyrolysed carbon was ground, mixed with silver powder, and pressed onto a copper disc which served as target holder for the measurement (Bonani et al. 1984). Some samples were dated at both laboratories, the results of these comparison tests are given in Haas et al. (1987).

In 1995, 353 samples were collected. At the end of the collection effort these samples were divided into three groups: 1) to be dated by conventional method at the Desert Research Institute (DRI) in Las Vegas, Nevada (7 samples), 2) to be dated with AMS at the ETH laboratory in Zurich (163 samples), and 3) samples of lower priority, held in a reserve pool. The samples to be dated were sent directly to the respective laboratories. Pretreatment was handled separately at these facilities. The conventional samples received treatments similar to the details given above.

At the ETH the samples were given the traditional acid-base–acid treatment (0.5 M HCl at 60 °C for 1 hr, 0.1 M KOH at 60 °C for 1 hr and 0.5 M HCl at 60 °C for 1 hr). Between the steps, the material was rinsed to pH 7 with ultrapure, distilled water and then dried in an oven at 60 °C. The samples were then combusted to CO_2 for two hours at 950 °C in evacuated and sealed quartz tubes together with copper oxide and silver wire. Finally, the purified carbon dioxide was reduced in a hydrogen atmosphere to filamentous graphite over a cobalt catalyst as described by Vogel et al. (1987, 1984). The resulting graphite-cobalt mixtures were pressed onto copper discs which were used as targets in the ion source.

Measurement Procedures for ^{14}C

The carbon content of conventionally dated samples was converted to benzene. ^{14}C beta decays were detected with liquid scintillation counting. Procedures for obtaining high accuracy results are described in Haas (1979); Devine and Haas (1987); Haas and Trigg (1991), Polach et al. (1987). Calculation of ^{14}C ages were performed by the standard method described in Stuiver and Polach (1977).

In 1984, the $^{14}C/^{12}C$ and $^{13}C/^{12}C$ ratios of the samples dated with AMS were determined relative to those of secondary standards of charcoal prepared in the same way as the unknown samples. The secondary standards were normalized to the NBS oxalic acid I standard by means of high precision beta decay counting (Bonani et al. 1984). The $^{14}C/^{12}C$ and $^{13}C/^{12}C$ ratios of the 1995 batch of samples were determined relative to the NBS oxalic acid I standard values, respectively (Bonani et al. 1987). The background was determined with chemistry blank samples, which were prepared from anthracite (dead carbon) in the same way as the unknowns. All samples (unknowns, standards, and blank) of one series were measured several times (typically 3 to 4). The total measuring time per sample was confined to about 30 to 40 minutes which yielded a statistical precision of about 1–2% in 1985 and of 0.5–0.6% per sample in 1995. The evaluation procedure described by Stuiver and Polach (1977) was used to determine the conventional radiocarbon ages.

Reporting of Sample Ages

The report is presented in two appendices. In Appendix 1, samples from each individual monument are listed in sequence of collection, i.e. by field number and are reported as a discrete group. The dates in each group are tested for their probability of belonging to the same event, which is the construction of the monument. Chi square is used for this test. Its numerical value and the associated probability in percent are reported at the end of the sample listing for each monument, as well as the weighted mean value, the 1 sigma error and the variance. Some monuments include sample dates which are much older or younger than the established mean. Screening was used in an attempt to remove dates from samples which are probably from another context. The difference between the weighted mean of all dates and the individual dates, divided by the product of $\sqrt{2}$ and the error of the date, was used to flag outliers. Consistently eliminated were all dates where the computed number exceeded 5.0. Occasionally, several samples show as a group a distinctly different age. In such cases the samples are reported with separate mean and statistics.

The results of calibration are reported in Appendix 2. The monuments are listed in the same sequence as in the first section. The historic age range of the king who built the monument is listed, the chronology of Clayton (1994), was consulted for this information. The ^{14}C age and the error used in the calibration are stated. The error is the larger value chosen between the 1 sigma error and the variance. In this report all calibrations were performed with the calibration program developed at ETH and described in Niklaus et al. (1992). The program uses the most recent tree ring data published by Stuiver et al. (1998). For almost all monuments calibration yields several probable age

ranges, up to five for most 4th Dynasty monuments. Listed are all ranges resulting from a one sigma error as well as from a two sigma error. The statistical weight of each range is listed as a percent value where the sum of all range weights equals 100 percent.

Figure 1 shows the calibrated monument ages. One sigma errors were used with the averaged monument dates and every calibration range is displayed. The lengths of the solid black bars corresponds to the BC time span, and their width is proportional to the statistical weight of the ranges. For comparison, the historical chronology of the monuments is shown with the hatched rectangles. Applying two sigma errors to the monument dates results in wider time spans but does not significantly alter observed differences between the two chronologies.

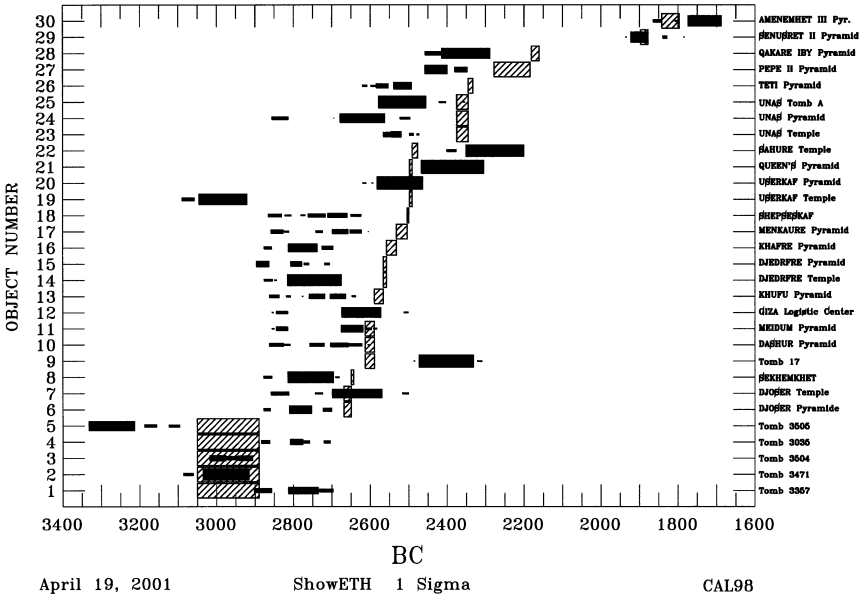

Figure 1 Comparison of the calibrated ^{14}C ranges (horizontal black bars) with the historical chronology of Clayton (1994; hatched areas). The width of the black bars is proportional to the probability of finding the true age within the corresponding one sigma range.

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APPENDIX 1 LISTING OF DATED SAMPLES BY DYNASTY AND MONUMENTS

Appendix 1: Radiocarbon Dates

1st Dynasty (Early Dynastic Period)

Tomb 3357 at Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-13612	212	W face of W wall, ~5 m S of NW corner	charcoal	4222	60	-20.0
		C14 Age single sample	**BP**	**4222**	**60**	

Tomb 3471 at Saqqara

lab nr.	field nr.	Collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
DRI-2970	220	~20 m S of NW corner	reed	4346	36	-22.7
ETH-13620	220	~20 m S of NW corner	reed	4460	52	-18.2
				mean	1 sigma	variance
		C14 Mean age (weighted) all data	**BP**	**4383**	**30**	**53**
		Chi square	3.2490		probability	19.70 %

Tomb 3504 at Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-13626	226	9th brick course, N & W walls	reed&twig	4236	57	-26.0
DRI-2968	227	9th brick course, N & W walls	reed&twig	4486	89	-23.2
ETH-13627	227	same sample as DRI-2968	reed&twig	4469	52	-21.6
ETH-13629	229	9th brick course, N & W walls	reed&twig	4311	53	-26.3
ETH-13632	232	9th brick course, N & W walls	reed&twig	4319	56	-16.8
				mean	1 sigma	variance
		C14 Mean age (weighted) all data	**BP**	**4352**	**26**	**46**
		Chi square	3.1041		probability	21.18 %

Tomb 3035 at Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-13605	205	interior of W wall, mid N - S length	charcoal	4242	56	-23.1
ETH-13610	210	interior of E wall, mid N - S length	charcoal	4142	60	-23.4
ETH-13608	208	W face of W wall, between brick rows	reed	4236	56	-16.1
				mean	1 sigma	variance
		C14 Mean age (weighted) all data	**BP**	**4210**	**33**	**32**
		Chi square	0.9132		probability	63.34 %

Tomb 3505 at Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
SMU-1358	ARCE 71	N - NE side of pit, from mud brick	charcoal	4482	37	-26.6
		C14 Age single sample	**BP**	**4482**	**37**	

3rd Dynasty (Old Kingdom)

Step Pyramid of Djoser at Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-0323	ARCE 39	E-face, from mortar in core, ~1 m above logs	charcoal	4510	100	-27.3 +
ETH-13660	260	~3.5 m above ground, ~20 m N of SE corner	charcoal	4289	48	-21.5
ETH-13652	252	~3 m above 4th tier, ~~5 m E of NW corner	reeds	4077	54	-20.8
ETH-13653	253	same location as 252	straw	4087	51	-20.0
ETH-13654	254	~1 m below location of 252	straw&reed	4224	57	-14.8
ETH-13658	258	same location as 252, in mud mortar	straw	4085	57	-13.7
ETH-13659	259	NW corner, 4th tier, in mud mortar	straw	4141	60	-14.9
SMU-1398	ARCE 38A	E face, 1st log from S, chips from top of log	wood	4206	52	-24.8
ETH-13669	269	same log as ARCE 38A, center rings	wood	4276	54	-22.2
ETH-13672	272	3rd log from S, outer rings	wood	4215	56	-18.8
ETH-13678	278	4th log from S, outer rings	wood	4190	51	-25.5

				mean	1 sigma	variance
C14 Mean age (weighted)	all data	**BP**	**4191**	**17**	**29**
	Chi square	3.0192		probability	22.10 %
C14 Mean age (weighted)	without +	**BP**	**4182**	**17**	**25**
	Chi square	2.1934		probability	33.40 %

Temple Complex associated with Step Pyramid

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-0451	ARCE 67B	earlier chapel on N side of entrance colonade	charcoal	4170	90	-24.8
ETH-0450	ARCE 67A	same mud brick as ARCE 67B	reed	4530	123	-21.2 +
SMU-1397	ARCE 40A	W wall of mortuary temple, E side	wood	4252	137	-26.3
SMU-1350	ARCE 68B	Mort. temple, E-most room, ash layer in floor	charcoal	3950	35	-25.9
ETH-0231	ARCE 68B	same sample as SMU-1350	charcoal	4210	105	-25.1
ETH-0448	ARCE 68B	same sample as SMU-1350	charcoal	4110	100	-26.8
ETH-0449	ARCE 68B	same sample as SMU-1350	charcoal	4055	95	-24.6
SMU-1503	ARCE 69	same location as ARCE 68B	wood	3744	362	-27.3 *
SMU-1362	ARCE 70	N wall of burial shaft in S tomb, NE corner	wood	4289	47	-25.2

				mean	1 sigma	variance
C14 Mean age (weighted)	all data	**BP**	**4106**	**23**	**59**
	Chi square	6.3527		probability	4.17 %
C14 Mean age (weighted)	without + & *	**BP**	**4092**	**24**	**60**
	Chi square	6.2652		probability	4.36 %

Pyramid of Sekhemkhet at Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-0325	ARCE 45A	N enclosure wall, N of entrance, clay mortar	charcoal	4545	80	-25.0 +
ETH-13750	350	step above entrance trench, embedded fabric	threads	4209	61	-26.8
ETH-13751	351	extracted with sample 350	charcoal	4135	59	-26.9
SMU-1368	ARCE 46B	3rd tier of masonry, from N, mud brick	grass&straw	4293	192	-23.1

				mean	1 sigma	variance
C14 Mean age (weighted)	all data	**BP**	**4254**	**37**	**90**
	Chi square	5.9616		probability	5.08 %
C14 Mean age (weighted)	without +	**BP**	**4176**	**41**	**31**
	Chi square	0.5734		probability	75.07 %

4th Dynasty (Old Kingdom)

Tomb 17, reign of Snefru at Meydum

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
SMU-1732	ARCE 66A	W face, ~10 m N of SW corner, mud brick	straw	3978	359	-23.9
ETH-13892	492	S face, 10 m E of SW corner, mud brick	grass	3925	55	-24.0
ETH-13893	493	W face, ~50 m N of SW corner, mud brick	grass	4195	61	-13.5 +
				mean	1 sigma	variance
		C14 Mean age (weighted) all data	**BP**	**4045**	**41**	**94**
		Chi square	5.4209		probability	6.65 %
		C14 Mean age (weighted) without +	**BP**	**3926**	**54**	**8**
		Chi square	0.0213		probability	98.94 %

Bent Pyramid of Snefru at Dhashur

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-13952	552	about 10th tier, collected in situ from seam	charcoal	4121	57	-27.5
ETH-13955	555	about same location as 552	charcoal	4146	58	-25.0
				mean	1 sigma	variance
		C14 Mean age (weighted) all data	**BP**	**4133**	**41**	**12**
		Chi square	0.0945		probability	95.38 %

Pyramid of Snefru at Meydum

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
SMU-1412	ARCE 65	burial chamber, log in E wall, outer rings	wood	4807	187	-21.0
SMU-1392	ARCE 66	E side of shaft to burial chamber, outer rings	wood	4103	148	-19.4
ETH-13887	487	burial chamber, log nr. NE corner, outer rings	wood	4112	53	-26.9
ETH-13888	488	from same log as 487	wood	4149	53	-24.4
ETH-13889	489	from same log as 487	wood	4156	56	-18.6
ETH-13890	490	from same log as 487	wood	4050	48	-24.6
ETH-13891	491	burial chamber, strut near ceiling, outer layer	wood	4102	49	-22.4
				mean	1 sigma	variance
		C14 Mean age (weighted) all data	**BP**	**4110**	**23**	**17**
		Chi square	0.5618		probability	75.51 %

Royal Production Center at Giza

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
SMU-2240	C-3	area A1, ash midden in East wall, above floor	charcoal	4282	267	-26.5
SMU-2275	C-4	area A1, feat. 15, compacted mud above floorl	charcoal	4232	49	-25.8
ETH-5331	C-5	area A5, level14, site of flexed burial	charcoal	4080	55	-23.7
SMU-2274	C-15	area A5, East wall, below brick veneer of room	charcoal	3982	71	-27.6
ETH-5330	C-16	area A6, feature 16, charred disk in floor	charcoal	4065	55	-28.1
ETH-13958	A7a-5	from basal grey pit in unit 11	charcoal	4205	45	-25.1
ETH-13959	A7a-7	from unit 33 above grey pit, acacia charcoal	charcoal	4005	50	-27.6
ETH-13960	A7a-9	from unit 6, 9 cm above contact to pit	charcoal	3985	45	-27.5
				mean	1 sigma	variance
		C14 Mean age (weighted) all data	**BP**	**4090**	**19**	**37**
		Chi square	3.7620		probability	15.24 %

Pyramid of Khufu at Giza

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-0302	ARCE 1	2nd course, N face, ~26 m W of NE corner	charcoal	4260	80	-24.3
ETH-0303	ARCE 2	2nd course, N face, ~44 m E of NW corner	charcoal	4300	90	-25.4
ETH-0304	ARCE 3	2nd course, N face, ~60 m E of NW corner	charcoal	4245	85	-24.2
ETH-0305	ARCE 4	2nd course, N face,~60 m E of NW corner	charcoal	4355	90	-23.5
ETH-4226	ARCE 4	same sample as ETH-0305	charcoal	4195	105	-28.5
ETH-0306	ARCE 5	2nd course, N face,~20 m E of NW corner	charcoal	4320	85	-25.0
ETH-0226	ARCE 13	5th course, near SE corner	charcoal	4350	125	-24.8
SMU-1418	ARCE 13	same sample as ETH-0226	charcoal	4258	273	-26.7
ETH-4229	ARCE 13	same sample as ETH-0226	charcoal	4195	105	-26.0
SMU-1417	ARCE 14	5th course, S face, ~5 blocks E of SW corner	charcoal	4359	241	-25.8
ETH-0227	ARCE 14	same sample as SMU-1417	charcoal	4360	125	-26.6
ETH-13762	362	9th course, ~210 m S of NW corner	charcoal	3927	58	-24.5
ETH-13754	354	10th course, near NW corner	charcoal	3980	57	-22.3
ETH-13756	356	10th course, ~30 m S of NW corner	charcoal	4143	61	-23.9
ETH-13757	357	10th course, ~35 m S of NW corner	charcoal	4225	79	-26.5
ETH-13761	361	10th course, ~200 m S of NW corner	charcoal	3928	54	-30.8
ETH-13763	363	10th course, above location of ETH-13762 on 9th	charcoal	3937	61	-29.2
ETH-0307	ARCE 6	between 25th & 26th course, ~4 m S of NW corner	charcoal	4440	90	-21.4
ETH-4227	ARCE 6	same sample as ETH-0307	charcoal	4215	105	-24.8
ETH-13770	370	49th course, ~4 m S of NE corner	charcoal	4087	53	-26.3
ETH-13771	371	same location as ETH-13770, #370	charcoal	4187	60	-25.0
ETH-13775	375	same location as ETH-13770, #370	charcoal	4190	52	-28.7
ETH-13777	377	51st course, ~3 m S of NE corner	charcoal	4313	57	-23.0
ETH-13778	378	52nd course, near NE corner	charcoal	4156	58	-24.6
ETH-13779	379	52nd course, near NE corner	charcoal	4062	61	-22.7
ETH-0308	ARCE 7	65th course, near NW corner	charcoal	4300	85	-24.1
ETH-4228	ARCE 7	same sample as ETH-0308	charcoal	4390	110	-27.9
ETH-13783	383	76th course, 1.5 m N of SE corner	charcoal	4237	62	-19.6
ETH-13784	384	same context as sample 383	charcoal	4068	54	-24.8
ETH-13785	385	same context as sample 383	charcoal	4083	53	-27.7
ETH-13782	382	77th course, ~2 m N of SE corner	charcoal	3984	55	-25.2
ETH-13787	387	81st course, 1 block N of SE corner	charcoal	4197	49	-26.4
ETH-13791	391	86th course, 1 m N of SE corner, surface	charcoal	3810	60	-22.2 *
ETH-0309	ARCE 8	108th course, near NW corner	charcoal	4420	100	-23.9
ETH-13800	400	141st course, on SW corner	charcoal	4195	55	-31.1
ETH-13799	399	143rd course, ~3 m E of SW corner	charcoal	4128	58	-26.5
ETH-13801	401	same context as sample 399	charcoal	4189	60	-21.2
ETH-13802	402	145th course, ~3 m E of SW corner	charcoal	4174	61	-27.3
ETH-13803	403	same context as sample 402	charcoal	4062	60	-25.6
ETH-13804	404	same context as sample 402	charcoal	4254	59	-27.1
ETH-13805	405	146th course, 1 m E of SW corner	charcoal	4267	57	-25.5
ETH-0311	ARCE 10A	198th course, near SW corner (preserved top)	charcoal	4395	85	-24.5
ETH-0312	ARCE 10B	198th course, near SW corner (preserved top)	charcoal	5020	130	-22.6 +
ETH-0334	ARCE 10B	same context as ETH-0312	charcoal	4440	320	-19.7
ETH-0313	ARCE 11	top of pyramid, on S side	reed	4330	125	-24.7
ETH-13900	500	top of pyramid, on E side	charcoal	4068	60	-21.4
				mean	1 sigma	variance
		C14 Mean age (weighted) without +	**BP**	**4147**	**10**	**21**
		Chi square	4.2246		probability	12.10 %
		C14 Mean age (weighted) without + & *	**BP**	**4157**	**10**	**20**
		Chi square	3.5683		probability	16.79 %

Pyramid Temple of Djedefre at Abu Roash

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
DRI-2969	345	N half of temple, ~14 m N of boat pit	straw	4258	89	-22.5
ETH-13745	345	same sample as DRI-2969	straw	4156	50	-21.7
ETH-13745a	345	same sample as DRI-2969	straw	4047	58	-21.5
ETH-13746	346	1 m E of sample 345	straw	4118	63	-21.6
ETH-13747	347	N part of outermost E wall	straw	4333	53	-22.8
SMU 1357	ARCE 35A	mudbrick in wall on E side of SE part of temple	straw	4126	147	-24.3
SMU 1356	ARCE 35B	same mudbrick as ARCE 35A	straw	3915	142	-24.3
				mean	1 sigma	variance
		C14 Mean age (weighted) all data	**BP**	**4169**	**26**	**46**
		Chi square	3.1679		probability	20.52 %

Pyramid of Djedefre at Abu Roash

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-13742	342	E face of pyramid, 3 courses from ground	charcoal	4073	56	-27.7
ETH-13743	343	same location as 342	charcoal	4099	58	-25.2
ETH-13744	344	same location as 342	charcoal	4187	61	-26.5
ETH-0317	ARCE 30	W face, s part, 3 or 4 m above ground level	charcoal	4385	85	-25.0
ETH-4235	ARCE 30	same sample as ETH-0317	charcoal	4330	115	-24.1
ETH-0321	ARCE 34	W face, ~ 30 m N of SW corner, nr. top of core	charcoal	4410	95	-23.7
ETH-0319	ARCE 32	various contexts on outside of core masonry	charcoal	4495	100	-22.6
ETH-0318	ARCE 31	core masonry, N part, 4 to 5 m E of entrance trench	charcoal	4230	85	-25.0
ETH-0320	ARCE 33	core masonry, ~ 7 m W of E face	charcoal	4360	85	-24.6
ETH-13739	339	top of pyramid ~11 m from E face, center N to S	charcoal	4230	60	-21.5
ETH-13741	341	~10 m E of entrance trench, ~40 m S of N face	charcoal	4246	63	-26.1
				mean	1 sigma	variance
		C14 Mean age (weighted) all data	**BP**	**4229**	**22**	**38**
		Chi square	3.0551		probability	21.71 %

Pyramid of Khafre at Giza

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-0316	ARCE 19	1st or 2nd course, near SW corner	charcoal	4500	90	-23.9
ETH-13822	422	betw bedrock & 1st course, ~13 m E of SW corner	charcoal	4170	59	-25.8
SMU-1470	ARCE 17	2nd course, ~20 blocks W of SE corner	charcoal	4511	258	-25.0 +
ETH-4663	ARCE 17	same sample as SMU-1470	charcoal	4330	95	-32.0
ETH 0453	ARCE 18A	same general location as ARCE 17	charcoal	4330	90	-24.8
SMU-1369	ARCE 18B	~30 cm above location of ARCE 17	charcoal	4144	140	-26.5
SMU-1302	ARCE 15B	3rd course N face, ~ 15 m from passage axis	charcoal	4165	81	-27.1
ETH-0314	ARCE 15C	same location as ARCE 16B	charcoal	4440	85	-24.6
ETH-13825	425	6th course, ~31 m E of SW corner	charcoal	4072	60	-26.4
ETH-13826	426	from the same seam as sample 425	charcoal	4267	65	-26.3
ETH-13827	427	from the same seam as sample 425	charcoal	3975	58	-28.4
ETH-13828	428	from the same seam as sample 425	charcoal	4089	57	-26.9
ETH-13829	429	from the same seam as sample 425	charcoal	4026	56	-27.1
ETH-13830	430	~6th course, ~30 m E of SW corner	charcoal	4129	60	-23.3
ETH-13819	419	10th course, near SW corner	charcoal	4005	59	-26.7
ETH-13834	434	11th course, near NE corner	charcoal	4180	64	-31.7
ETH-13832	432	12th course, on SE corner	charcoal	4205	60	-26.7
ETH-0315	ARCE 16	13th course, near SE corner	charcoal	4235	90	-21.9
ETH-13837	437	13th course, near NE corner	charcoal	4210	59	-26.9
ETH-13838	438	from the same seam as sample 437	charcoal	4058	53	-27.3
ETH-13833	433	15th course, near SE corner	charcoal	4216	58	-24.4
ETH-13937	537	45th course, NE corner	charcoal	4125	52	-27.9
ETH-13936	536	46th course, 8 m W of NE corner	charcoal	4250	52	-18.6
ETH-13943	543	84th course, near NE corner	charcoal	4381	70	-23.9
ETH-0322	ARCE 37	half to 2/3 way to top, SE corner	charcoal	4475	95	-26.1
				mean	1 sigma	variance
		C14 Mean age (weighted) all data	**BP**	**4174**	**13**	**26**
		Chi square	3.8874		probability	14.32 %
		C14 Mean age (weighted) without +	**BP**	**4173**	**13**	**27**
		Chi square	3.9820		probability	13.66 %

Sphinx Temple of Khafre at Giza 1)

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-0228	ARCE 20	S side of eastern columned recess	charcoal	4160	125	-26.9
SMU-1416	ARCE 20	same sample as ETH-0228	charcoal	3687	230	-26.9
ETH-4231	ARCE 20	same sample as ETH-0228	charcoal	3895	115	-25.8

Pyramid of Menkaure at Giza

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-13850	450	6th course, ~15 m S of NE corner	charcoal	4335	60	-27.0
ETH-4232	ARCE 21	~9th course (~4th above granite casing) E face	charcoal	4145	105	-25.0
ETH-13852	452	10th course, 4 m S of NE corner	charcoal	4489	54	-23.5 +
ETH-13853	453	12th course, ~15 m S of NE corner	charcoal	4074	47	-25.2
ETH-13854	454	12th course, ~15 m S of NE corner	charcoal	4236	53	-22.0
ETH-13855	455	same location as 454	charcoal	3917	48	-28.0
ETH-13857	457	13th course, ~18 m S of NE corner	charcoal	3954	64	-26.5
ETH-0454	ARCE22/1	15th course, near SE corner	charcoal	4420	105	-22.8
ETH-0455	ARCE22/2	same sample as ARCE 22/1	charcoal	4310	105	-28.0
ETH-4233	ARCE 22B	same location as ARCE 22/1	charcoal	4245	95	-28.9
ETH-13859	459	16th course, ~5 m S of NE corner	charcoal	3803	63	-27.6 *
ETH-13861	461	18th course, ~5 m S of NE corner	charcoal	3833	62	-26.7
ETH-13862	462	in same mortar seam as 461	charcoal	3939	55	-27.1
ETH-13863	463	in same mortar seam as 461	charcoal	3994	54	-26.5
ETH-13864	464	in same mortar seam as 461	charcoal	4226	54	-26.4
ETH-13865	465	in same mortar seam as 461	charcoal	4060	54	-26.6
ETH-13867	467	18th course, ~3.5 m S of NE corner	charcoal	4082	55	-26.0
ETH-13868	468	21st course, ~10 m W of NE corner	charcoal	4319	61	-25.1
ETH-13869	469	24th course, near NE corner	charcoal	4115	53	-25.1
ETH-13871	471	27th course, near NE corner	charcoal	4163	56	-23.4
SMU-1370	ARCE 23	37th course, E face near SE corner	charcoal	4048	48	-25.9
ETH-4234	ARCE 23	same sample as SMU-1370	charcoal	4180	90	-29.1
ETH-13910	510	45th course, near NE corner	charcoal	4062	49	-26.7
ETH-13911	511	48th course, near NE corner	charcoal	4186	59	-25.5
SMU-1415	ARCE 25	54th course, S face, 2 blocks W of SE corner	charcoal	4418	250	-26.1
ETH-0229	ARCE 25	same sample as SMU-1415	charcoal	4310	135	-22.0
ETH-13914	514	56th course, E face near SE corner	charcoal	4445	67	-23.4
ETH-13915	515	57th course, E face near SE corner	charcoal	4188	59	-24.4
ETH-13918	518	70th course, E face near SE corner	charcoal	4257	60	-24.5
ETH-13919	519	70th course, E face near SE corner	charcoal	4122	51	-26.6
SMU-1352	ARCE 26A	58th course, near SE corner, gap betw. blocks	brown powder	3735	59	-21.9 *
SMU-1419	ARCE 26B	same as ARCE 26A	brown powder	3685	60	-21.9 *
SMU-1414	ARCE 27A	same general location, below block	brown powder	3768	51	-20.9 *
ETH-13918	518	70th course, E face near SE corner	charcoal	4257	60	-24.5
ETH-13919	519	70th course, E face near SE corner	charcoal	4122	51	-26.6

			mean	1 sigma	variance
C14 Mean age (weighted)	without *	**BP**	**4132**	**11**	**29**
	Chi square	7.2814		probability	2.62 %
C14 Mean age (weighted)	without + & *	**BP**	**4127**	**11**	**25**
	Chi square	5.3294		probability	6.96 %

Mortuary Temple of Shepseskaf at South Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-13732	332	West retain. wall, interior face, ~25 m N of SW end	charcoal	4041	60	-22.6
ETH-13734	334	~5 m N of sample 332 location	charcoal	4014	58	-26.1
SMU-1395	ARCE 55	West retaining wall, interior face	charcoal	3769	208	-27.0 *
ETH-0233	ARCE 55	same sample as SMU-1395	charcoal	4380	150	-25.9
SMU-1472	ARCE55A	West retaining wall, interior face, amalgamated	charcoal	4265	138	-25.7
ETH-13729	329	East retaining wall, exterior face	straw	4220	59	-22.4
ETH-13729a	329a	same mudbrick as sample 329	straw	4319	63	-5.3
ETH-13729b	329b	same mudbrick as sample 329	reed	4101	59	-22.0

			mean	1 sigma	variance
C14 Mean age (weighted)	all data	**BP**	**4140**	**26**	**48**
	Chi square	3.4788		probability	17.56 %
C14 Mean age (weighted)	without *	**BP**	**4146**	**26**	**48**
	Chi square	3.5191		probability	17.21 %

Mastaba el-Faraoun of Shepseskaf at South Saqqara 2)

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
SMU-1371	ARCE 54B	1st course on platform, 18 blocks W of SE corner	charcoal	3330	56	-26.8
ETH-0230	ARCE 54C	same location as ARCE 54B	charcoal	4350	170	-20.1
SMU-1396	ARCE 54C	same location as ARCE 54B	charcoal	3792	34	-25.8
ETH-13731	331	3rd course, 20 m W of SE corner	wood	4086	57	-23.8
ETH-0329	ARCE 56	1st course, core masonry, from E and W faces	charcoal	4320	80	-23.5

				mean	1 sigma	variance
C14 Mean age (weighted)	all data	**BP**	**3819**	**24**	**148**

5th Dynasty (Old Kingdom)

South Pyramid Temple of Userkaf at Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-0326	ARCE 51	bedding of basalt paving blocks, mortar	charcoal	4410	85	-23.0
SMU-1495	ARCE 51	same sample as ETH-0326	charcoal	4316	265	-27.1
ETH-4236	ARCE 51	same sample as ETH-0326	charcoal	3850	95	-27.3 *
ETH-0327	ARCE 52	bedding of basalt paving blocks, mortar	charcoal	4290	100	-17.4
ETH-4237	ARCE 52	same sample as ETH-0326	charcoal	3750	105	-31.9 *
ETH-0328	ARCE 53	bedding of basalt paving blocks, mortar	charcoal	4470	80	-24.0

				mean	1 sigma	variance
C14 Mean age (weighted)	without *	**BP**	**4400**	**49**	**41**
	Chi square	0.6966		probability	70.59 %
C14 Mean age (weighted)	2 * dates	**BP**	**3805**	**70**	**50**
	Chi square	0.4988		probability	77.93 %

Pyramid of Userkaf at Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-13706	306	3 m below top of pyramid, SE corner	charcoal	4067	57	-26.7
ETH-13707	307	same location as sample 306	charcoal	3990	56	-24.8
ETH-13703s	303s	Center of S face, inside packed stone	reed 3)	2521	53	-22.5 *
ETH-13704	304	Center of S face, inside packed stone	reed 4)	2589	53	-18.9 *
ETH-13710	310	S face, 1/3 of way to top, inside packed stone	reed 5)	2432	51	-26.2 *
ETH-13714	314	same location as sample 310	charcoal	4114	55	-28.7
ETH-13715	315	same location as sample 310	charcoal	3859	57	-25.2

				mean	1 sigma	variance
C14 Mean age (weighted)	without *	**BP**	**4009**	**28**	**56**
	Chi square	3.9068		probability	14.18 %
C14 Mean age (weighted),	3 * dates	**BP**	**2512**	**30**	**46**
	Chi square	2.3001		probability	31.66 %

Queen's Pyramid of Userkaf at Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
SMU-1413	ARCE 50	E of entrance passage, below core blocks	reed&wood 6)	3985	129	-23.7
ETH-13703	303	mudbrick from wall, SE of Quenn's Pyramid	charcoal 7)	2498	51	-23.4 *
ETH-13703a	303a	same mudbrick as 303	charcoal	3884	66	-18.5

				mean	1 sigma	variance
C14 Mean age (weighted)	without *	**BP**	**3905**	**59**	**41**
	Chi square	0.4858		probability	78.43 %

Mortuary Temple and Pyramid of Sahure at Abusir

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-0330	ARCE 60	wall between sanctuary and S storage chambers	charcoal	4260	85	-27.7 +
ETH-4239	ARCE 60	same sample as ETH-0330	charcoal	3925	125	-28.8
ETH-0331	ARCE 61	SW corner, S storage chambers, 3rd from W	charcoal	3400	85	-20.0 *
ETH-13722	322	wall in center of temple, mortar beneath block	charcoal	3447	56	-26.7 *
ETH-13723	323	same location as 322, different discrete s.	charcoal	3647	50	-26.3
ETH-13724	324	same location as 322, different discrete s.	charcoal	3618	50	-26.0
ETH-13725	325	same location as 322, amalgamated s.	charcoal	3760	51	-25.1
SMU-1372	ARCE 59	S doorway to satellite pyramid, below block	charcoal	4042	99	-26.8
ETH-13717	317	basalt pavement N of satellite pyramid	charcoal	3918	59	-26.6
ETH-13718	318	same location as 317	charcoal	4042	51	-23.7
ETH-13720	320	SE part of temple, top of block S of 2 columns	charcoal	4003	59	-22.9
ETH-13721	321	SE part of temple, core of wall S of 2 columns	charcoal	3942	58	-23.1
ETH-13719	319	core or N retaining wall, satellite Pyramid	reed	3821	59	-9.6
ETH-13726	326	10 m N of SE corner Sahure Pyramid, core	wood	4397	51	-17.8 +

			mean	1 sigma	variance
C14 Mean age (weighted)	all data	**BP**	**3862**	**16**	**76**
	Chi square	22.1344		probability	0.00 %
C14 Mean age (weighted)	without + & *	**BP**	**3840**	**19**	**52**
	Chi square	7.7737		probability	2.05 %

Mortuary Temple of Unas at Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-13681	281	SW quadrant, wall E of archaic tomb entrance	charcoal	4058	55	-25.5
ETH-13682	282	same location and mortar seam as 281	charcoal	4036	55	-27.0
ETH-13683	283	same location and mortar seam as 281	charcoal	4040	53	-25.1
ETH-13684	284	same location and mortar seam as 281	charcoal	3921	48	-25.1
ETH-13685	285	same location and mortar seam as 281	charcoal	4004	51	-25.9
SMU-1373	ARCE 41	interior of NW corner, paving of temple floor	charcoal	4041	100	-25.9

			mean	1 sigma	variance
C14 Mean age (weighted)	all data	**BP**	**4009**	**23**	**22**
	Chi square	0.9699		probability	61.57 %

Pyramid of Unas at Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-0456	ARCE 42	~10 m E of SW corner, mortar under core	charcoal	4255	100	-25.9
SMU-1475	ARCE43a	~9 m E of SW corner, 1st to 2nd tier, core	charcoal	4101	126	-27.7
ETH-0324	ARCE 44	~7 m S of NW corner, foundation masonry	charcoal	4290	100	-22.9
ETH-13686	286	SE corner, about 1/3 way to top, in gypsum	straw	4035	54	-3.8
ETH-13692	292	SE corner, about 1/2 way to top, small flecks	charcoal	4015	51	-25.4

			mean	1 sigma	variance
C14 Mean age (weighted)	all data	**BP**	**4079**	**32**	**50**
	Chi square	2.4547		probability	29.31 %

Tomb A, reign of Unas at Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-13693	293	S facing exterior wall, middle course, mudbrick	charcoal	4035	53	-24.6
ETH-13698	298	same general location than 293	charcoal	3924	54	-22.1

			mean	1 sigma	variance
C14 Mean age (weighted)	all data	**BP**	**3981**	**38**	**55**
	Chi square	2.1521		probability	34.09 %

6th Dynasty (Old Kingdom)

Pyramid of Teti at Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
SMU-1355	ARCE 62a	burial chamber, log under sarcophagus, outer rings	wood	4161	57	-21.0
ETH-0332	ARCE 63	E face, all of 2nd tier, amalgamated sample	charcoal	4520	120	-11.5 +
ETH-4240	ARCE 63	same sample as ETH-0332	charcoal	3829	155	-24.4
ETH-13646	246	E face, ~1/3 way to top, under ext. casing	charcoal	3884	53	-23.1
ETH-13647	247	split of same piece as 246	charcoal	3915	55	-27.1
ETH-13648	248	split of same piece as 246	charcoal	3919	59	-25.4
ETH-13649	249	split of same piece as 246	charcoal	3931	59	-29.9
ETH-13636	236	SW corner, 1/2 to 1/3 way to top, mudbrick	straw	707	44	-24.7 *
ETH-13637	237	same mudbrick as 236	straw	609	48	-21.8 *
ETH-13638	238	S face, 2/3 of way to top, mudbrick under block	straw	4238	55	-20.5
ETH-13639	239	same mudbrick as 238	straw	4134	50	-23.2
ETH-13640	240	SE corner, 2/3 of way to top, mudbrick u. block	straw	4094	53	-19.9
ETH-13541	241	same mudbrick as 240	straw	4018	50	-25.5
ETH-13542	242	same mudbrick as 240	straw	4165	49	-24.0
ETH-13543	243	same mudbrick as 240	straw	4019	55	-23.3

				mean	1 sigma	variance
C14 Mean age (weighted)	without *	**BP**	**4055**	**16**	**38**
	Chi square	5.6119		probability	6.04 %
C14 Mean age (weighted)	without + & *	**BP**	**4046**	**16**	**35**
	Chi square	4.7305		probability	9.39 %

Mortuary Chapel of Queen Neith (reign of Pepi II) at Saqqara 8)

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-4238	ARCE 57	bedding of pavement	charcoal	3565	135	-23.8
SMU-1469	ARCE 57a	same context as ARCE 57, larger pieces	charcoal	4458	140	-26.6

Pyramid of Pepi II at Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
SMU-1351	ARCE 58	S face, 1st course, amalgamated sample	charcoal	3900	24	-26.4

C14 Age	single sample	**BP**	**3900**	**24**

8th Dynasty (First Intermediate Period)

Pyramid of Qakare-Iby at South Saqqara

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-13728	328	core of pyramid, mudbrick	straw	3872	54	-17.2

C14 Age	single sample	**BP**	**3872**	**54**

12th Dynasty (Middle Kingdom)

Pyramid of Amenemhet I at Lisht 9)

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
ETH-13885	485	E face, middle, ~5 m above mortuary temple	straw	2916	50	-24.1
ETH-13886	486	N face near NE corner, mud layer in stone core	charcoal	2944	54	-23.9
				mean	1 sigma	variance
		C14 Mean age) (weighted) all data	**BP**	**2929**	**37**	**14**
		Chi square	0.1448		probability	93.02 %

Pyramid of Senusret II at Illahun

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
DRI-2947	524	SE corner, freshly fallen brick	straw	3580	104	-25.1
ETH-13924	524	same mudbrick sampled for DRI-2947	straw	3545	51	-24.6
ETH-13925	525	SW corner, mud mortar above limestone blocks	straw	3488	54	-24.0
ETH-13926	526	SW corner, mud mortar on limestone blocks	charcoal	3641	55	-28.7
ETH-13927	527	NW corner, mud brick with dense straw content	straw	3538	54	-28.0
ETH-13928	528	N-side, twig in mud brick	wood	3527	54	-11.1
ETH-13931	531	N-side, sandy layer between mud bricks	reed	3582	52	-9.5
ETH-13932	532	N-side, palm wood fragment in mud brick	wood	3534	58	-19.8
DRI-2971	524	same mudbrick sampled for DRI-2947	humates 10)	4342	70	-19.7 +
				mean	1 sigma	variance
		C14 Mean age (weighted) without +	**BP**	**3552**	**20**	**17**
		Chi square	0.6893		probability	70.85 %

Pyramid of Amenemhet III at Dashur

lab nr.	field nr.	collection site	material	corr. ^{14}C age y BP	error 1 sigma	δ^{13}C permil
DRI-2948	556	mudbrick from the pyramid	straw	3442	41	-24.2
DRI-2958	556	same mudbrick sampled for DRI-2948	humates 10)	4452	73	-19.6
		C14 Age single sample	**BP**	**3442**	**41**	

Remarks and Footnotes

Errors for δ^{13}C values: 0.05 permil for SMU and DRI dates
1.5 permil for ETH-0200 to ETH-4999 dates
1.1 permil for ETH-13000 to ETH-13999

\+ too old date
* too young date
1) dates reported without evaluation
2) most samples are amalgamated: large scatter of dates does not support further analyses
3) sample and piece of rope found under rubble
4) at level of modern excavated surface
5) possible later activity
6) loose debris, context?
7) may not be related to temple
8) data not analyzed
9) possibility of later occupation on pyramid debris for both samples; data not further analyzed
10) date includes older organic content in clay used for brick making

APPENDIX 2 LISTING OF CALIBRATED DATES BY DYNASTY AND MONUMENT

Appendix 2: Calibrated Dates

1st Dynasty (Early Dynastic Period)

Tomb 3357 at Saqqara — precise date unknown
Historical Range of 1st Dynasty: 3050 - 2890 BC
Sample details: number dated: 1

C14 Age of single sample date: 4222 BP
1 sigma: 60

Calibrated Age BC		ranges	probability of range %
	one sigma	2902 - 2857	30.1
		2813 - 2736	49.6
		2732 - 2697	20.3
	two sigma	2919 - 2621	99.4
		2607 - 2602	0.6

Tomb 3471 at Saqqara — precise date unknown
Historical Range of 1st Dynasty: 3050 - 2890 BC
Sample details: number dated: 2 — number used for mean: 2

C14 Mean age (weighted): 4383 BP
1 sigma: 30
variance: 53 used for calibration
Chi square: 3.2490
probability: 19.70 %

Calibrated Age BC		ranges	probability of range %
	one sigma	3086 - 3061	15.2
		3035 - 2916	84.8
	two sigma	3326 - 3320	0.5
		3314 - 3231	9.2
		3172 - 3160	1.2
		3118 - 3109	0.7
		3104 - 2888	88.4

Tomb 3504 at Saqqara — precise date unknown
Historical Range of 1st Dynasty: 3050 - 2890 BC
Sample details: number dated: 5 — number used for mean: 5

C14 Mean age (weighted): 4352 BP
1 sigma: 26
variance: 46 used for calibration
Chi square: 3.1041
probability: 21.18 %

Calibrated Age BC		ranges	probability of range %
	one sigma	3017 - 2976	40.4
		2973 - 2945	25.1
		2944 - 2907	34.5
	two sigma	3092 - 3056	9.7
		3050 - 2884	90.3

Tomb 3035 at Saqqara — precise date unknown
Historical Range of 1st Dynasty: 3050 - 2890 BC
Sample details: number dated: 3 — number used for mean: 3

C14 Mean age (weighted): 4210 BP
1 sigma: 33 used for calibration
variance: 32
Chi square: 0.9132
probability: 63.34 %

Calibrated Age BC		ranges	probability of range %
	one sigma	2883 - 2862	26.1
		2808 - 2776	40.0
		2774 - 2758	17.0
		2720 - 2704	16.9
	two sigma	2896 - 2843	26.0
		2815 - 2673	74.0

Tomb 3505 at Saqqara precise date unknown
Historical Range of 1st Dynasty 3050 - 2890 BC
Sample details: number dated: 1

C14 Age of single sample date 4482 BP
1 sigma 37

		ranges	probability of range %
Calibrated Age BC	one sigma	3332 - 3214	68.0
		3187 - 3156	16.9
		3123 - 3096	15.0
	two sigma	3345 - 3082	91.8
		3067 - 3030	8.2

3rd Dynasty (Old Kingdom)

Step Pyramid of Djoser at Saqqara
Historical Range 2668 - 2649 BC
Sample details: number dated: 11 number used for mean: 10

C14 Mean age (weighted) 4182 BP
1 sigma 17
variance 25 used for calibration
Chi square 2.1934
probability 33.40 %

		ranges	probability of range %
Calibrated Age BC	one sigma	2877 - 2860	18.3
		2810 - 2753	58.5
		2722 - 2700	23.2
	two sigma	2881 - 2840	18.9
		2816 - 2668	80.3
		2646 - 2642	0.8

Temple Complex associated with Step Pyramid
Historical Range 2668 - 2649 BC
Sample details: number dated: 9 number used for mean: 7

C14 Mean age (weighted) 4092 BP
1 sigma 24
variance 60 used for calibration
Chi square 6.2652
probability 4.36 %

		ranges	probability of range %
Calibrated Age BC	one sigma	2858 - 2812	22.1
		2743 - 2724	7.7
		2698 - 2570	63.5
		2516 - 2501	6.7
	two sigma	2872 - 2800	20.2
		2784 - 2547	67.2
		2544 - 2489	11.9
		2479 - 2474	0.7

Pyramid of Sekhemkhet at Saqqara
Historical Range 2649 - 2643 BC
Sample details: number dated: 4 number used for mean: 3

C14 Mean age (weighted) 4176 BP
1 sigma 41 used for calibration
variance 31
Chi square 0.5734
probability 75.07 %

		ranges	probability of range %
Calibrated Age BC	one sigma	2877 - 2856	14.9
		2814 - 2696	79.7
		2690 - 2681	5.3
	two sigma	2882 - 2828	20.2
		2823 - 2658	72.2
		2652 - 2623	7.3
		2605 - 2604	0.3

4th Dynasty (Old Kingdom)

Tomb 17, reign of Snefru at Meydum

Historical Range 2613 - 2589 BC
Sample details: number dated: 3 number used for mean: 2

C14 Mean age (weighted) 3926 BP
1 sigma 54 used for calibration
variance 8
Chi square 0.0213
probability 98.94 %

		ranges	probability of range %
Calibrated Age BC	one sigma	2486 - 2485	0.9
		2473 - 2332	93.5
		2321 - 2310	5.7
	two sigma	2570 - 2516	9.5
		2501 - 2280	87.0
		2251 - 2231	2.4
		2219 - 2209	1.0

Bent Pyramid of Snefru at Dashur

Historical Range 2613 - 2589 BC
Sample details: number dated: 2 number used for mean: 2

C14 Mean age (weighted) 4133 BP
1 sigma 41 used for calibration
variance 12
Chi square 0.0945
probability 95.38 %

		ranges	probability of range %
Calibrated Age BC	one sigma	2862 - 2826	21.5
		2824 - 2809	9.1
		2757 - 2720	21.2
		2703 - 2657	27.6
		2653 - 2622	18.6
		2606 - 2603	1.9
	two sigma	2875 - 2797	28.3
		2788 - 2617	63.5
		2612 - 2581	8.2

Pyramid of Snefru at Meydum

Historical Range 2613 - 2589 BC
Sample details: number dated: 7 number used for mean: 6

Sample details
C14 Mean age (weighted) 4110 BP
1 sigma 23 used for calibration
variance 17
Chi square 0.5618
probability 75.51 %

		ranges	probability of range %
Calibrated Age BC	one sigma	2855 - 2850	3.8
		2844 - 2815	27.8
		2675 - 2619	50.4
		2610 - 2597	11.7
		2591 - 2583	6.3
	two sigma	2860 - 2810	27.8
		2753 - 2722	8.4
		2700 - 2616	46.6
		2614 - 2579	17.1

Royal Production Center at Giza

Historical Range not established
Sample details: number dated: 8 number used for mean: 8

C14 Mean age (weighted) 4090 BP
1 sigma 19
variance 37 used for calibration
Chi square 3.7620
probability 15.24 %

		ranges	probability of range %
Calibrated Age BC	one sigma	2855 - 2853	1.3
		2844 - 2815	19.7
		2674 - 2573	73.4
		2512 - 2502	5.6
	two sigma	2863 - 2808	20.2
		2777 - 2773	0.5
		2759 - 2719	7.7
		2704 - 2558	62.9
		2537 - 2494	8.8

Pyramid of Khufu at Giza

Historical Range 2589 - 2566 BC
Sample details: number dated: 46 number used for mean: 45

C14 Mean age (weighted) 4147 BP
1 sigma 10
variance 21 used for calibration
Chi square 4.2246
probability 12.10 %

		ranges	probability of range %
Calibrated Age BC	one sigma	2862 - 2837	19.7
		2818 - 2808	8.1
		2776 - 2774	1.8
		2758 - 2719	32.1
		2704 - 2664	32.0
		2647 - 2638	6.3
	two sigma	2871 - 2828	19.2
		2823 - 2801	8.8
		2783 - 2658	60.0
		2653 - 2623	11.4
		2606 - 2604	0.5

Pyramid Temple of Djedefre at Abu Roash

Historical Range 2566 - 2558 BC
Sample details: number dated: 7 number used for mean: 7

C14 Mean age (weighted) 4169 BP
1 sigma 26
variance 46 used for calibration
Chi square 3.1679
probability 20.52 %

		ranges	probability of range %
Calibrated Age BC	one sigma	2876 - 2855	13.2
		2849 - 2844	3.1
		2815 - 2675	83.7
	two sigma	2882 - 2621	98.7
		2608 - 2601	1.3

Pyramid of Djedefre at Abu Roash

Historical Range 2566 - 2558 BC
Sample details: number dated: 11 number used for mean: 11

C14 Mean age (weighted) 4229 BP
1 sigma 22
variance 38 used for calibration
Chi square 3.0551
probability 21.71 %

		ranges	probability of range %
Calibrated Age BC	one sigma	2896 - 2864	40.9
		2807 - 2778	34.9
		2772 - 2760	12.3
		2718 - 2706	11.9
	two sigma	2912 - 2855	36.4
		2850 - 2844	0.7
		2814 - 2676	62.9

Pyramid of Khafre at Giza

Historical Range			2558	- 2532	BC
Sample details: number dated:	25		number used for mean:		24
C14 Mean age (weighted)			4173	BP	
1 sigma			13		
variance			27	used for calibration	
Chi square			3.9820		
probability			13.66 %		
			r a n g e s		probability of range %
Calibrated Age BC		one sigma	2876	- 2857	16.1
			2813	- 2738	59.7
			2725	- 2697	24.2
		two sigma	2879	- 2835	18.6
			2819	- 2663	78.4
			2648	- 2634	3.0

Pyramid of Menkaure at Giza

Historical Range			2532	- 2504	BC
Sample details: number dated:	35		number used for mean:		30
C14 Mean age (weighted)			4127	BP	
1 sigma			11		
variance			25	used for calibration	
Chi square			5.3294		
probability			6.96 %		
			r a n g e s		probability of range %
Calibrated Age BC		one sigma	2858	- 2827	24.4
			2823	- 2812	9.0
			2741	- 2724	11.9
			2698	- 2658	30.6
			2652	- 2623	23.5
			2605	- 2605	0.6
		two sigma	2864	- 2806	28.8
			2779	- 2770	1.8
			2761	- 2717	17.0
			2708	- 2618	45.4
			2611	- 2595	4.7
			2594	- 2582	2.3

Mortuary Temple of Shepseskaf at South Saqqara

Historical Range			2504	- 2500	BC
Sample details: number dated:	8		number used for mean:		7
C14 Mean age (weighted)			4146	BP	
1 sigma			26		
variance			48	used for calibration	
Chi square			3.5191		
probability			17.21 %		
			r a n g e s		probability of range %
Calibrated Age BC		one sigma	2865	- 2831	19.0
			2821	- 2806	8.5
			2780	- 2770	5.5
			2761	- 2717	25.0
			2710	- 2660	28.0
			2650	- 2624	14.0
		two sigma	2878	- 2618	93.6
			2611	- 2595	3.9
			2594	- 2582	2.5

5th Dynasty (Old Kingdom)

South Pyramid Temple of Userkaf at Saqqara

Historical Range 2498 - 2491 BC
Sample details: number dated: 6 number used for mean: 4

C14 Mean age (weighted) 4400 BP
1 sigma 49 used for calibration
variance 41
Chi square 0.6966
probability 70.59 %

		ranges	probability of range %
Calibrated Age BC	one sigma	3089 - 3058	19.9
		3045 - 2921	80.1
	two sigma	3327 - 3225	13.8
		3174 - 3159	1.8
		3119 - 2902	84.4

South Pyramid Temple of Userkaf at Saqqara

Sample details: two younger samples

C14 Mean age (weighted) 3805 BP
1 sigma 70 used for calibration
variance 50
Chi square 0.4988
probability 77.93 %

		ranges	probability of range %
Calibrated Age BC	one sigma	2398 - 2383	5.5
		2346 - 2139	94.5
	two sigma	2461 - 2115	91.0
		2099 - 2038	9.0

Pyramid of Userkaf at Saqqara

Historical Range 2498 - 2491 BC
Sample details: number dated: 7 number used for mean: 4

C14 Mean age (weighted) 4009 BP
1 sigma 28
variance 56 used for calibration
Chi square 3.9068
probability 14.18 %

		ranges	probability of range %
Calibrated Age BC	one sigma	2619 - 2611	4.4
		2596 - 2593	1.6
		2582 - 2464	94.0
	two sigma	2856 - 2814	3.7
		2695 - 2691	0.2
		2681 - 2397	92.6
		2383 - 2345	3.5

Pyramid of Userkaf at Saqqara

Sample details: three intrusive younger samples

C14 Mean age (weighted) 2512 BP
1 sigma 30
variance 46 used for calibration
Chi square 2.3001
probability 31.66 %

		ranges	probability of range %
Calibrated Age BC	one sigma	787 - 757	15.8
		695 - 541	84.2
	two sigma	796 - 502	93.8
		490 - 484	0.8
		464 - 449	2.1
		440 - 427	1.8
		423 - 413	1.4

Queen's Pyramid of Userkaf at Saqqara

Historical Range		2498 - 2491	BC	
Sample details: number dated: 3		number used for mean: 2		
C14 Mean age (weighted)		3905	BP	
1 sigma		59	used for calibration	
variance		41		
Chi square		0.4858		
probability		78.43 %		
		r a n g e s		probability of range %
Calibrated Age BC	one sigma	2467 - 2305		100.0
	two sigma	2560 - 2535		3.3
		2534 - 2524		1.0
		2496 - 2265		85.8
		2264 - 2203		9.9

Mortuary Temple and Pyramid of Sahure at Abusir

Historical Range		2491 - 2477	BC	
Sample details: number dated: 14		number used for mean: 10		
C14 Mean age (weighted)		3840	BP	
1 sigma		19		
variance		52	used for calibration	
Chi square		7.7737		
probability		2.05 %		
		r a n g e s		probability of range %
Calibrated Age BC	one sigma	2401 - 2377		12.9
		2351 - 2201		87.1
	two sigma	2462 - 2193		93.9
		2176 - 2142		6.1

Mortuary Temple of Unas at Saqqara

Historical Range		2375 - 2345	BC	
Sample details: number dated: 6		number used for mean: 6		
C14 Mean age (weighted)		4009	BP	
1 sigma		23	used for calibration	
variance		22		
Chi square		0.9699		
probability		61.57 %		
		r a n g e s		probability of range %
Calibrated Age BC	one sigma	2566 - 2546		33.2
		2545 - 2520		41.6
		2498 - 2488		16.7
		2479 - 2474		8.5
	two sigma	2575 - 2509		67.8
		2504 - 2469		32.2

Pyramid of Unas at Saqqara

Historical Range		2375 - 2345	BC	
Sample details: number dated: 5		number used for mean: 5		
C14 Mean age (weighted)		4079	BP	
1 sigma		32		
variance		50	used for calibration	
Chi square		2.4547		
probability		29.31 %		
		r a n g e s		probability of range %
Calibrated Age BC	one sigma	2856 - 2814		20.3
		2695 - 2695		0.4
		2678 - 2563		66.0
		2522 - 2497		13.4
	two sigma	2864 - 2807		16.9
		2778 - 2771		0.9
		2760 - 2718		7.9
		2705 - 2485		72.6
		2485 - 2472		1.7

Tomb A, reign of Unas at Saqqara
Historical Age not established
Sample details: number dated: 2 number used for mean: 2

C14 Mean age (weighted)		3981 BP	
1 sigma		38	
variance		55 used for calibration	
Chi square		2.1521	
probability		34.09 %	
		ranges	probability of range %
Calibrated Age BC	one sigma	2578 - 2456	90.7
		2421 - 2404	7.1
		2359 - 2354	2.2
	two sigma	2826 - 2824	0.2
		2658 - 2652	0.5
		2622 - 2606	2.5
		2605 - 2304	96.8

6th Dynasty (Old Kingdom)

Pyramid of Teti at Saqqara
Historical Range 2345 - 2333 BC
Sample details: number dated: 15 number used for mean: 12

C14 Mean age (weighted)		4046 BP	
1 sigma		16	
variance		35 used for calibration	
Chi square		4.7305	
probability		9.39 %	
		ranges	probability of range %
Calibrated Age BC	one sigma	2620 - 2609	11.1
		2598 - 2588	8.6
		2584 - 2554	31.5
		2539 - 2493	48.8
	two sigma	2836 - 2818	3.4
		2664 - 2646	3.9
		2637 - 2469	92.6

Pyramid of Pepi II at Saqqara
Historical Range 2278 - 2184 BC
Sample details: number dated: 1

C14 Age of single sample date		3900 BP	
1 sigma		24	
		ranges	probability of range %
Calibrated Age BC	one sigma	2458 - 2400	64.5
		2380 - 2348	35.5
	two sigma	2464 - 2326	92.9
		2324 - 2306	7.1

8th Dynasty (First Intermediate Period)

Pyramid of Qakare-Iby at South Saqqara
Historical Range 2181 - 2161 BC
Sample details: number dated: 1

C14 Age of single sample date		3872 BP	
1 sigma		54	
		ranges	probability of range %
Calibrated Age BC	one sigma	2457 - 2415	23.9
		2414 - 2289	76.1
	two sigma	2471 - 2198	98.8
		2161 - 2149	1.2

12th Dynasty (Middle Kingdom)

Pyramid of Senusret II at Illahun

Historical Range		1897 - 1878 BC		
Sample details: number dated: 9		number used for mean: 8		
C14 Mean age (weighted)		3552 BP		
1 sigma		20 used for calibration		
variance		17		
Chi square		0.6893		
probability		70.85 %		
		r a n g e s		probability of range %
Calibrated Age BC	one sigma	1935 - 1934		2.1
		1922 - 1879		79.4
		1839 - 1829		17.5
		1785 - 1785		1.0
	two sigma	1949 - 1874		70.2
		1843 - 1810		19.5
		1800 - 1776		10.3

Pyramid of Amenemhet III at Dashur

Historical Range		1842 - 1797 BC		
Sample details: number dated: 2		number used for mean: 1		
C14 Age of single sample date		3442 BP		
1 sigma		41		
		r a n g e s		probability of range %
Calibrated Age BC	one sigma	1864 - 1843		16.9
		1808 - 1802		4.7
		1774 - 1688		78.4
	two sigma	1880 - 1837		19.1
		1831 - 1680		76.0
		1670 - 1658		2.4
		1651 - 1637		2.6