Hidden Text: Imaging and reading an ancient tablet encased in an envelope

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Abstract: A tablet from Nimrud, which is encased in an inscribed clay envelope IA5.074 (ND 3430), was imaged at the Australian Synchrotron Imaging Medical Beamline (IMBL). This confirmed that there was a cuneiform tablet inside the envelope, the text of which could be read. The paper provides the details of the imaging, describes the tomography, offers a reading of the enclosed tablet and comments on the variation between the text on the envelope and tablet and the significance of this for Assyrian contract law.

Introduction

In 1953, a collection of forty-seven tablets was found in a private residence at Nimrud, ancient Kalḫu (Biblical Calah), by archaeologist Sir Max Mallowan, who directed the excavation sponsored by the British School of Archaeology in Iraq. The residence belonged to a moneylender named Šamaš-šarru-uṣur who lived during the reign of King Ashurbanipal (668 – 627 BC). The house had been burned in antiquity, which by a fortunate accident fired the clay tablets, preserving them in impeccable condition (Wiseman 1953: 135). All the tablets were deeds recording the transactions relating to items from slaves to barley, in which Šamaš-šarru-uṣur was the creditor or buyer.

Donald Wiseman, the excavation's epigraphist, established that Šamaš-šarru-uṣur was a high-official (*ša rēši* commonly thought to be a eunuch) who probably owned land in Calah and the house where the tablets were discovered. He had a four-decade career as a moneylender like many of his wealthy contemporaries during the reign of Ashurbanipal (Wiseman 1953: 135). Stephanie Dalley and Nicholas Postgate (1984: 2) identified Šamaš-šarru-uṣur as the chariot driver of the crown prince.

Simonetta Ponchia (1990), Melanie Groß (2011) and Ran Zadok (2013) have undertaken the most recent significant studies of this archive. Zadok's study is particularly informative because he analysed the prosopographical data and assessed the nature of the documented transactions in order to come to an understanding of Šamaš-šarru-uṣur's career and his status in the Assyrian empire. We now know that Šamaš-šarru-uṣur was professionally active between the years of 671-619 BC and was indeed a high official of merit, who regularly engaged in business with significant members of the imperial and temple administrations at Calah (Zadok 2013: 401–405).

One of the tablet envelopes found in the archive, IA5.074 (ND 3430), is now in the collection of the Australian Institute of Archaeology (the Institute), a member

Figure 1: *The obverse of the clay envelope IA5.074 (ND 3430), 48 mm x 36 mm x 27 mm, that contains the tablet. Photo: the Institute.*

organisation of the consortium supporting Mallowan's excavation (Figure 1). Its locus was TW. 53, House III, Room 19, the House of the Merchant. The tablet arrived in Melbourne on 21 January 1955 as part of the 1954 division of finds from Nimrud (AIA Doc 5403).

The enclosed tablet

Although the envelope does not rattle when shaken, it was deemed to contain a tablet from the time of its discovery. Rather than break the envelope and risk destroying the inscription on it to gain access to the tablet it contains, imaging at the Australian Synchrotron's Imaging and Medical Beam Line (IMBL) and data processing at the Australian Nuclear Science and Technology Organisation (ANSTO) were undertaken to obtain an image of the enclosed tablet in October 2018.

The study of cuneiform tablets and envelopes has mostly been limited to surface studies, using photogrammetry, 3D modelling, and conventional X-ray micro-CT methods (Mara *et al*., 2010; Hameeuw and Willems, 2011; Lewis

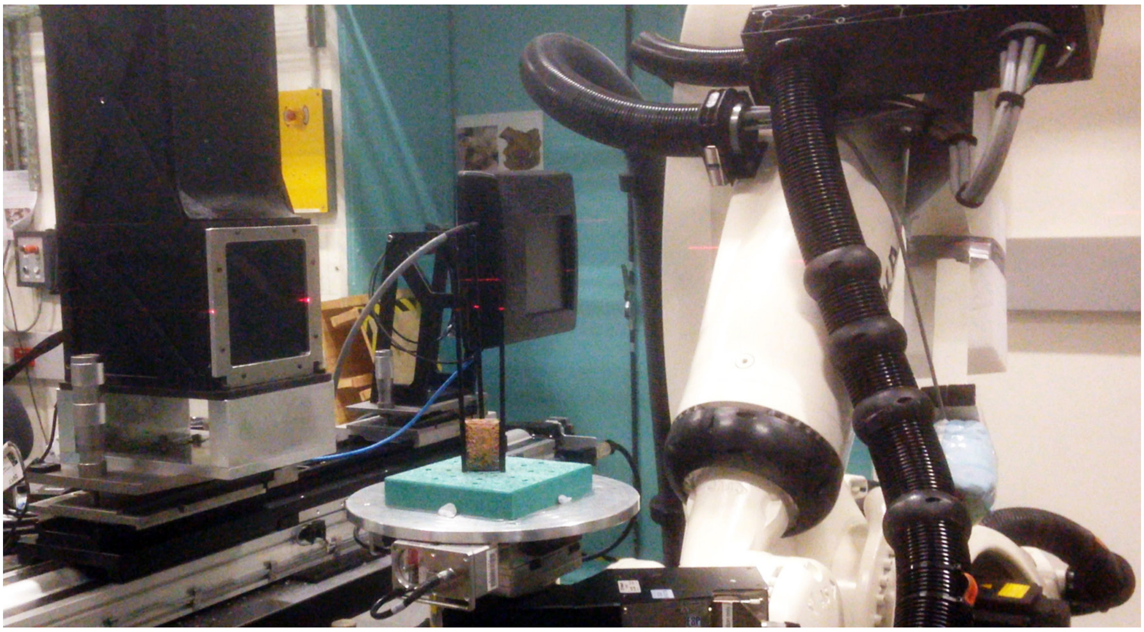


Figure 2: *Tablet on the rotation stage of the Australian Synchrotron IMBL. Photo: C.J. Davey.*

et al., 2015), and raster imaging (Massa *et al*. 2016) to visualise better or enhance etched scripts or seals. There is, to date, little published work on the internal study of cuneiform envelopes using tomographic methods, with the first X-ray CT study attained in 1994 by Nachum and Yaakov Applbaum. They presented their results at the Radiological Society of North America 84th Scientific Assembly and Annual Meeting at McCormick Place in 1998 and subsequently published a book chapter about their cuneiform and X-ray CT research (Applbaum & Applbaum 2005).

Additionally, Steven Dey noted the potential and limitations of his work with X-ray micro-CT and cuneiform tablets, where the results were used to create 3D printed replicas for further study (Dey 2018). Similar investigations have been done by the British Museum in 2017 by Dan O'Flynn[1], the University of Leiden (2018), Delft University of Technology (2018) and the Cincinnati Art Museum (2019). These works have been shared on social media outlets and do not yet appear in the peer-reviewed literature. We believe that this study reports the first application of synchrotron-based X-ray CT to the investigation of a cuneiform tablet and, more specifically, to reveal the hidden text of a cuneiform tablet that remains fully encased within its original, sealed clay envelope.

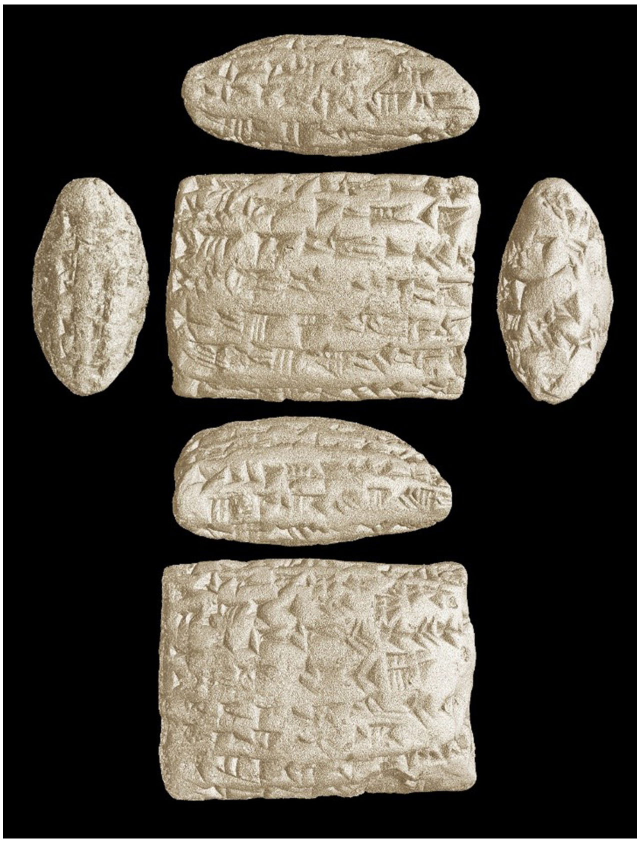
Method of analysis

This study utilised the Imaging and Medical Beamline (IMBL) at the Australian Nuclear Science and Technology Organisation's (ANSTO) Australian Synchrotron, Clayton, Victoria, Australia to image this specimen non-invasively.

X-rays were converted to visible photons and detected using 'Ruby', a Gadox/CsI(Tl)/$CdWO_4$ scintillator screen coupled with a PCO.edge sCMOS camera (16-bit, 2560 × 2160 pixels) and a Nikon Makro Planar 50 mm lens. The field-of-view was set to 25 mm high x 78 mm wide with a pixel size of 31.0 x 31.0 μm, monochromatic beam energy of 60 keV and sample-to-detector distance of 50 cm. A total of 1800 equally-spaced angle shadow-radiographs with an exposure length of 0.05 seconds was obtained every 0.10° as the sample was continuously rotated 180° about its vertical axis. One hundred dark (closed shutter) and beam profile (open shutter) images were obtained for calibration before initiating shadow-radiograph acquisition. Due to a limited beam height, two successive sets of radiographs were attained, with a vertical displacement of 25 mm between each tomographic dataset. Total time for the scan of 4040 projections (26 GB) was 5.2 min.

The raw 16-bit radiographs were stitched together and normalised relative to the beam calibration files using IMBL Stitch, the in-house software, and reconstructed using the X-TRACT [ref/CSIRO] available on Australian Synchrotron Computing Infrastructure (ASCI). The Gridrec reconstruction method was used to form a 16-bit, three-dimensional volume image of the sample. The reconstructed volume data were rendered and visualised using VGStudio Max 2.2 (Volume Graphics GmbH).

Segmentation of the inner tablet was achieved using VG Studio Max 2.2, using combinations of thresholding, region-growing and manual segmentation, to overcome the challenges of direct contact between portions of the inner tablet and outer envelope. This may have been due to the nature of how it was lying when the tablets were unintentionally baked, when the house was burned in antiquity. The segmented inner tablet was then volume-rendered and a clay tone overlayed for aesthetic purposes (Figure 3).



D
F A E
B
C

Figure 3: *The enclosed tablet of IA5.074 (ND 3430) rendered from synchrotron X-ray CT imaging. The tablet is inscribed on sides A, B, C, D and F. Side E is inscribed with cuneiform signs that have run over from sides A and C. Images were made using VG Studio Max 2.2 and enhanced and arranged in Adobe Photoshop.*

A transliteration and translation of the enclosed tablet

Obverse (AE)	1	é 2 anše *ina u-šal-li*	An estate of 2 homers on the river-flats
	2	*gab-di* ^{m}sanga-15	adjoining (that of) Sangî-Issār;
	3	é 2 anše *ina mu-li*	an estate of 2 homers on high grounds
	4	*gab-di* kaskal ^{uru}nina	adjoining the Nineveh Road.
	5	pab$^{!}$ é 4 anše a.šà	A total of 4 homers of fields.
	6	*ku-um ru-bé-e šá* kù.babbar	Instead of interest on the silver,
Lower edge (B)	7	$^{m.d}$*šá-maš*-man-pab kú	Šamaš-šarru-uṣur will have usufruct (of the pledged land).
	8	3 *me-re-še* 3 *kar-ap-ḫi*	Three (years) cultivated (and) three fallow:
Reverse (C)	9	pab 6 mu.an.na kú	a total of six years he will have usufruct.
	10	*ina* u$_{4}$*-me šá* kù.babbar sum-*nu*	When he pays back the silver
	11	a.šà-*šú u-še-ṣa*	he will redeem his field(s).
	12	nu *ši-pi-še* nu še *nu-sa-ḫi*	There will be no straw or corn tax.
	13	iti.bár u$_{4}$ 28	28th Nisannu,
	14	*lim-me* ^{m}en-kaskal-kur-*u-a*	Eponym of Bēl-Ḫarran-šadû'a.
	15	igi ^{m}*ṣil*-en-*dal- *	Before Ṣīl-Bēl-dalli,
	16	igi ^{m}sanga$^{!}$-15 igi $^{m.d}$pa-ka-pab$^{!}$-pab	before Sangî-Issār, before Nabû-pī-aḫi-uṣur;
Upper edge (D)	17	*ina* igi ^{m}*qur-d*[*i*-^{d}u.g]ur	at the disposal of Qurdi-Nergal,
	18	*ina* igi ^{m}gig-šà-dingir	at the disposal of Limraṣ-libbi-ili;
Left edge (F)	19	igi $^{m.d}$pa-zu	before Nabû-lē'i,
	20	igi $^{m.uru}$*arba-ìl-a-a*	before Arbailāiu.

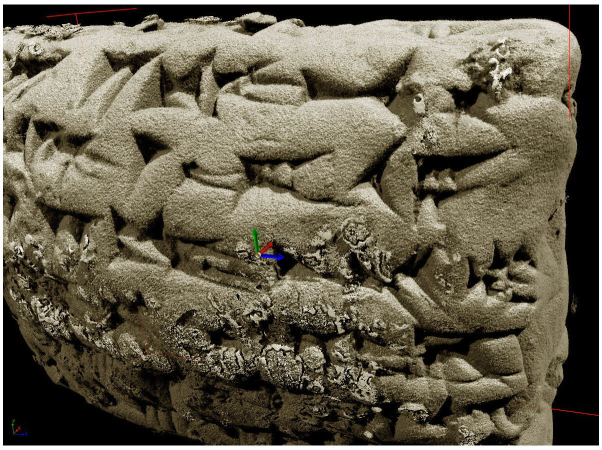


Figure 4: *The end of Line 1 of the enclosed tablet, which needed more detailed segmentation of the reconstructed tomographic data.*

Comments on the enclosed tablet text

Line 1: Close study of the end of line 1 in Figure 3 is not possible because it is oblique in the traditional fat-cross representation and indistinct due to the challenge of segmenting that part of the tablet, which is in direct and intimate contact with the envelope. A more precise segmentation of that region, shown in Figure 4, was completed and achievable due to the high-resolution and inherent edge-enhancement of the synchrotron X-ray CT data.. This clearly revealed the tablet's text, which was found to have a highly unusual writing of *ušallu* with a U-sign over the expected Ú-sign. Our research suggests that this is the only attested occurrence of this orthography. If this reading is correct, then the scribe most likely elected for a rare, purely phonological writing of *ušallu* utilising the much smaller U-sign over the normal and longer Ú-sign because of the lack of space on the corner of the tablet. The parallel section of text on the envelope in line 6 (see below) is obscured by surface damage, but the traces fit Postgate's reading in Herbordt et al. (forthcoming: no. 77) of the signs on the envelope as *a.š[à ina] ú-šal-li*. We follow Postgate's reading in our edition below.

Line 2: Singi-Issār's name is written without the divine determinative in this line, but in line 7 of the envelope the determinative sign is present.

Line 5: The word for field is written a.šà here, while on the envelope it is a.šà.ga.

Line 10: The scribe has written a *šá* on the tablet, where a *ša* appears on the envelope (line 15).

Line 10–11: There is a difference in grammatical number in the text of the tablet. Both the verb (*u-še-ṣa*) and the possessive pronominal suffix (*-šu*) are singular, whereas in the text of the envelope (lines 15–17) they are in the plural (*-šu-nu*, *u-še-ṣu-u*). The writing of sum-*nu* is unclear whether it is singular or plural, but has been understood as singular in the present context. It is unclear why the scribe did this since there were two debtors for this contract listed in lines 17–18 of the tablet and lines 1–2 of the envelope.

Line 12: The negative particle is written with the logogram 'nu' here, while on the envelope (line 14) it is written in Akkadian, *lā*.

Line 15: igi ᵐ*ṣil*-en-*dal*-<*li*>: The scribe has not written the LI-sign to finish the name despite the ample space on the tablet.

Line 16–20: The witness list is in a different order from the envelope and has omitted Bēl-dūri. What is more curious is that the list is interrupted in lines 17–18 by the names of the debtors, who are recorded with their seals in lines 1–2 of the envelope (see below). The debtors are identified with *ina panī*(igi), which equates to *ina panīšunu* in line 4 of the envelope. It is unclear why the scribe did this but it could be that he originally finished the text in line18 neatly at the bottom of the reverse, and then as an afterthought, or by request, the he added the names of some of the remaining witnesses on the left edge, but ran out of space for Bēl-dūri.

The envelope

The envelope has two round stamp seals on the obverse and writing on the obverse, reverse and the edges. The text is clear but the seals are indistinct and were the subject of Reflectance Transformation Imaging (RTI) at the Institute in 2016 (Saunders *et al.* 2016: 46). Algorithmic Rendering and specular enhancement revealed the seals to be apparently identical images of a running quadruped such as a deer stag or oryx (Figure 6A). This is all the more interesting because the first two lines of the text on the envelope (see below) state that the seal impressions belonged to different individuals, Qurdi-Nergal and Limraṣ-libbi-ili.

The imaging at the IMBL also has the capacity to render the surface of the envelope. The result for the seals is shown in Figure 6B and can be seen to be comparable with the RTI image. Open source viewers are available for both RTI and tomographic data to manipulate the light direction when examining the image. Cost of equipment for data acquisition and processing is another issue. RTI can be undertaken by anyone with a camera, flashlight, computer and expertise but it is, of course, limited to surface analysis.

Comments on the envelope text

The transliteration and translation of the envelope text is opposite and has the following explanatory comment:

Line 15: ŠE-⸢x⸣: The reading of these signs is not clear. Postgate (Herbordt et al. forthcoming) has interpreted the traces as še.k[i.u]d? for the logogram kislaḫ, 'threshing floor'. We have tentatively followed Postgate's translation but leave the reading of the traces open to interpretation.

Figure 5: *The external surface of the envelope IA5.074 (ND3430).*

The envelope text

Obverse	1	^{na4}kišib ^{m}*qur-di-*^{d}u.gur	Seal of Qurdi-Nergal.
	2	^{na4}kišib ^{m}gig-šà-dingir	Seal of Limraṣ-libbi-ili.
	3	10 gín^{meš} kù.babbar luḫ.u	10 shekels of refined silver
		(Two seal impressions)	
	4	*ša* $^{m.d}$*šá-maš*-man-pab *ina pa-ni-šú-nu*	belonging to Šamaš-šarru-uṣur, at their disposal,
	5	*ku-um ru-bé-e ša* kù.babbar	instead of interest on the silver
	6	é 2 anše ˹a˺.š[à *ina*] *ú-šal-li*	an estate of 2 homers of field
	7	*gab-di* ^{m}sanga-^{d}15	adjoining Sangi-Issār;
Reverse	8	é 2 anše *ina mu-li-e*/*gab-di* kaskal ^{uru}nina	an estate of 2 homers of high ground adjoining the Nineveh Road.
	9	pab 4 anše a.šà.ga	A total of 4 homers of field
	10	*ina* uru.še *ú-sa-a-ni*	in the village of Usāni.
	11	3 *me-re-še* 3 *kar-ap-ḫi*	3 (years) cultivated (and) 3 fallow;
	12	pab 6 mu.an.na^{meš} kú	a total of 6 years they will have usufruct.
	13	*la še-pi-ši la* še *nu-sa-ḫi*	There will not be straw nor corn taxes.
	14	*ina* u$_{4}$*-me ša* kù.babbar *ina* ugu	[14–15] When the silver is deposited on the
	15	ŠE-˹x˺ *i-šak-<kan>-u-ni*	*threshing floor*$^{?}$
	16	a.šà-*šú-nu u-še-ṣu-u*	they will redeem their fields.
	17	iti.bár u$_{4}$.28.kam	28th of Nisan,
	18	*lim-mu* ^{m}en-kaskal-kur-*u-a*	Eponym of Bēl-Ḫarrān-šadû'a.
	19	igi ^{m}*ṣil*-en-*dal-li*	Before Ṣīl-bēl-dalli,
	20	igi $^{m.d}$pa-zu	before Nabû-lē'i,
Left edge	21	igi $^{m.uru}$*arba-ìl-a-a*	before Arbailāiu,
	22	igi $^{m.d}$pa-ka-pab-pab	before Nabû-pī-aḫi-uṣur,
	23	igi ^{m}sanga-15	before Sangî-Issār,
	24	igi ^{m}en-bàd	before Bēl-dūri.

Figure 6A: *Inverted image of seals on obverse of tablet, IA5.074 (ND 3430) taken with RTI and processed as a PTM composite image rendered using specular enhancement. From Saunders, Collmann and Siddall (2016).*

Figure 6B: *Inverted image of seals on obverse of tablet, IA5.074 (ND 3430). VG studio Max 3.0 was used to create this visualisation of the seals, using directional light sources and shadow enhancers (2019).*

Discussion

The text on the tablet records the same contract for a pledge of land as is inscribed on its envelope. However, the text of the tablet is much shorter than that of the envelope and the arrangement of the contract is different from that on the envelope.

The relationship between the texts on the tablet and the envelope has the potential to illuminate the practice of Neo-Assyrian contract law. According to Postgate it is not uncommon for Neo-Assyrian contracts to include more details in the version on the envelope than that on the enclosed tablet (Postgate 1976: 4). This appears to be the case here.

The text on the envelope is a far fuller record of the contract than that inscribed on the inner tablet. A comparison of the two versions of the contract reveals the following:

1. The text of the tablet is formulated more as a land pledge with associated silver loan, whereas the envelope is set out as a silver loan with associated land pledge.

2. As noted in the comments on the tablet, there is orthographic variation between the two texts.

3. There is less information about the location of the fields in the text on the inner tablet.

The relationship between the text on the envelope and the enclosed tablet has implications for the practice of contract law in Assyrian society. A full treatment of the relationship between tablets and envelopes is well beyond the scope of this paper but we postulate some possible reasons for the practice. The envelope text, with the seal impressions of the two debtors, appears to be the formal version of the contract, while the enclosed tablet has an abridged version of the contract that includes the essential information to be used in the event of a dispute between the parties. Should a dispute occur and the envelope be unreadable because of damage, accidental or intentional, a city or imperial official could open the envelope to check the details of the contract according to the tablet. Hence, the enclosed tablet was insurance against accidental damage or corrupt alteration of the text on the sun-dried envelope, the principal contract between parties. It is also possible that the tablet might have had an archival purpose. Had the terms of the contract been fulfilled and the seals on the envelope, together with the envelope itself, be destroyed, then the tablet might have been kept by one of the parties as proof that the contract had been fulfilled.

The relationship between the texts of the tablet and envelope, as proposed here, is not straight forward when one considers the process of making the physical objects. Naturally, the tablet had to be inscribed before the envelope, which means the shorthand version was composed before the full text of the contract. Such a process seems counter-intuitive, but the materials dictate that this had to be order of composition.

In any case, the very existence of this tablet and envelope surviving intact up to the time of the house fire indicates that the obligations outlined in the contract were outstanding. Had the silver been repaid at the very least, the envelope would have been destroyed (Radner 1995: 68).

Concluding comments

Finally, it is appropriate to comment on the cost and accessibility for this technique. Merit-based access to the Australian Synchrotron is free, with proposals for consideration due 3-times a year.

If access is sought outside the peer-review process, IMBL time is charged at $A650/h for use of the beam, plus $A300/h for staff time (included data acquisition, analysis and image processing). Basically, if a scan takes 5-7 minutes, then approximately 10-12 specimens can be scanned per hour at a facility cost of $A55-60 each, ignoring time for initial instrument setup.

The main issue for this research is the processing of the scanned data. Not many people are trained in the software used to visualise computer-tomography datasets and few are skilled enough to segment an image of this type. As described above, the challenge of dealing with curved surfaces of the tablet and the envelope occasionally in contact is not straight forward and is potentially very time consuming. The tomography is the limiting aspect of this form of research, with highly-trained instrument staff necessary for determining optimum CT scan quality, while the participation and training of research students in tomographic segmentation is essential for fast turnaround of processed data and building future expertise in tomographic data rendering, a skill that is increasingly in demand. However, the output can exceed that presented in this paper. A 3D directionally lit video sequence rolling the tablet from the first line to the last is possible using this technique.

It is understood that this is the first occasion a cuneiform envelope has been imaged by a synchrotron. The clarity of the text of the enclosed tablet obtained by this approach has provided an insight into the practice of Assyrian contract law.

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Endnotes:

1 Oflynn Dan (2017, December 21) 'With X-ray CT imaging, we were able to virtually strip back the clay envelope surrounding this Cuneiform tablet, allowing us to read text that hasn't been seen in over 4000 years – without damaging the artefact @britishmuseum @JonTaylor_BM' [Twitter Post] retrieved from *https://twitter.com/dan_oflynn/status/943816144061976577*