Radiocarbon (2025), **67**, pp. 155–175
doi:10.1017/RDC.2024.100

CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

Dating the Egyptian Old Kingdom: The reign of Djedkare (5th dynasty)

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Received: 17 April 2024; **Revised:** 11 July 2024; **Accepted:** 16 July 2024; **First published online:** 05 November 2024

Keywords: Abusir; Djedkare; Egyptian chronology; Saqqara

Abstract

This study aims to discuss the chronology of the Egyptian 5th dynasty of the Old Kingdom and the tentative date of accession of king Djedkare based on material from his royal necropolis at South Saqqara and non-royal cemetery of Abusir South, Egypt. A series of radiocarbon (^{14}C) dates were established through analysis of archaeological material from several monuments at the necropolis, including the king's pyramid complex, pyramid complex of his queen, and two elite tombs (Isesiankh and Khuwy). In addition, two samples from non-royal tombs in the Abusir South cemetery, were taken into consideration for further precision during the modeling, associated with king Huni (end 3rd dynasty) and king Niuserre (5th dynasty). The contextualized ^{14}C dates together with re-evaluation of historical evidence on Djedkare's rule, results in a new model of temporal probability density which can be further refined with any new data from archaeological research. It shows that Djedkare's reign can be currently modelled between 2503 and 2449 BCE (95.4%), thus slightly older than expected by literature. This presented model provides a more precise chronological frame for the late 5th dynasty period of Egyptian history, which was period of a significant socio-economic transformation.

Introduction

A series of recent studies on ancient Egyptian chronology based on new archaeological findings made considerable contribution to our understanding of temporal frame of the Early Dynastic and Old Kingdom periods (Quiles et al. 2023; Quiles and Tristant 2023). Compared to later periods of ancient Egyptian history, we have rather limited sources of contextualised archaeological material and textual sources from the 3rd millennium BCE, which makes the tentative Early Dynastic and Old Kingdom absolute dates particularly uncertain. Therefore, new evidence from well-documented archaeological contexts is essential for further research in this field.

New evidence became available between 2018 and 2022 through archaeological work of the Djedkare-Project mission at South Saqqara, which focuses on exploration of the royal necropolis of king Djedkare of the 5th dynasty. The necropolis is situated half-way between the 3rd dynasty Step Pyramid of Netjerykhet Djoser, the earliest Egyptian pyramid, and the early 4th dynasty Red Pyramid built by king Snofru at Dahshur, the earliest true-shaped pyramid. In addition, Djedkare's necropolis lies directly west of the early capital of Egypt, Inebu-Hedj (later Mennefer, Gr. Memphis) with the temple of Ptah (Megahed and Vymazalová 2023). The position of Djedkare's necropolis is thus very symbolic and it reflects the political message he aimed to fulfil during his reign. Historical sources from Djedkare's long rule provide evidence on socio-economic transformation that reflected significant changes in power-balance between the king

and the elites during that period (Bárta 2013a, 2017; Vymazalová 2019) but innovations also appeared in religious beliefs and funerary practices during this period.

The consensus Egyptian chronology suggests to date Djedkare's reign to late 25th and early 24th century BCE, estimating the absolute dates of his reign to ca. 2414–2375 BCE (Shaw 2000, 479–483), or even later to ca. 2365–2332 BCE (Hornung et al. 2006, 490–495). New findings from Djedkare's necropolis give us the opportunity to reconsider the previously suggested dates and set Djedkare's reign to a more precise chronological frame.

Four 5th-dynasty monuments have been explored and documented on Djedkare's royal necropolis up until today, which provided findings related to their construction as well as burials of their owners. A series of ^{14}C dates have been carried out on samples of archaeological material from these four monuments, which help us model Djedkare's accession date and chronology of his reign. Further precision has been achieved through analysing two additional samples from the Abusir South cemetery.

Materials and methods

Djedkare's royal necropolis—archaeological context

The royal necropolis established by king Djedkare is located on a small hill at South Saqqara, surrounded by a valley on its north and south and by cultivated area on the east. The location was undoubtedly chosen due to its clear visual link to the capital at Inebu-Hedj with its temple of Ptah, one of the most important deities in Old Kingdom period, and the position between pyramid complexes of earlier kings of the 3rd and 4th dynasties mentioned above. It is possible that the position of Djedkare's pyramid complex reflects his aim to strengthen his legitimacy and right to the throne and send a clear political message. During the following 6th dynasty, kings Pepy I and Merenre constructed their pyramid complexes in the neighbourhood of Djedkare's monument, and Pepy II built his complex further south. All these pyramid complexes are surrounded by tombs or pyramids of members of the royal family and the elite. Only a small part of South Saqqara has been, however, archaeologically explored (Figure 1).

Djedkare's royal necropolis started to be excavated in the 1946 and the 1952, followed by short and small-scale works in the 1980^{s} and 2000–2001 (Mathieu 2001, 2002). The results of these projects have never been fully published (see also Megahed 2011). In 2009, Djedkare-Project mission of the Charles University (Prague) reopened the field work on this site with the aim to document and protect Djedkare's pyramid complex and explore its surrounding. The consolidation and mapping of Djedkare's pyramid and funerary temple have been concluded in 2020 (see e.g. Megahed and Jánosi 2020; Megahed et al. 2017; 2018). Since 2018, works have been pursued in the pyramid complex of his wife, queen Setibhor, focusing on the pyramid itself and her unusual funerary temple (Megahed et al. 2019; Megahed and Vymazalová 2022). The tomb of Khuwy was discovered in 2019 and the tomb of Isesiankh in 2022 in the area to the east of Setibhor's pyramid complex (Megahed 2023; Megahed and Vymazalová 2019) (Figure 2). Their location, architecture and grave goods confirm the elite character of these tombs; their owners belonged to the king's family and his closest circle of dignitaries. All the monuments were heavily plundered and their architecture devastated in the antiquity. The elite nature of the necropolis has been emphasized by a large concentration of later graves and burials documented within and above these monuments, which date to the 2nd and 1st millenniums BCE and attest to the high significance of the Old Kingdom pyramids and tombs on the site for later local population (Hashesh and Gabr 2020; Vymazalová et al. 2021; Vymazalová and Hashesh 2019; Vymazalová forthcominga).

From a chronological perspective, the king's pyramid complex was the pivotal monument built at the cemetery. The earliest phase of its construction can be dated to the beginning of Djedkare's reign when the foundation ritual was performed, the layout of the pyramid and other parts of the complex was outlined, and the substructure of the pyramid started to be built followed by its superstructure. It is generally presumed that pyramid-complex construction continued for decades of Djedkare's reign and

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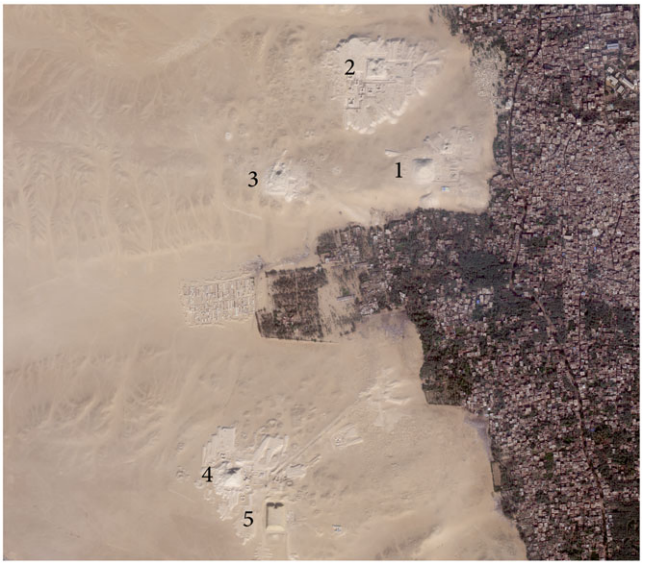

Figure 1. *A satellite image of the necropolis with the pyramid complexes of Djedkare (1), Pepy I (2), Merenre (3) and Pepy II (4), and the 4th Dynasty Mastabat Faraun of Shepseskaf (5) shows also the vast unexcavated areas of the South Saqqara site (detail of the satellite image by World View 2, Nov. 30, 2020, after Bárta and Brůna 2021, 115).*

ended with the king's death and burial. The neighbouring pyramid complex of Djedkare's wife, queen Setibhor, was built from early Djedkare's reign and its construction probably lasted for several decades. Its unusual layout and size indicate that its owner was a queen of high significance and power during Djedkare's reign, perhaps providing the king with legitimacy (Megahed and Vymazalová 2020). The two elite mastabas situated to the east of Setibhor's pyramid complex were constructed during the later part of Djedkare's reign. Isesiankh, the eldest son of the king and heir to the Egyptian throne, apparently died prematurely before assuming the royal office (Megahed 2023; Vymazalová 2024). He was therefore with no doubt buried during Djedkare's reign. Khuwy's tomb seems to be slightly later than Isesiankh's tomb, and it was most likely constructed towards the end of Djedkare's reign. Its substructure contains decoration in painted relief, which represents one of the earliest attested decorated tomb substructures in the Old Kingdom, reflecting the above-mentioned transformation of funerary beliefs during Djedkare's reign (Megahed and Vymazalová 2019; Vymazalová forthcomingb).

Abusir South necropolis—archaeological context

The Abusir South, extending to the south of the 5th dynasty pyramids at Abusir towards the North Saqqara necropolis, was the cemetery of officials who served the Egyptian state during the 3rd millennium BCE. Tombs attested at this site belonged to the members of the elite between the late 3rd dynasty and the end of the Old Kingdom period (for an overview see Bárta 2020).

Since the early 1990s Abusir South has been excavated by the Czech mission of the Charles University, which up until today uncovered e.g. the tombs of Fetekti and Kaaper (Bárta 2001), the tomb of the priest Neferinpu (Bárta et al. 2014a), and the tombs of the vizier Qar and his son, judge Inti (Bárta et al. 2009; Bárta and Vachala et al. forthcoming). Between 2011 and 2019, the anonymous tomb AS 54 was uncovered, including a wooden boat buried to the south of it (Bárta 2011, 2019, 112–113). In 2012–2016, the tomb complex of Nefer and princess Sheretnebty (AS 68) was explored (Bárta et al. 2014b; Vymazalová 2015).

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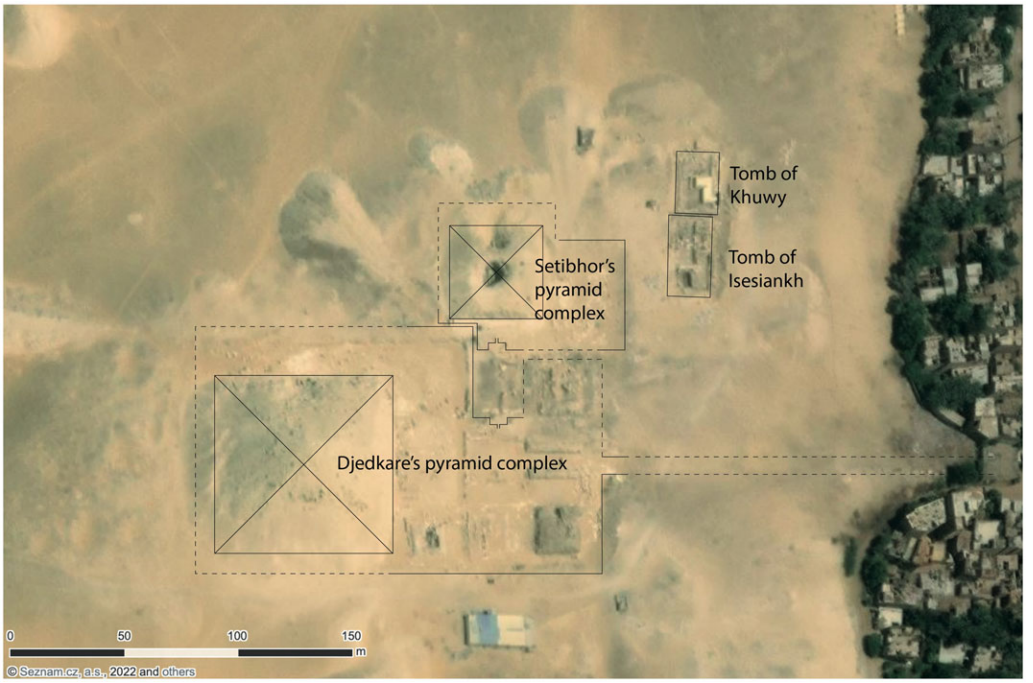

Figure 2. *Djedkare's necropolis at South Saqqara (Djedkare Project, © Hana Vymazalová).*

From the chronological perspective the last-mentioned monument provides a certain frame for the chronological study, additional to the evidence form Djedkare's necropolis. The tomb complex of Nefer and Sheretnebty (AS 68) contains four rock cut chapels with the total of 14 burial shafts and chambers. They belonged to four elite families of mid to late 5th dynasty, including Niuserre's daughter and her non-royal husband and children. Additional 14 shafts situated in the courtyard and corridor in front of these tombs probably belonged to their relatives and priests. The burial activities in this tomb complex seem to have started in mid-5th dynasty during the reign of Niuserre and continued until the late Old Kingdom (Bárta et al. 2014b; Vymazalová 2015: 57).

Sampling

Eight samples were selected (Figure 3) from Djedkare's necropolis in 2021 (IFAO_0971 and IFAO_0972, Ikram et al., 2023) and 2022 (IFAO_1047, IFAO_1052 to IFAO_1056), another was taken in 2017 from Abusir South (IFAO_0759). They were carefully collected using gloves, sterilised stainless-steel scalpels and steel tweezers, and preserved in burnt aluminium foil. Their collection was supervised by the Research and Conservation Centre of the Ministry of Tourism and Antiquities, and the samples were sent to the IFAO laboratory in Cairo.

Sample IFAO_1052 is a fragment of a rope from the substructure of Djedkare's pyramid, collected among the stones and debris of the pyramid core masonry in the in the south wall of the antechamber where the casing blocks of the room walls were missing (Megahed et al. 2017).

Sample IFAO_1047 are pieces of charcoal collected in queen Setibhor's pyramid complex, namely in the portico of her funerary temple (Megahed et al. 2019) inside the pit for the western column base, which itself is missing. Sample IFAO_1055 is a textile fragment found in the substructure of Isesiankh's tomb, collected in the fill of the burial chamber at the floor level by the sarcophagus.

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Figure 3. *Examples of samples collected in the Djedkare's cemetery: rope sample (IFAO_1052 © Ifao) and its original position (© Djedkare Project, Mohamed Megahed), pieces of mummy wrappings and textiles (IFAO_0971 and IFAO_0972 © Djedkare Project, Ahmed Gabr).*

Five samples are from Khuwy's tomb, and all of them were collected in its substructure. IFAO_0971 is a textile fragment from the mummy wrappings collected on the mummified remains (Ikram et al. 2023; Megahed and Vymazalová 2019). IFAO_0972 and IFAO_1056 are textiles found scattered in the fill of Khuwy's substructure, which may have come from his mummy wrappings and burial goods, but some may have been intrusive. IFAO_1053 and IFAO_1054 are pieces of charcoal found in Khuwy's substructure near the sarcophagus where some offerings were also scattered.

The sample from the Abusir South cemetery, IFAO_0759, are fragments of a wooden box from one burial in Nefer's rock cut tomb (AS 68d).

Digital microscopic observation

Observations were first made on the textile samples using a portable digital microscope (DinoLite Edge) using visible and UV light controlled by a flexible LED, with a magnification of 20 to 220×, in order to assess their state of conservation and the possibility of external contamination.

It has not been possible to identify the species of wood from which the charcoal samples originate.

ATR-FTIR control

ATR-FTIR analyses were carried out on the Nicolet Is5 instruments from Ifao Lab (Quiles et al. 2022). Acquisition was done using the ATR-diamond module of the Nicolet (ThermoScientific), and absorbance was recorded between 4000 and 400 cm^{-1} with a resolution of 4 cm^{-1}, by accumulating 128 scans for each spectrum. The band at 1030 cm^{-1} was used and the spectrum of each archaeological sample was set at the same intensity in order to allow for normalization and comparison between

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spectra. Analyses were carried out three times on each sample to check the reproducibility of analyses. The most representative spectrum is reported.

^{14}C analyses

Samples were subjected to radiocarbon analysis using the routine protocol running at the IFAO lab (Quiles et al. 2017). After physical cleaning, around 20 g of samples are chemically pre-treated by AAA protocol [HCl, 8% (80°C); NaOH, 0.1–0.5N; HCl 8%] and then rinsed and cleaned using an automated ultrapure water system based on sand, bacteria, UV and resin filters.

Combustions are performed using a combustion bomb. Samples are placed in a stainless-steel cup inside the bomb, in contact with a tungsten filament and in a stream of around 10 bars oxygen, under an accurate vacuum ($\sim 10^{-1}$ mbar). The CO_2 gas is then purified using ethanol traps (–80°C) and collected in liquid nitrogen cooled traps (–196°C). A subsample of the purified CO_2 is collected to measure the $\delta^{13}C$ value by IRMS on a Thermo Delta V Plus at the Stratochem laboratory in Cairo. CO_2 is then slowly released into a furnace in the presence of molten lithium in stoichiometric quantity with an excess of 1 g to form lithium carbide (Li_2C_2). Once the lithium carbide is cooled, it is then slowly hydrolysed into acetylene gas (C_2H_2) using tritium-free water. The acetylene gas is purified by passing it successively through ethanol (–80°C) and orthophosphoric acid (H_3PO_4) bubble traps, and finally trimerized to benzene using an alumina-vanadium-chromium catalyst. Liquid benzene at atmospheric pressure is finally stored in glass vials in the fridge prior to being measured.

A cocktail of Bis-MSB and butyl-PBD scintillators dissolved in equal ratio in 4 mL benzene solution is then prepared to be measured on two Perkins Elmer Tricarb 3100 liquid scintillation counters. Each sample is measured eight times with each run lasting 1000 minutes.

The ^{14}C activity is calculated in percent relative to the activity of an international standard of oxalic acid NIST SRM 4990C (OxII), using the Libby half-life (5568 yr) and taking into account the isotopic fractionation normalised to –25‰ (versus VPDB) (Mook and van der Plicht 1999; Stuiver and Polach 1977). Radiocarbon probability densities are converted into calendar ages using the IntCal20 calibration curve (Reimer et al. 2020) using the OxCal4.4 software (Bronk Ramsey 1995, 2009a).

Bayesian modeling

Bayesian statistics were applied to model ^{14}C results by incorporating historical and textual information as prior information. All the modeling was done using OxCal v4.4.4 software (Bronk Ramsey 1995, 2009a, 2009b, 2017), using the IntCal20 calibration curve (Reimer et al. 2020).

Results

Contextualized archaeological samples and the reign of Djedkare

The archaeological context of each sample was carefully examined in order to identify more precisely how these samples can be connected to the reign of Djedkare.

IFAO_1052, a rope sample collected in core masonry of the substructure, attests to the early stage of Djedkare's reign. The substructure was most probably built during year 1 or 2 of his reign, prior to the construction of the pyramid itself. This appears to be the earliest sample from the examined group and most closely associated with the date of king Djedkare's ascension to the throne. Even though the missing casing blocks in the substructure indicate later activities associated with quarrying of building material in the pyramid complex, which may have left traces in the pyramid core masonry as well, the results of our examination confirm the dating of this sample to early Djedkare's reign.

IFAO_1047, charcoal from queen Setibhor's pyramid complex, was found inside the pit for the western column base in the temple portico. The exact origin of the charcoal remains uncertain; it may

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have been placed to the pit during the construction of the queen's pyramid complex before the column base, or it may have ended up in the pit during later activities after the removal of the column and its base. This charcoal is likely to be later than the sample from Djedkare's pyramid substructure, its chronological relation to the sample from Isesiankh's burial is unclear but it is most probably earlier than Khuwy's burial.

IFAO_1055, a textile from the Isesiankh tomb's substructure, was collected at floor level by the sarcophagus in the fill of the burial chamber, and it probably came from Isesiankh's mummy wrappings. The burial of Isesiankh, who was the king's eldest son and died before his father, dates safely to Djedkare's reign. The family relationship indicates that he was (at least) a generation younger than Djedkare, but the time of his birth during Djedkare's reign remains unknown. No skeletal remains were found in Isesiankh's tomb and therefore his age at time of death is unknown. Chronologically, this sample dates Isesiankh's death and it is likely to be later than Djedkare's pyramid substructure and earlier than Khuwy's mummy. No chronological relation can be suggested between IFAO_1047 and IFAO_1055.

IFAO_0971 and IFAO_0972, are associated with the burial of Khuwy, who was probably a generation younger than Isesiankh. His mummy dates to the late part of Djedkare's reign or early in the reign of Unas. The first sample is a textile from the mummy wrappings collected on the mummified remains found in the substructure of the tomb, which thus dates Khuwy's death. The second sample comes from textiles found in the fill of Khuwy's substructure that are presumed to have come from his looted mummy wrappings and burial goods.

Another sample of textile, IFAO_1056, appears to be intrusive. These textile fragments collected in the fill of Khuwy's substructure confirm later activities in the tomb, associated with looting of the burial and other secondary activities.

IFAO_1053 and IFAO_1054 are pieces of charcoal found in Khuwy's substructure at the ground level near the south-western corner of the sarcophagus where some scattered offerings were also found. The charcoal is most likely to be associated with Khuwy's burial offerings, but it may also come from later activities in the tomb when Khuwy's burial was looted.

The sample from the Abusir South cemetery helps further precision of the chronological frame. The fragments of a wooden box from Nefer's rock-cut tomb (AS 68 tomb d), IFAO_0759, attest to the date of one of four burials in this tomb. Nefer himself seems to have lived in Niuserre's reign (Bárta et al. 2014b), and the burial in this shaft is probably a generation later and is estimated to late Niuserre's reign of slightly later.

Digital microscopic observation

Although visually the textile samples appear very different in colour, no clear contamination could be identified by digital observations using visible and UV light.

ATR-FTIR analyses

ATR-FTIR analyses were carried out on IFAO_0971 and IFAO_0972 samples prior and after cleaning's pretreatment in order to check that all contaminants were properly removed, in particular ancient organic chemicals used for the bodies' embalming (Quiles et al. 2023, 2014; Ferrant et al. 2022).

Figure 4 shows FTIR spectra for IFAO_0971 (above) and IFAO_0972 (below), before and after A-A-A chemical cleaning (black and green). They are compared to the spectrum of a modern linen textile. IFAO_0971 and IFAO_0972 spectra before cleaning display quite similar signatures, except in the CH area (3000–2800 cm^{-1}). As already observed in a previous study (Quiles et al. 2023), when there are organic contaminations due to the embalming process (e.g. resin, bitumen), we would expect a double band at 2900 and 2850 cm^{-1} in the CH massif, and another double band in the CO/C-C region

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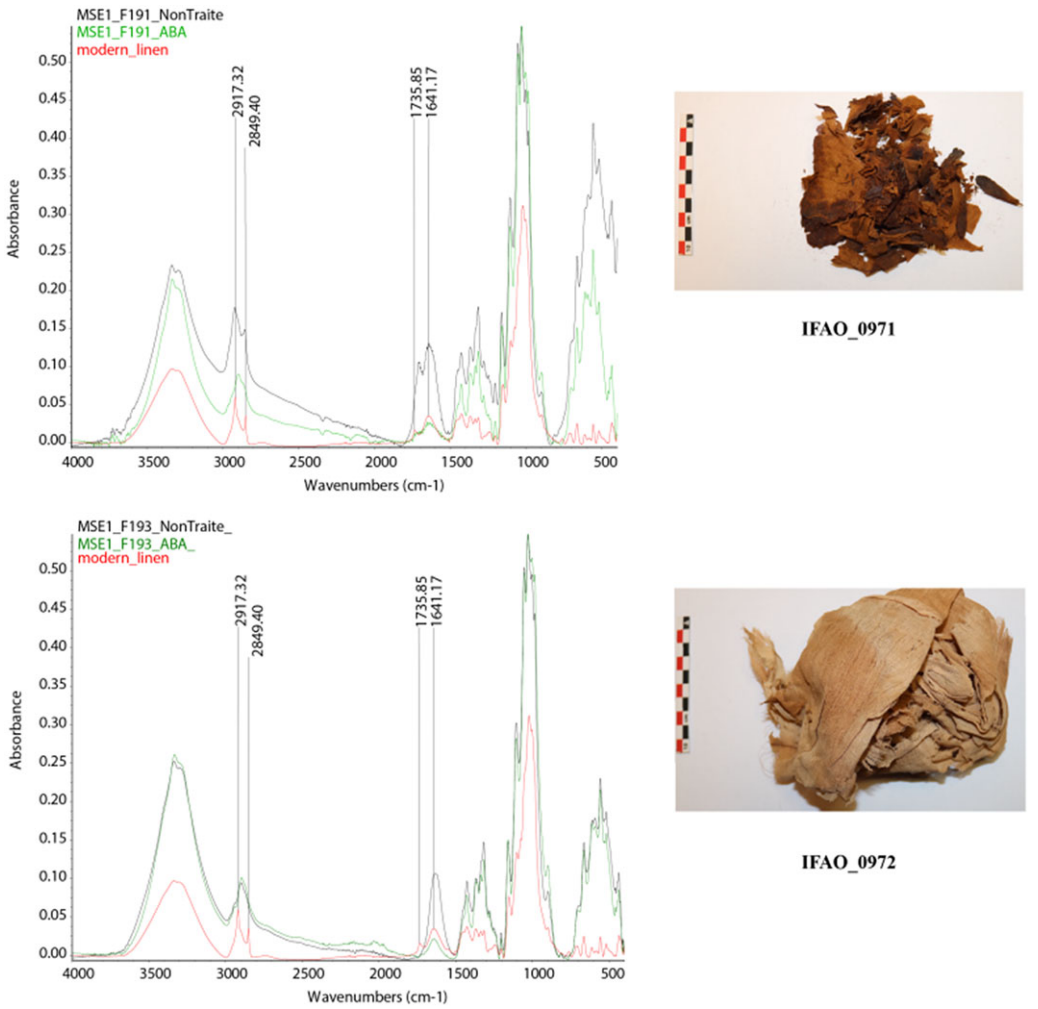

Figure 4. *Comparison of FTIR spectra on samples IFAO_0971(above) and IFAO_0972 (below) before (in black) and after cleaning (in green). They are compared to the spectrum of a modern linen (in red).*

(1710 and 1700 cm^{-1}) (Ferrant 2021). They are present on the IFAO_0971 spectrum, and missing on the IFAO_0972 spectrum. This is consistent with the visual observations of the samples, IFAO_0971 being much darker than IFAO_0972. In the latter case, the two bands at 2917 and 2850 cm^{-1} are supplanted by a massif centered at 2900 cm^{-1}. For both, the band at 1735 cm^{-1} is not observed, but the one at 1640 cm^{-1} has increased. This demonstrates the hemicellulose degradation due to thermal ageing. In conclusion, no organic contamination can be observed on IFAO_0972 whereas it could be suspected on IFAO_0971, even if this has not been definitively demonstrated.

The IFAO_0971 spectrum repeated after cleaning shows that the CO/C-C bands are not visible anymore. For both samples, the extensive band at 1640 cm^{-1} has been reduced. This demonstrates the efficiency of the classic A-A-A cleaning protocol and that it ensures samples are free of organic contaminants.

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^{14}C results

$\delta^{13}C$ values are all consistent, ranging for textile samples from –25.9‰ to –23.4‰, for charcoal samples from –27.0‰ to –25.1‰, for wood samples from –27.5‰ to –24.9‰ (consistent with C3 organism), while the value for the rope sample is of –10.0‰ as would be expected for alfa palm (Table 1). ^{14}C results range from 4130 ± 30 BP (IFAO_0759) to 3227 ± 30 BP (IFAO_1056), thus cumulated probability densities range from 2871 to 1426 calBCE (Table 1). IFAO_1056 is clearly outside the temporal ranges expected for the 5th Egyptian dynasty, but this is not entirely surprising since we suspect later intrusive activity in the Khuwy substructure. In this case, it would have been at the very beginning of the New Kingdom, which is consistent with archaeological evidence. This result has not been integrated into the modeling.

Figure 5 (right) shows the calibrated probability densities of each individual result obtained on the samples from the Djedkare's cemetery. They are displayed according to the nature of samples (red for textile, orange for the rope and black for charcoal). Results for the two pieces of charcoal collected together at the entrance of the Khuwy's burial chamber (IFAO_1053 and IFAO_1054) are fully consistent. They have been combined in a unique temporal probability density since they come from exactly the same archaeological context. Plotting the results on the calibration curve (Figure 5, left) highlights the difficulty of interpreting these results in the absence of other constraints. Temporal probability densities extend from 2550 to 2300 calBCE, centered around two age plateaus: a small one from 2550 and 2500 calBCE and a larger one between 2450 to 2300 calBCE. We note that all the textiles and the rope appear to be slightly older and are concentrated around the first age plateau, whereas the results from the three pieces of charcoal are around the second one. While this is an important observation, it is difficult to make definitive interpretations because the data set is too small and two of the charcoal pieces come from a single context. Further investigations will be undertaken to try and better investigate whether this is a random finding or whether it has archaeological significance.

The OxCal model

Results were modeled according to the nature of samples and their archaeological context. On the basis of archaeological evidence, they have been organized in *Phase* and *Sequence* according to the expected chronological order within the reign of Djedkare. Three different stages have been identified, as a prior information (Table 1):

- Stage 1: construction of the pyramid complex of Djedkare
- Stage 2/3: construction of the pyramid complex of queen Setibhor and burial of Isesiankh (tomb MSE3)
- Stage 4: Khuwy's burial

Outlier distributions were modeled based on the nature of samples. Several tests have been run to get the most appropriate representation of the archaeological contexts (Bronk Ramsey 2009b). The textiles were down-weighted using an exponential distribution with a prior of 50% because it cannot be ruled out that the textiles were made during the individuals' life (and therefore before their death). The charcoal samples' results were firstly modeled using a *Charcoal* outlier probability density with a prior set to 100% (Bronk Ramsey 2009b). At the same time, the archaeological record does not allow to exclude the possibility that the pieces of charcoal are linked to shortly later activities in the tomb (albeit close to the death of its owner), which is why we have preferred using a distribution with a Normal function [N(0,2)] to take into account this information. The prior probability was set to 50%. The Combined probability density for the two charcoal pieces was down-weighted using a *Combine* outlier probability density resulting in a normal function, with a prior set to 5%.

Following results of previous studies (Dee et al. 2010; Manning et al. 2020a, 2020b) suggesting a variation of radiocarbon activity of 19 ± 5 ^{14}C yrs to the IntCal curve for the Nile valley due to a

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Table 1. ^{14}C results of analyses carried out on Djedkare's cemetery samples and the Abusir South sample

Lab code	Excav. no./ sampling no.	Material	$\delta^{13}C$ (‰)	^{14}C year (BP)	σ (BP)	Site reference	Tomb	Stage	
IFAO_0971	excav. no. MSE1-F191-2019 DJP-sample-2021-19	Textile wrappings	–25.9	4038	30	Saqqara, Djedkare's cemetery	Khuwy's tomb (MSE1)	Stage 4, late part of Djedkare's reign	
IFAO_0972	excav. no. MSE1-F193-2019 DJP-sample-2021-20	Textile wrappings	–24.5	4021	30	Saqqara, Djedkare's cemetery	Khuwy's tomb substructure	Stage 4, late part of Djedkare's reign	
IFAO_1047	excav. no. DJ-F352-2018 DJP-sample-2022-06	Charcoal	–27.0	3874	30	Saqqara, Djedkare's cemetery	Queen Setibhor's pyramid complex	Stage 2/3, any time during Djedkare's reign	
IFAO_1052	excav. no. DJ-F170-2018 DJP-sample-2022-12	Rope	–10.0	4030	30	Saqqara, Djedkare's cemetery	Djedkare's pyramid substructure	Stage 1, early stage of the Djedkare's reign	
IFAO_1053	excav. no. MSE1-F200-2019 DJP-sample-2022-13	Charcoal	–25.1	3852	30	Saqqara, Djedkare's cemetery	Khuwy's tomb substructure	Stage 4, late part of Djedkare's reign	*duplicate*
IFAO_1054	excav. no. MSE1-F200-2019 DJP-sample-2022-14	Charcoal	–26.8	3847	30	Saqqara, Djedkare's cemetery	Khuwy's tomb substructure	Stage 4, late part of Djedkare's reign	*duplicate*

IFAO_1055	excav. no. MSE3-F401-2022 DJP-sample-2022-15	Textile wrappings	–23.4	3999	30	Saqqara, Djedkare's cemetery	Isesiankh's tomb (MSE3)	Stage 2/3, any time during Djedkare's reign	
IFAO_1056	*excav. no. MSE1-F193-2019 DJP-sample-2022-16*	*Textile wrappings*	*–24.4*	*3227*	*30*	*Saqqara, Djedkare's cemetery*	*Khuwy's tomb substructure*	*Stage 4, late part of Djedkare's reign*	*rejected*
IFAO_0759	406/AS68d/2014	Wood	–27.5	4130	30	Abusir South	Nefer's tomb (AS 68d)	Niuserre's reign, probably late stage	

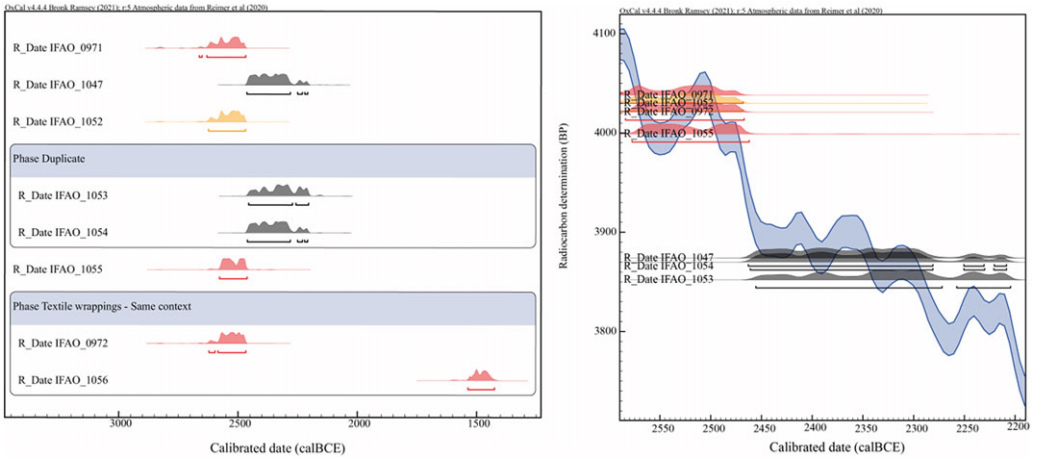

Figure 5. *Calibrated probability densities obtained on samples coming from the Djedkare's cemetery. Textiles samples are in red, the rope is in orange and the pieces of charcoal are in black.*

seasonal effect, revised to 16 ± 4 using IntCal20, a Delta_R "seasonal effect" has been integrated. This value is consistent with current investigations on this offset for plants species having grown up close to the Nile Valley (Quiles et al. 2021).

Discussion

The Djedkare's cemetery complex

The results were modeled in a *Sequence*, in three *Phases*, in accordance with the three identified stages. IFAO_1053 and IFAO_1054 were combined, Outlier probability densities added to each single probability density. Figure 6 shows the simulated *boundaries* in green, standing for the start and the end of the whole sequence. It calculates the start of the reign between 2682 and 2458 BCE (95.4%) and its end between 2465 and 2205 BCE (95.3%). These two time-ranges are quite wide, which is due to the lack of a priori constraints in the model before and after Djedkare's reign, the relatively low number of ^{14}C dates, and to the calibration plateaus.

Length of Djedkare's reign

The length of Djedkare's reign is another important piece of historical information that should be integrated into this study. According to historical and archaeological data, we can expect a reign of around 40 years. The attested dates of Djedkare's reign come from various sources. A text of a papyrus from the pyramid complex of Neferikare Kakaï in Abusir [N.41.c2] mentions the year of 22 (or 21?) cattle count, 4th month of the Akhet season, day 22 (Posener-Kriéger 1976; Posener-Kriéger and de Cenival 1968; Spalinger 1994; Verner 2001, 2006, 2008), and a dipinto on the sarcophagus of Idu in his tomb in Abusir refers to the year after the 17th cattle count, 1st month of Shemu, day 23 (Verner 2001, 2006, 2008; Verner and Callender 2002). In addition, another dipinto in the tomb of Shepespuptah in Abusir South (tomb AS 68c) attest to the year after the 20th cattle count, 1st month of Akhet, day 9, which undoubtedly refers to Djedkare's reign (Vymazalová and Dulíková 2012). This would be the highest known attestation of a year after cattle count of his reign.

The frequency and regularity of the census (cattle count) during the Old Kingdom is a well-known and much debated question (Verner 2006; see also Redding 2024). At this point of research, it is impossible to demonstrate definitively that the census was biennial or irregular during the reign of

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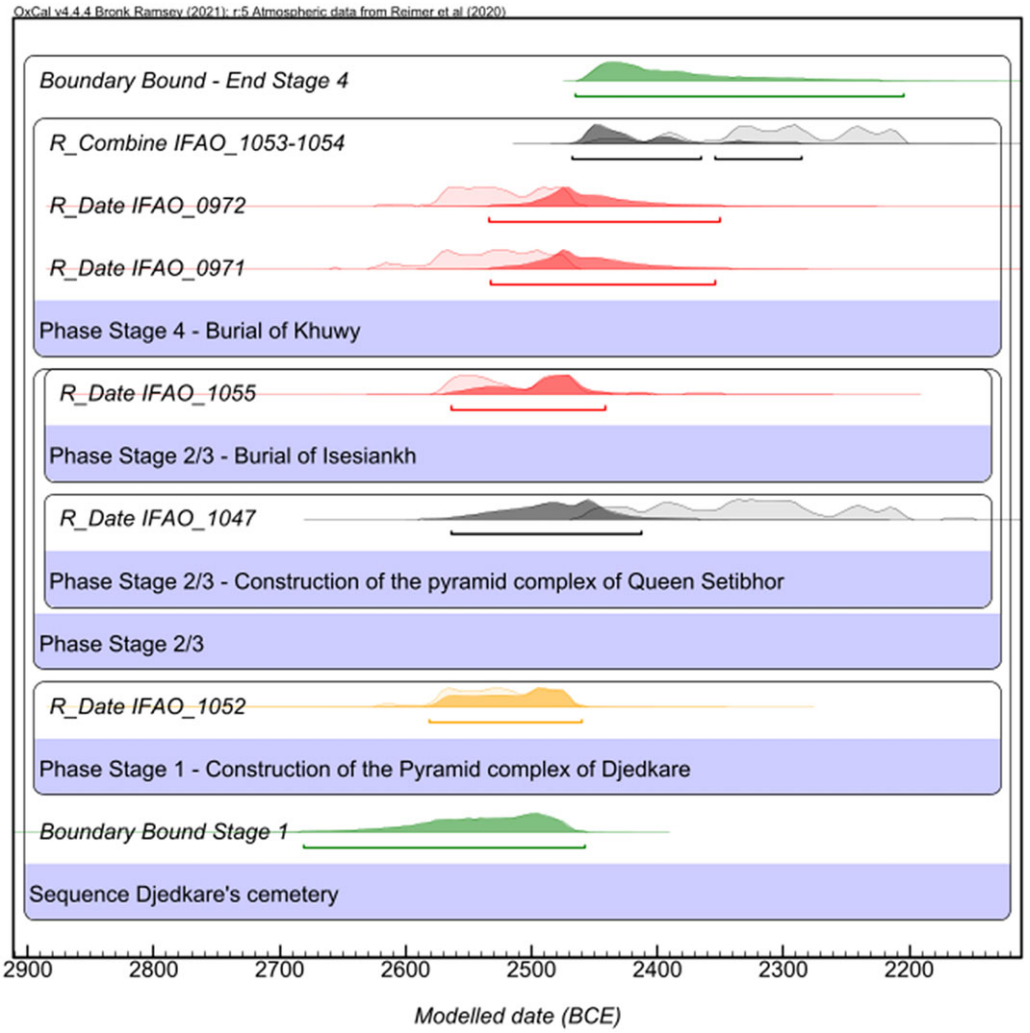

Figure 6. *Sequence model of the ^{14}C results obtained on samples archaeologically attributed to the reign of king Djedkare.*

Djedkare but the latter seems more likely from the extant evidence. Djedkare's "years of cattle count" are much more frequently attested than his years 'after the cattle count' (Nolan 2008; Verner 2008). This leads us to suggest that Djedkare's reign lasted for minimum 22 years, as indicated by the highest attested date of census, while the 13 attested years after the census give evidence of at least seven additional years of his reign. If the census was irregular during Djedkare's reign, as the evidence seems to indicate, we can assume that his reign lasted certainly 29 years or more and could have lasted for 44 years. We cannot exclude that Djedkare's reign was even longer than suggested by the currently available evidence.

The previous model was run again with this constraint included, forcing the time-span between the start and the end of Djedkare's reign to be from 29 to 44 years. An *Interval* was modeled using a probability distribution *After(29)&Before (44+5*T(5)),* which forces the model to give at least 29 years, and as many as 44, with a low probability that it might be higher (Figure 7 c). The deduced correlation matrix confronting temporal probabilities of the simulated boundaries for *"Djedkare ascension date"* (x-axis) and *"Djedkare's end of reign"* (y-axis) shows that the reign of Djedkare was most probably

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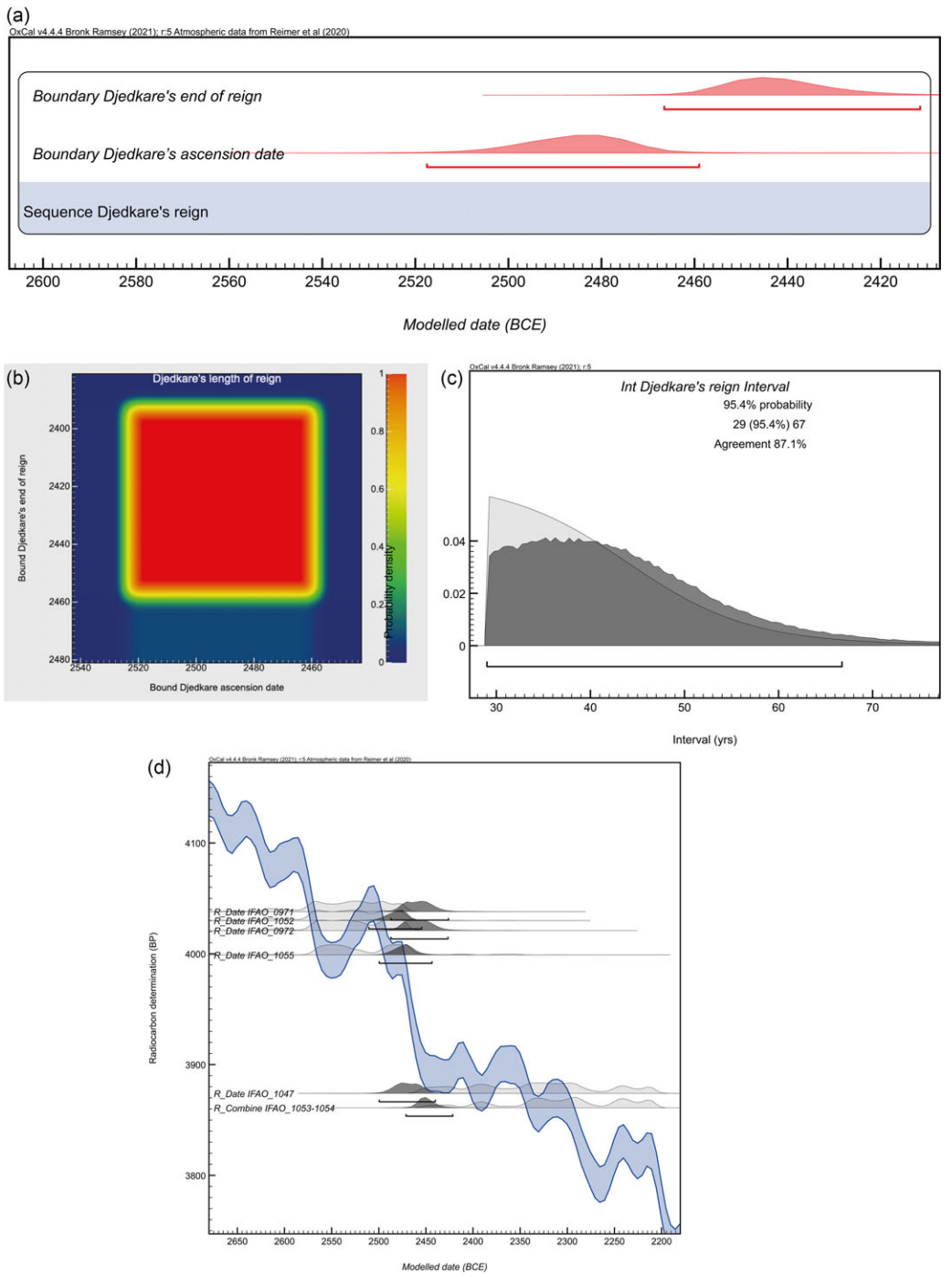

Figure 7. *Modeling of the previous sequence by constraining the whole sequence to have lasted from 29 to 44 years maximum. a] simulated boundaries for the beginning and end of Djedkare's reign; b] correlation graph between the two previous simulated boundaries; c] modeling of the interval corresponding to the duration of Djedkare's reign, described a priori as After(29)&Before (44+5*T(5)), d] results modeled on the calibration curve (IntCal20).*

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between 2520 and 2390 BCE (Figure 7 b), providing temporal ranges of 2518–2460 BCE (95.4%) for the ascension date, and 2467–2412 BCE (95.4%) for the end of reign (Figure 7 a). As expected, the modeling is forcing the temporal probability densities to be between the two age plateaus (Figure 7 d). Several other tests were run using different outlier-model distributions. If the prior probability for textile samples is set to 25% instead of 50%, the time-range for the end of the reign is 2470–2419 BCE (95.4%); if all the prior probabilities are set to 5%, we reach 2481–2416 BCE (93.5%). Besides, if the charcoal outlier-model distribution is a student's *t*-distribution instead of a Normal function (Bronk Ramsey et al., 2009b), it gives 2468–2411 BCE (95.4%). That shows that the way we are modeling the outlier distributions does not drastically impact the results.

The reign of Djedkare within the 5th dynasty

Analysis of another sample was carried out on wood fragments from a close archaeological context, at the Abusir South cemetery. IFAO_0759 is from a burial dated most probably to the late stage of Niuserre's reign (5th dynasty, see I.3).

In addition, a previous ^{14}C analysis was carried out at the Ifao lab in 2011 on an *Acacias sp.* sample used in the construction of the mastaba AS 54 in Abusir South, archaeologically attributed to the reign of Huni (Bárta 2011, 2013b, 222). Its age of 4069 ± 57 BP (IFAO_0412) was added in a single *Phase "Huni's reign"* in the previous model. It has been down-weighted using the *Charcoal* outlier-model as defined in Bronk Ramsey (2009b), with a prior probability of 100%.

Niuserre's and Djedkare's reigns are separated by the reign of Menkauhor, for which the higher attestations we have are a year 7 [531x/I/82-a1, a2] and a year after the year 7 [763x/I/82]. They come from jar labels from Raneferef funeral temple in Abusir (Verner et al. 2006: 281[40], pl. 7; Verner 2008: 32). In addition, a year after the 1st census is also attested, which means we can estimate the length of Menkauhor's reign to be at least 9 yrs, possibly as many as 15 years.

It is more difficult to estimate the time-gap between the ends of the reigns of Huni and Niuserre which encompasses the whole 4th dynasty and the start of the 5th. According to our most recent estimates, we suggest that it was no less than 130 yr and could be as many as 200 yr (personal communication), which is consistent with what was suggested by Hornung et al. (2006).

These two results have been used to constraint the start of Djedkare's reign. The length between the reign of Huni and Niuserre has been modeled by an Interval tool "*Interval("Int Huni-Niuserre", After(130)&Before(200+10*T(5)))*, whereas the length of Menkauhor's reign has been modeled by *"Interval("End Niuserre-Djedkare", After(9)&Before(15+5*T(5)))*.

Besides, the sample IFAO_0759 is archaeologically precisely attributed to the end of Niuserre's reign, which is a direct *Boundary* information. This is why we have directly integrated this result in a *Boundary*, within an *After* tool. It means that the *Bound* 5th *dyn.* is statistically clearly defined by a ^{14}C distribution.

Boundary("Bound 5th *dyn.", After("Niuserre", R_Date("IFAO_0759", 4130,30)));*

Modeled probability densities for the date of Djedkare's ascension and his end of reign are more constrained (Figure 8). It shows that Djedkare began to reign between 2508 and 2454 BCE (95.4%) and that he died between 2468 and 2415 BCE (95.4%). These time-ranges are almost the same as those obtained previously.

The reign of Djedkare within the Old Kingdom

Previous studies have already suggested temporal probability densities for the 5th-dynasty reigns, in particular Djedkare's reign. In Bronk Ramsey et al. (2010), the reign of Djedkare is estimated to be 2486–2400 BCE (95%). A single ^{14}C analysis is associated with the reign of Djedkare (and for the whole 5th dynasty), carried out on a papyrus plant from the Abusir site, held at the British Museum

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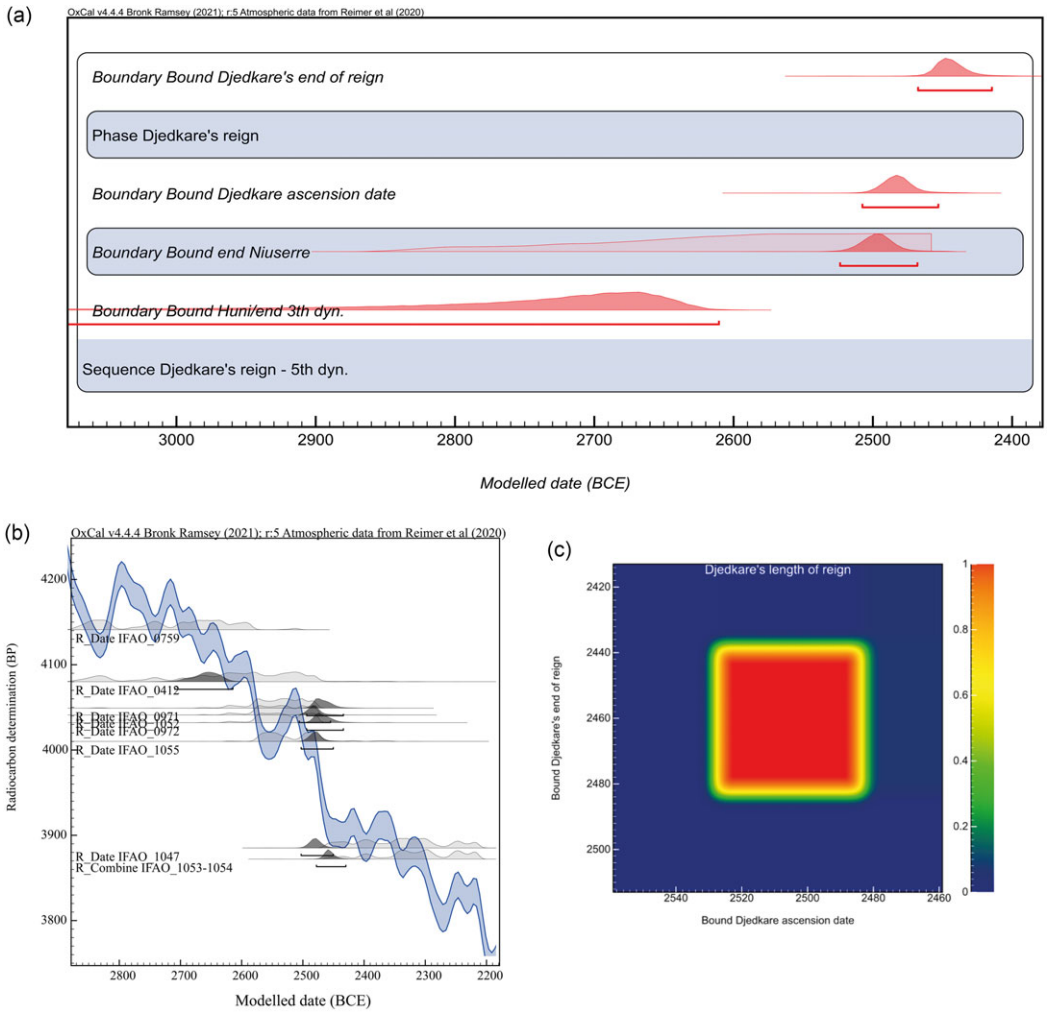

Figure 8. *Niuserre's reign. a] Modeled boundaries corresponding to the end of the 3rd dyn., the end of Niuserre reign and surrounding the reign of Djedkare; b] plotting results on the calibration curve (IntCal20); c] correlation plot between the start (x-axis) and end (y-axis- modeled probability density for Djedkare's reign.*

(BM 10735/10). It gave an age of 3911 ± 31 BP (OxA 20212), consistent with results obtained on the charcoal samples (Figure 9). We should notice that the OK model is based on a weak number of analyses (17) compared with other more recent periods (MK, NK), with no constraints on earlier periods.

This result (OxA 20212) was added in the Phase ("Djedkare"s reign"). With the addition of this last ^{14}C-constraints, the estimates for the accession date of Djedkare is 2503–2449 BCE (95.4%, Table 2). The model was run again by putting only 5% of prior probability on the textile samples and using the Charcoal outlier-model for all charcoal samples. It gives a time range of 2503–2451 BCE (95.4%) for the accession date of king Djedkare, demonstrating the consistency of this modeling.

From historical and archaeological evidence, Kitchen (2000) suggested an accession date for Djedkare at 2431 BCE, Shaw (2000) at 2414 BCE, Verner (2006) at 2402 BCE and Hornung et al. (2006) at 2365 BCE. While the results obtained may be consistent with Kitchen's suggestion, they clearly demonstrate higher estimates than those suggested by other scholars.

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Table 2. *Results of modeling obtained for the accession date and the end of reign of king Djedkare*

Model	Number of dates	Djedkare's accession date (BCE)	Djedkare's end of reign (BCE)
Djedkare's cemetery samples	7	2518–2460 (95.4%)	2467–2412 (95.4%)
With Niuserre's and Huni's dates	9	2508–2454 (95.4%)	2468–2415 (95.4%)
With previous published dates	10	2503–2449 (95.4%)	2461–2411 (95.4%)

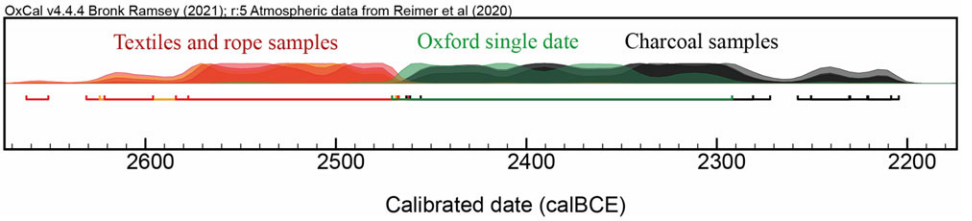

Figure 9. *Comparison of ^{14}C results obtained on Textiles and Rope samples (red), Charcoal samples (black), and the analysis carried out by the Oxford lab on a Papyrus sample from the British Museum (green).*

In order to establish an updated overview of our knowledge on the OK chronology, the model obtained so far has been integrated into a larger model, into which the temporal estimates of the accession dates of kings Den and Pepy II obtained in two previous studies (Quiles et al. 2023; Quiles and Tristant 2023) have also been incorporated. Figure 10 shows the three estimates as a comparison, estimates of the accession dates of Den and Pepy are in black, and the estimates for the *Accession date* and *end of Djedkare's reign* have been summarized in the red distribution.

The period between the end of the Djedkare's reign and the beginning of that of Pepy II is likely to be at least 80 years and could be as long as 150 years. It is more difficult to estimate the length of time between the beginning of Den's reign and that of Huni, mainly because of the lack of evidence of attestations for the kings of the 2nd and 3rd dynasties. Seidlmeyer (2006) estimates the duration of the 3rd dynasty at between 50 and 75 years, while Kahl (2006) acknowledges the lack of information for the 2nd dynasty but identifies at least the reign of Nynetjer as having lasted more than 30 years. Thus, a minimum of 100 yrs. We have attempted to simulate these two gaps by integrating *interval* tools between the beginning of the reigns of Den-Huni and the end of the reign of Djedkare and the beginning of the reign of Pepy II without determining prior probability distributions (Figure 11). The model obtained suggests the length between the end of Djedkare–Pepy II's accession date to be up to 148 yrs, thus perfectly consistent with literature. For the Den-Huni time interval, the distribution is much more flexible, reaching up to 299 years (172 years at 68.3 %), which shows that more constraints are needed in this part of the model to obtain accurate results.

Conclusion

This study aims to refine the chronology of King Djedkare (5th dynasty, Old Kingdom), based on archaeological material from the royal necropolis of South Saqqara. A series of ^{14}C radiocarbon analyses were carried out on material from four different monuments in the necropolis: the substructure of the pyramid of Djedkare, the portico of the pyramid complex of Setibhor and the tombs of Isesiankh

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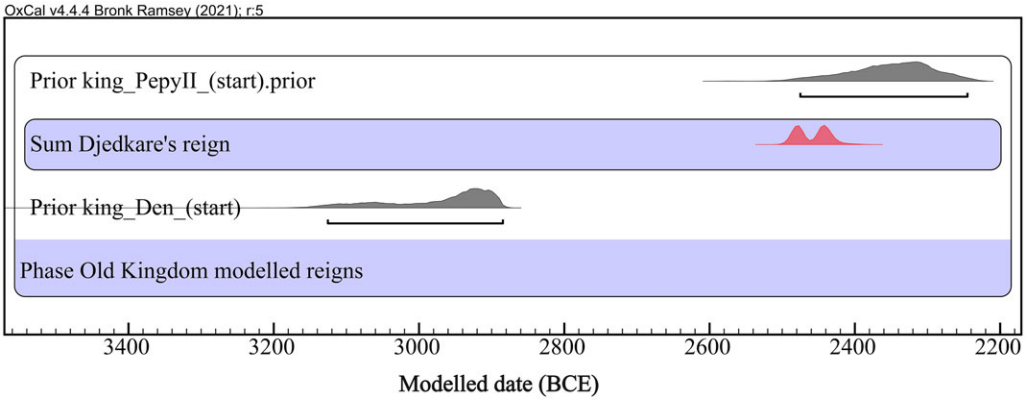

Figure 10. *Comparison of the modeled temporal estimates for the accession dates of king Den (from Quiles and Tristant 2023), king Pepy II (from Quiles et al. 2023), to the Sum of the modeled probability densities obtained for the Boundaries "Djedkare's accession date" and "Djedkare's end of reign.".*

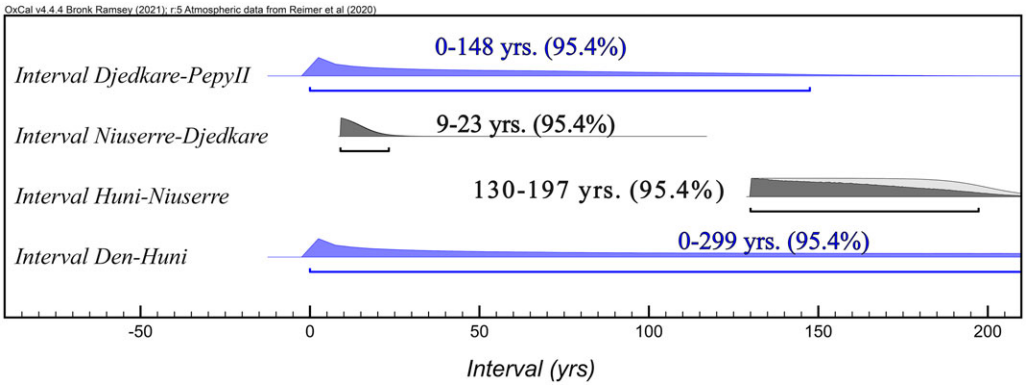

Figure 11. *Modeling of the intervals of years between the successive reigns. For Den-Huni and End Djedkare-Pepy II, no prior probability distribution was put in the model.*

and Khuwy. Other analyses associated with the earlier reigns of Huni and Niuserre were also included. Bayesian modeling of the ^{14}C results against the archaeological and historical evidence for the duration of Djedkare's reign suggests, in our state of knowledge, that his accession date was between 2503 and 2449 BCE (95.4%) which is slightly earlier than predicted in the current literature. Lastly, this result was compared with previous studies on other Old Kingdom and Early Dynastic kings (Den, Pepy II), in order to better assess the time elapsed between their reigns and thus better evaluate the duration of the Old Kingdom.

More constraints and analyses are now needed on samples associated with both Djedkare's reign and a larger number of different kings to be able to confirm these modelled results and refine them further, and thus propose a revised chronology of the Egyptian Old Kingdom.

Acknowledgments. This project has been funded by the French ANR project Meryt (ANR-19-CE27-0010) and the Ifao project "Chronologie," directed by Anita Quiles. The contextualisation of the samples from Djedkare's necropolis has been pursued within the project of the Czech Science Foundation no. 24-10886S "In Pharaoh's Shadow: Second Life of a Royal Monument." The research at Abusir South cemetery was supported by the "Cooperatio Programme, research area Archaeology," provided by Charles University, implemented at the Faculty of Arts of Charles University, and the non-investment subsidy no. 1-VEG 2024, MSMT 1232/2024-8. Authors are grateful to Adrian Travis for his thorough advice.

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Cite this article: Quiles A, Vymazalová H, Bárta M, and Megahed M (2025). Dating the Egyptian Old Kingdom: The reign of Djedkare (5th dynasty). *Radiocarbon* **67**, 155–175. https://doi.org/10.1017/RDC.2024.100