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Imaging the inside of clay tablets: the state so far

Jana Mynářová, Institute of Comparative Linguistics, Charles University, jana.mynarova@ff.cuni.cz
Jaroslav Valach, Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences, valach@itam.cas.cz
Daniel Vavřík, Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences, vavrik@itam.cas.cz

Securing Data in Mesopotamia: New Technologie for Secured Cuneiform Texts. Hybrid. 14–18 March 2022.
Lorentz Center@Oort, Leiden

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Research Objectives

- collection of cuneiform tablets kept at the Faculty of Arts, Charles University consists of ca. 400 Old Assyrian tablets from the excavations of Bedřich Hrozný at Kanesh (present-day Kültepe, Turkey);
- a very homogeneous collection, almost exclusively from a single archaeological site, dates from a narrowly defined period between 1950 and 1837 BC;
- mostly correspondence exchanged between merchants involved in trade relations between Assur and central Anatolia;
- geographical and temporal identification is not always secure;
- question of whether any conclusions can be drawn from the results of X-ray computed tomography together with X-ray fluorescence analysis, with regard to the possibility of identifying the site of production as well as production technology

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- "The Analysis, Description and Archiving of Comprehensive Information Concerning the Properties of Cultural Heritage Artifacts and Usage of Such Data in Restoration, Conservation and Research," (DG16P02M022)

- Funded by the Ministry of Culture of the Czech Republic ("Applied Research and Development of National and Cultural Identity Programme"), 2016-2020

- National Museum, Prague
- Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences
- Faculty of Arts, Charles University

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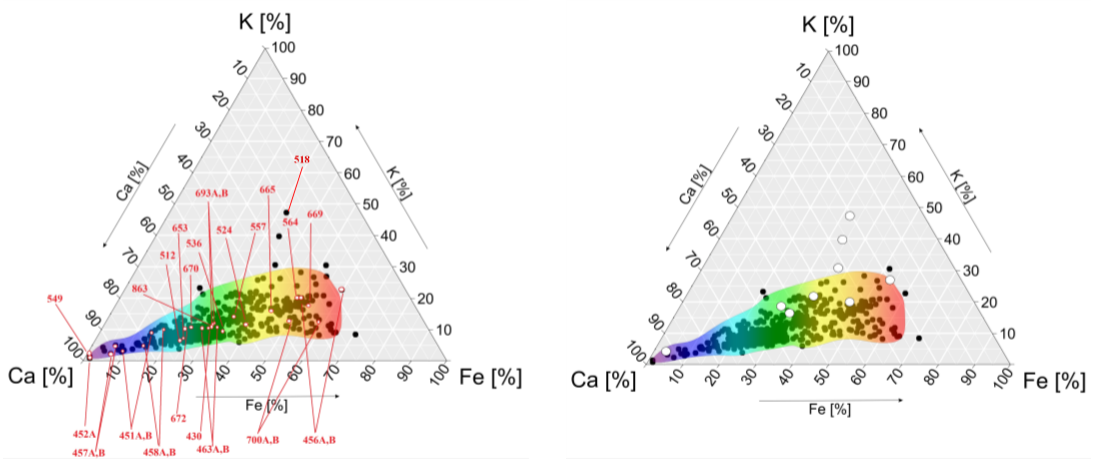
Elemental micro X-ray fluorescence analysis of cuneiform tablets

(Measuring, National Museum)

- Mobile energy dispersive spectroscope Artax 400, Bruker AXS GmbH used
- Air-cooled X-ray tube, molybdenum anode, max. voltage 50 kV and max. power 40 W.
- Analyzed area in dimensions from approx. 0.1 to several millimeters. The analyzed thickness depends on the properties of the material under investigation, in our case it has units of micrometers.



Element	Na	Mg	Al	Si	P	K	Ca	Ti	Mn	Fe
I463A	0.02	5.10	5.72	21.13	0.36	1.30	10.27	0.43	0.19	5.90
I463B	0.06	7.92	5.10	18.73	0.82	1.27	10.12	0.35	0.38	4.33
I549	2.76	1.66	1.45	5.42	2.26	0.74	50.01	0.05	0.09	0.60

- For the examined tablets, a total of 30 points were measured each time on the obverse and reverse, the results were averaged.
- As for the classification of the materials: the triplets potassium-calcium-iron and calcium-aluminum-magnesium were alternatively selected as representative elements for the three-element (ternary) diagram.

On the left: standard Fe-Ca-K ternary diagram of all tablets from the Bedřich Hrozný collection. The values are normalized for each tablet separately

The numbers indicate the tomographed tablets.
On the right, the white circles indicate the fakes

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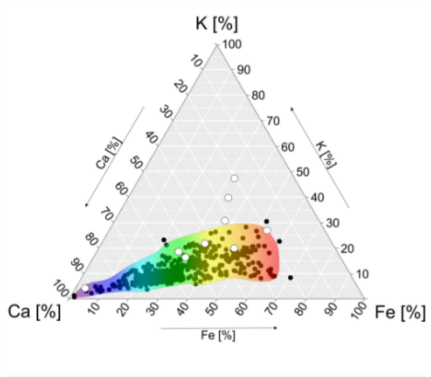
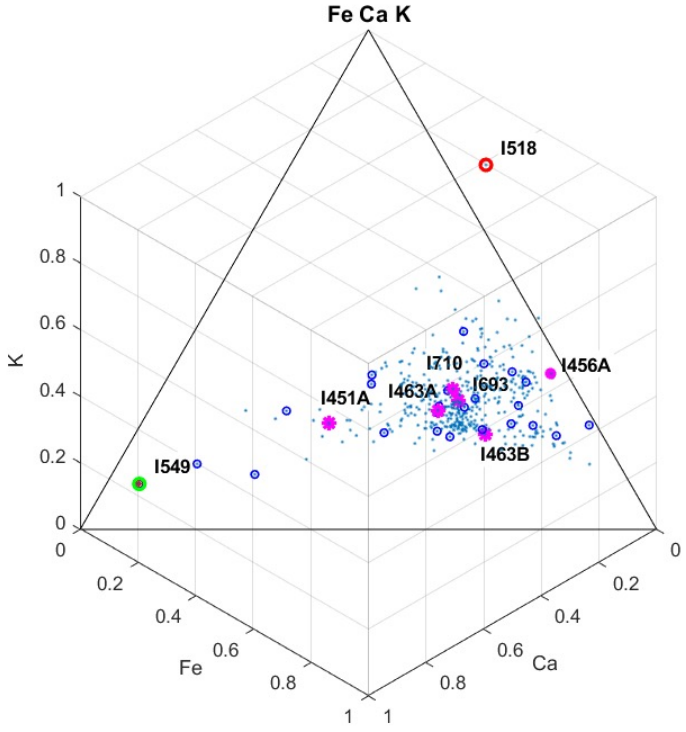
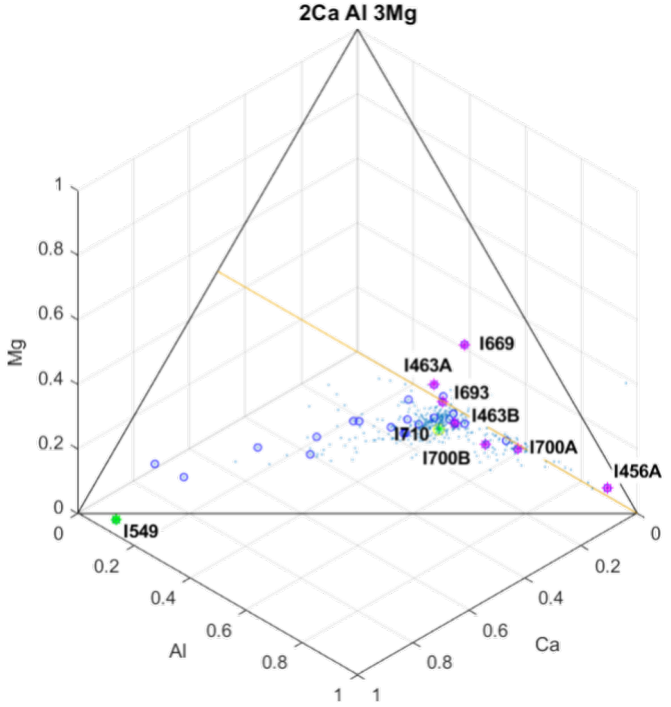
Elemental micro X-ray fluorescence analysis of cuneiform tablets (different representation of the ternary diagram)







On the left: a three-dimensional depiction of the standard Fe-Ca-K ternary diagram, I 518 is a falsum. Tablets in the 2Ca-Al-3Mg space on the right: the yellow line corresponds to dolomitic limestone.
Thanks to an independent orientation measuring* by mobile Raman spectroscopy, it was verified that the limestone in the analysed tablets is present mainly in the form of carbonate (calcite), while the presence of clay minerals was also noted.

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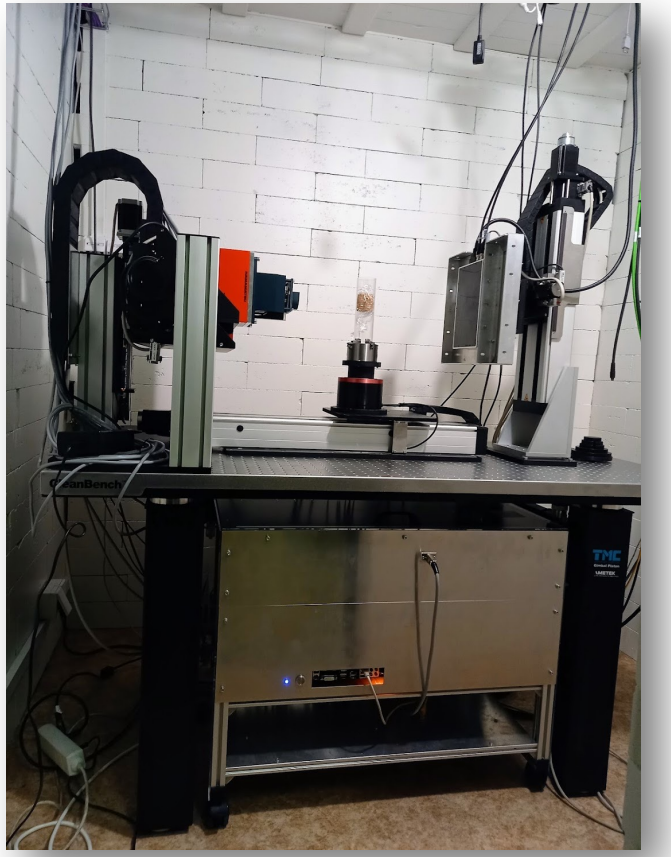
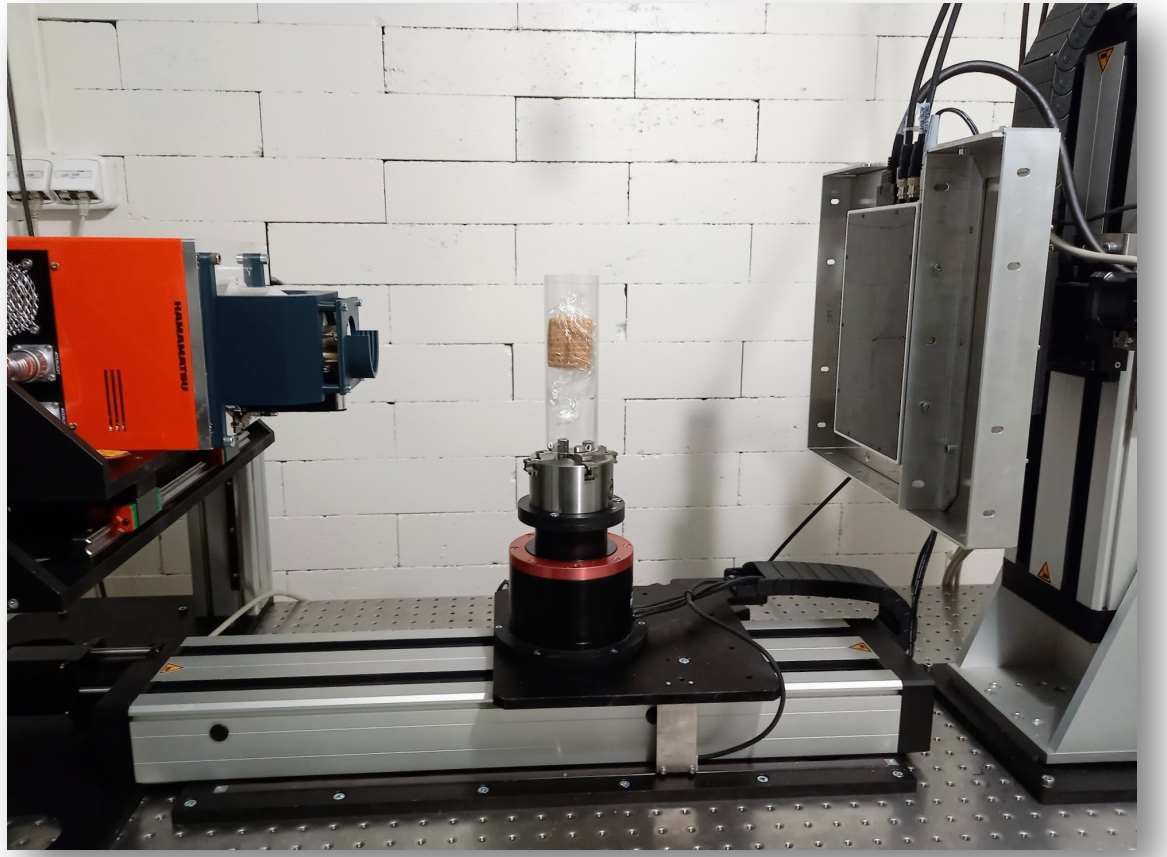
Tomographic Survey





- XWT-240-SE (X-Ray WorX, Germany), @150 kV, 20W on target
- Flat panel detector Dexela 1512 (Varex, USA), 145.4 × 114.9 mm, 1944 x 1536 pixels, pixel 74.8 µm
- Geometric magnification 1.9x, voxel ~40 mm

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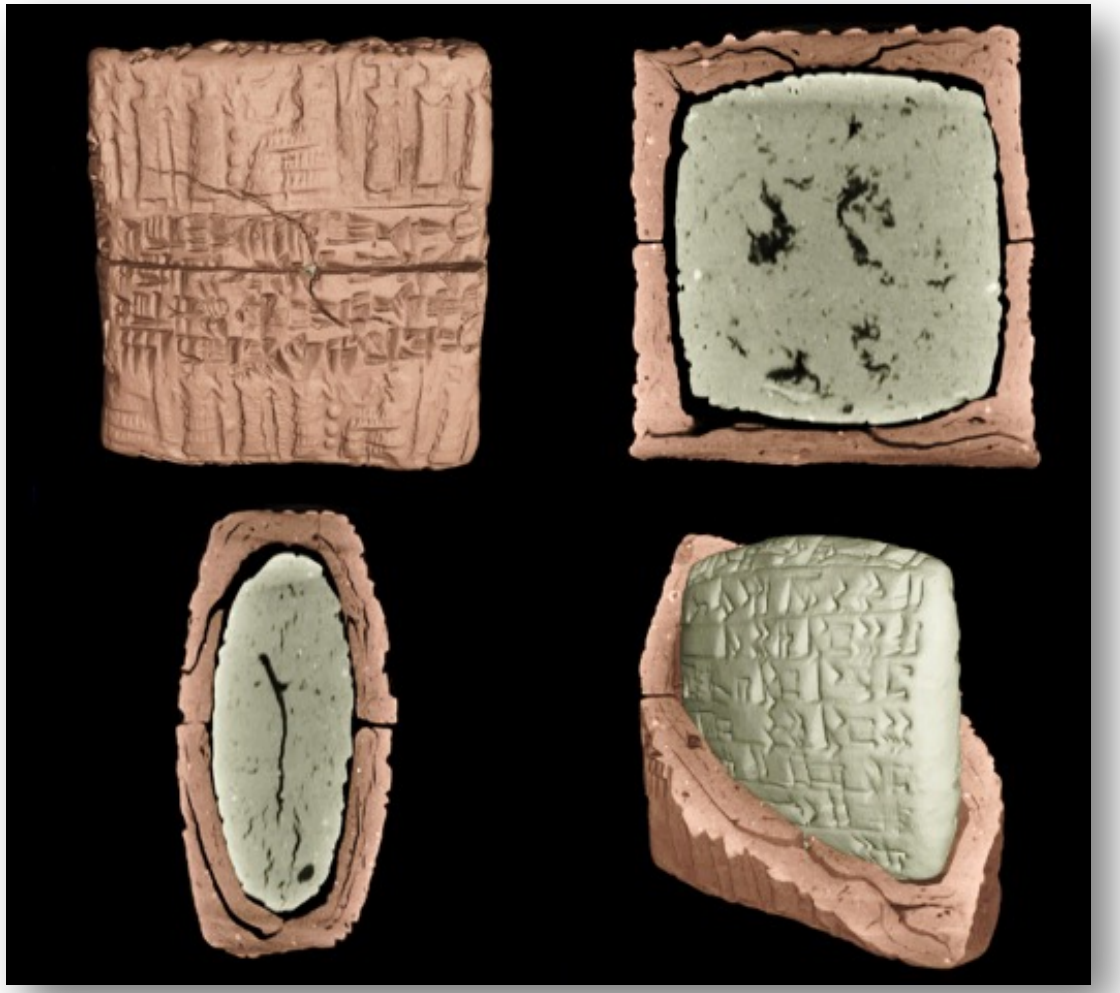
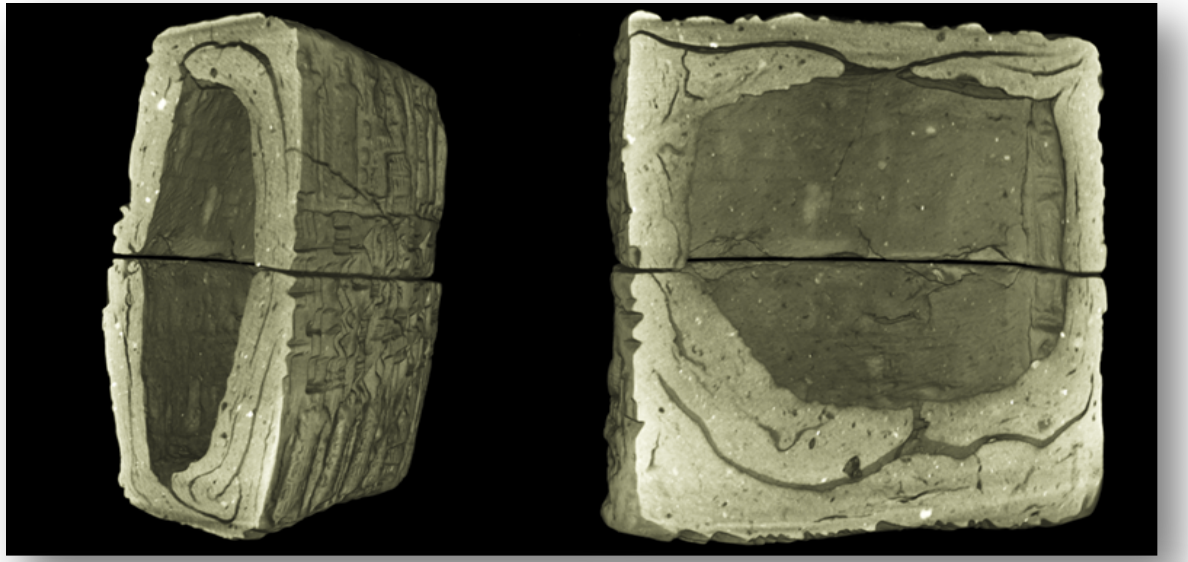
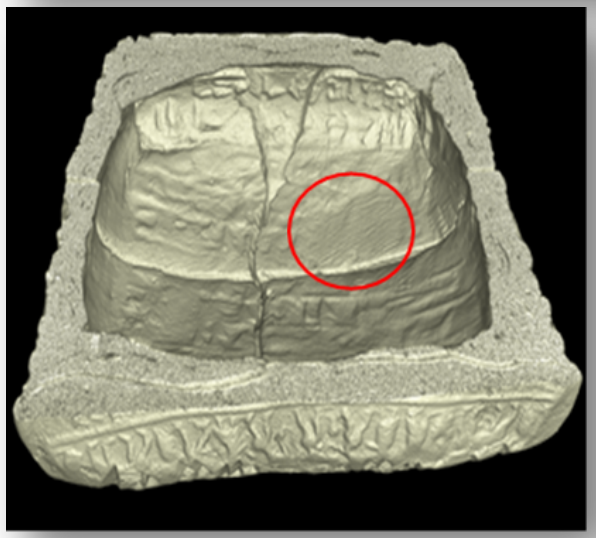
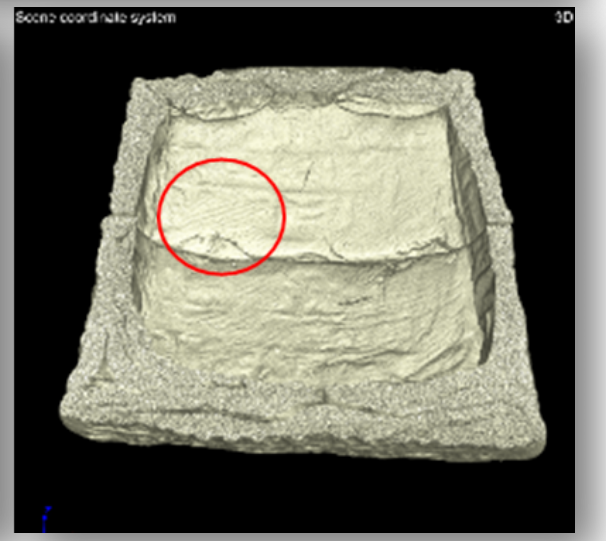
Tomographic Survey (I 463)









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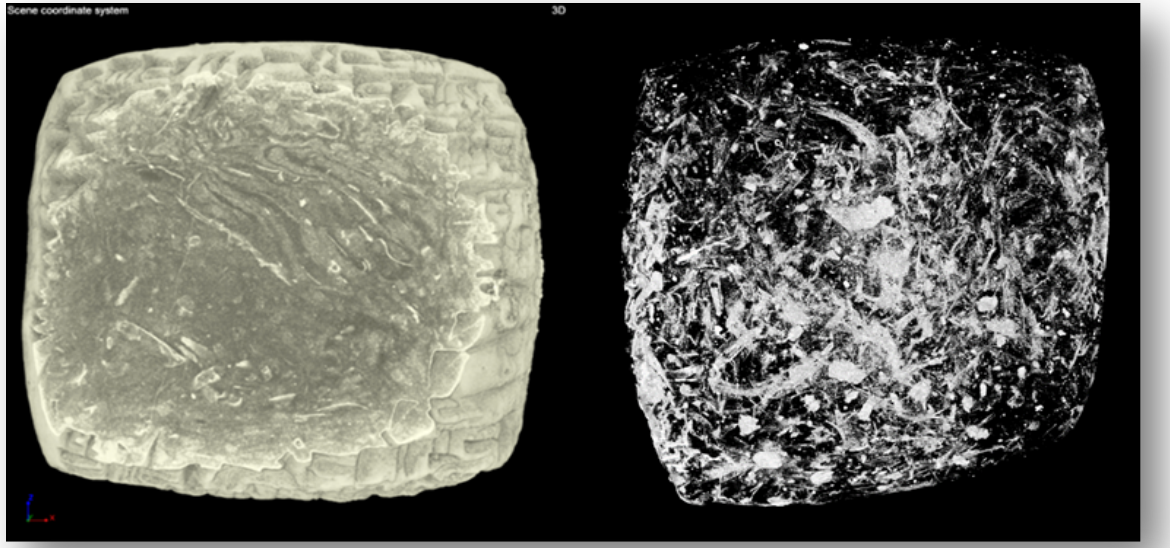
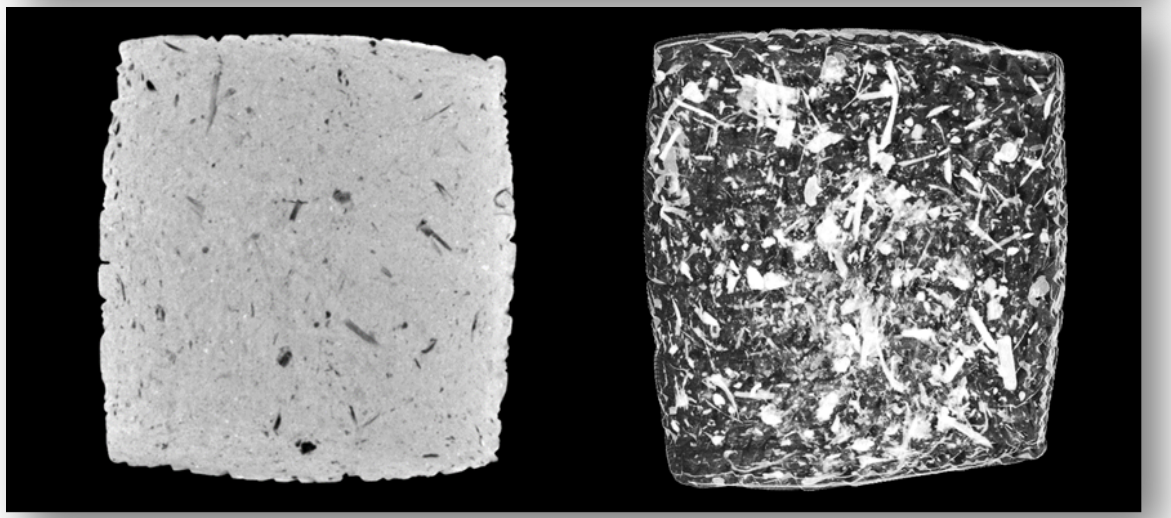
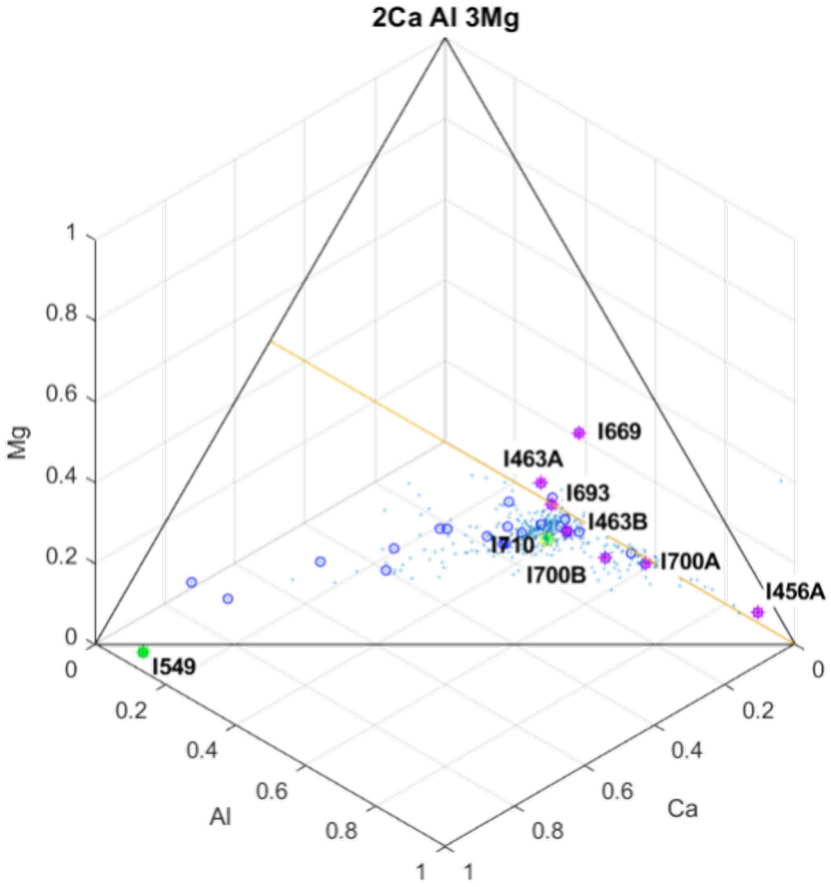
Tomographic Survey (I 549 and I 693)





I 549, extremely high Ca, filled cavities; "negative"

I 693, elementally average, grasses apparently a local tradition



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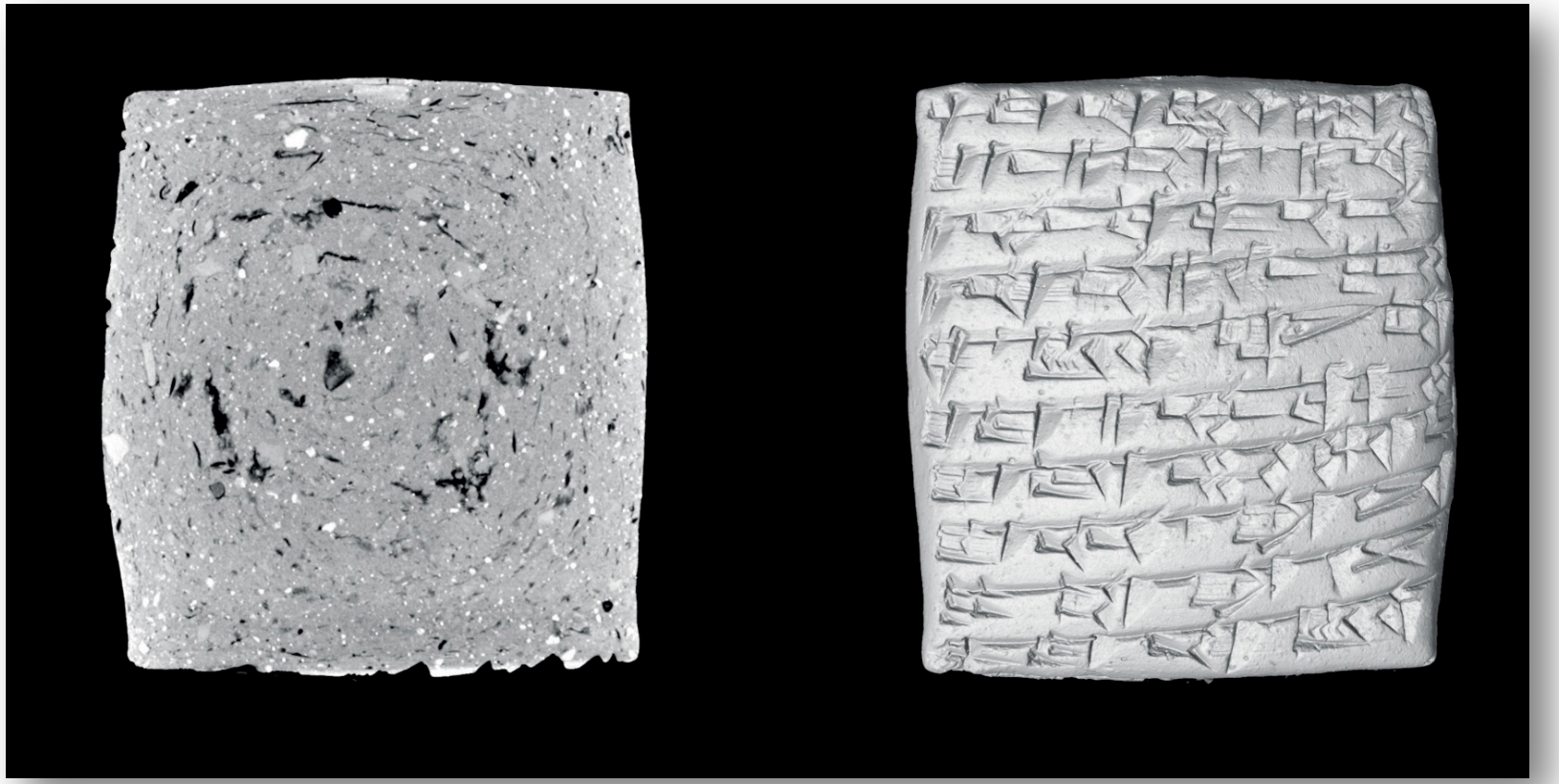
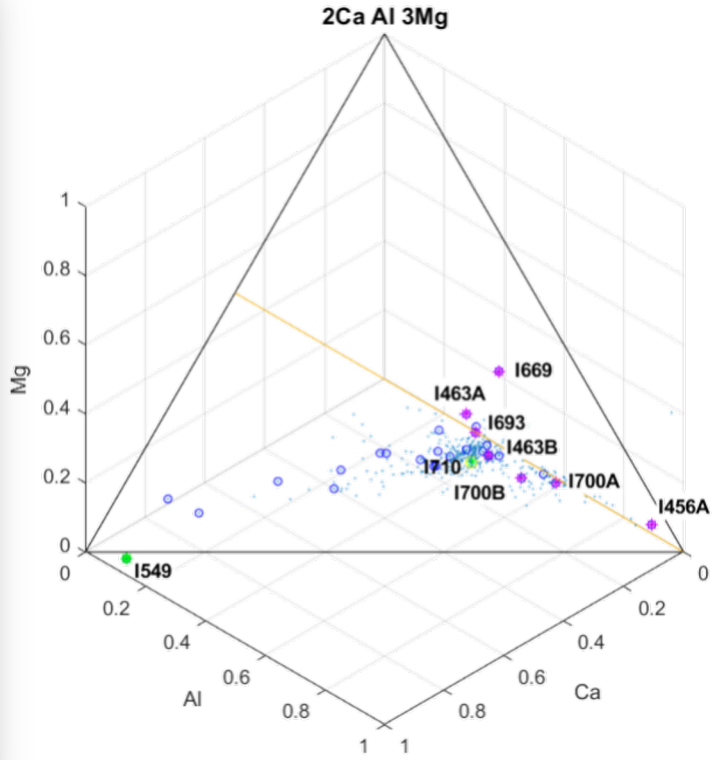
Tomographic Survey (I 456A)





I 456A, on the left: method of production of the semi-finished product

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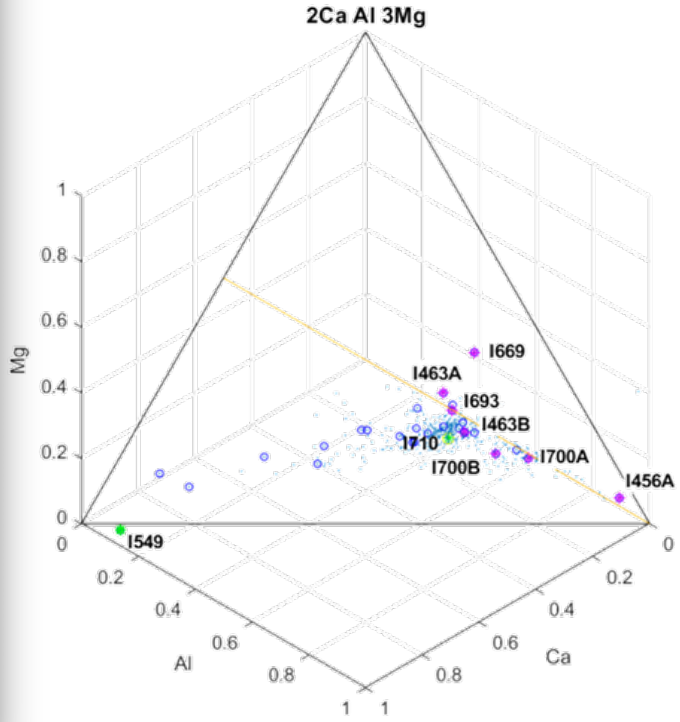
Tomographic Survey (I 669)



I 669, characterised by the highest amount of magnesium. It shows no temper, the amount of cracks is lower compared to other tablets

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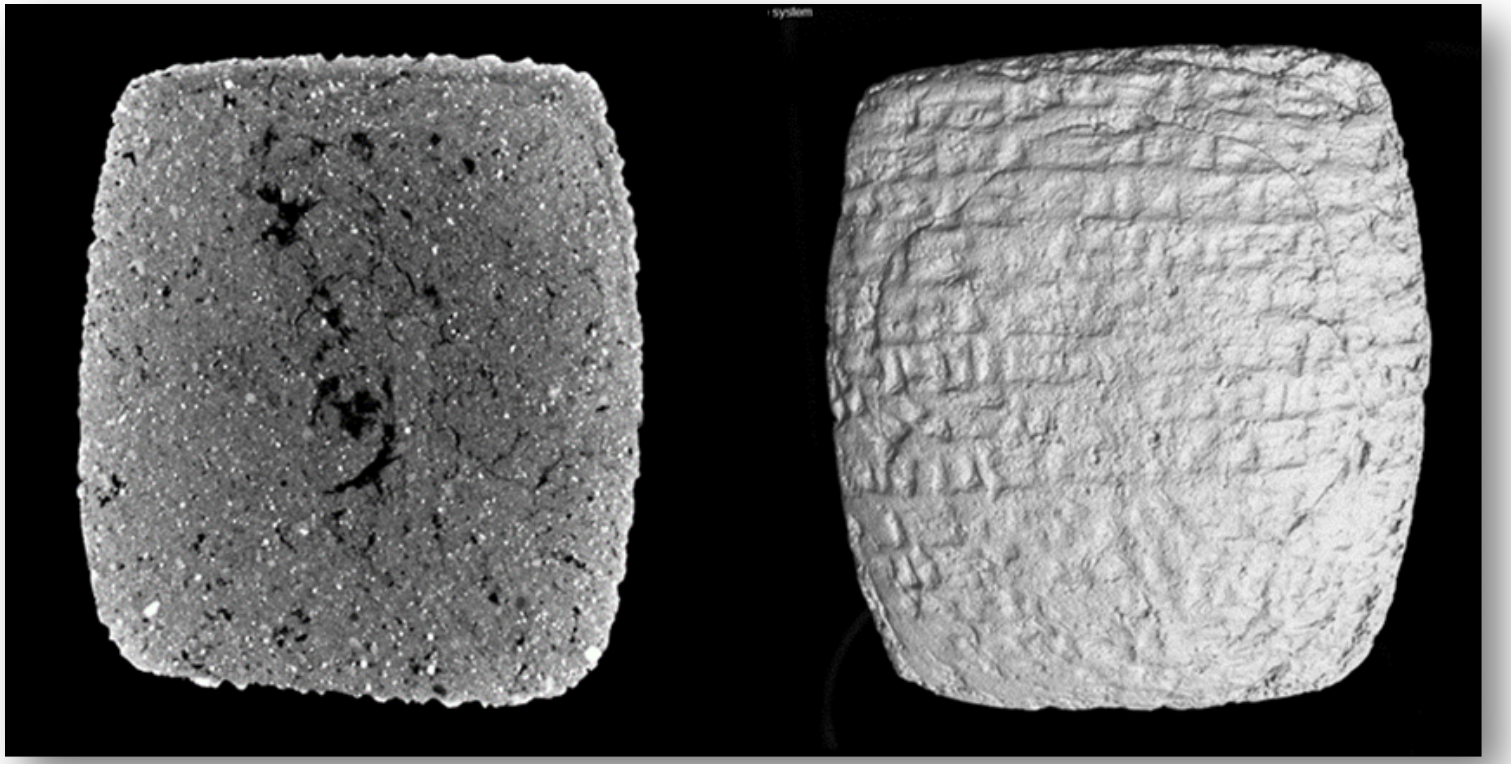
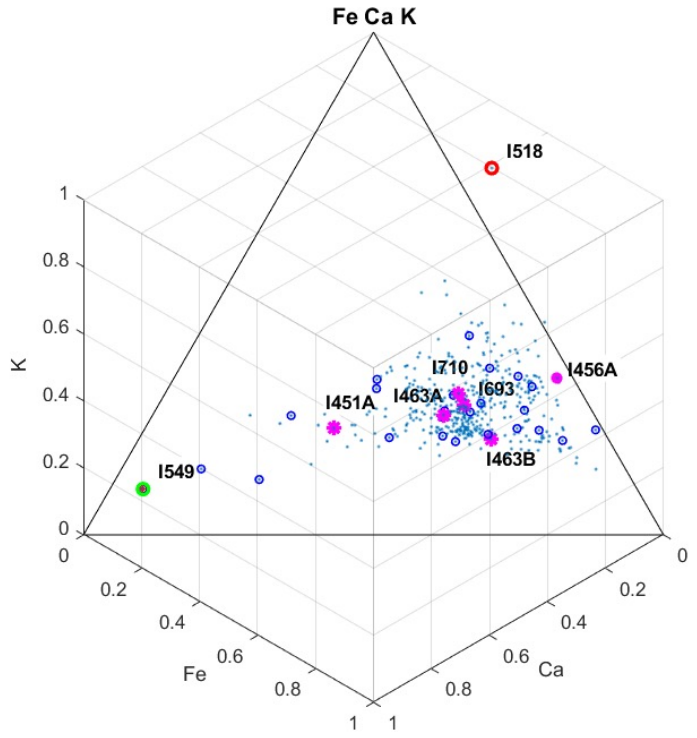
Tomographic Survey (I 518)





I 518 was identified as a counterfeit mainly by the impressions that only resemble a cuneiform script. The outline of the added material can be seen on the outer surface on the right.

The elemental composition is markedly different from the other tablets.

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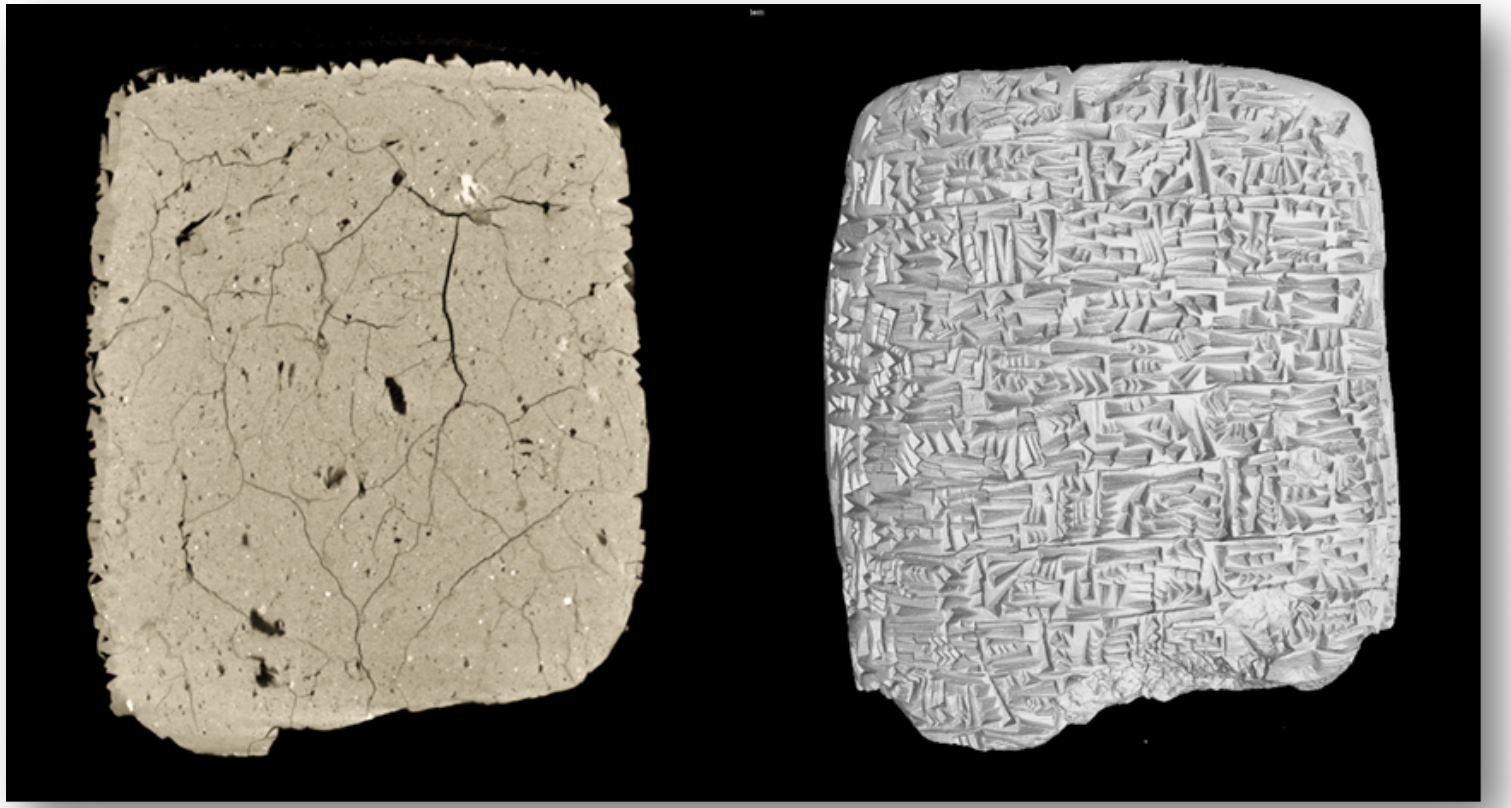
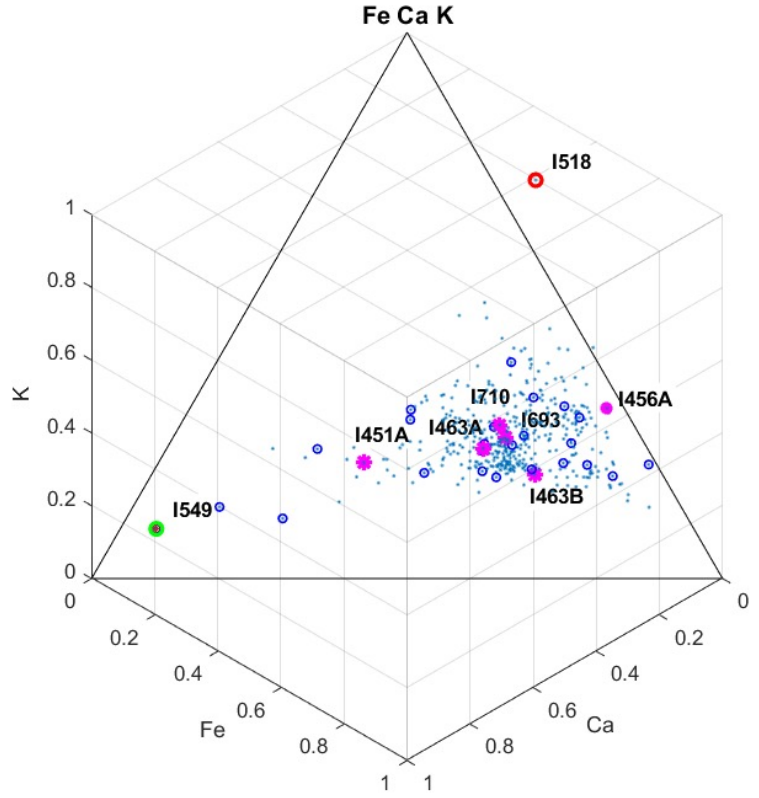
Tomographic Survey (I 710)





I 710, the shape of cuneiform is only hinted at, it looks like it has been carved rather than impressed into the surface. In terms of elemental composition it does not stand out, the same holds for the internal structure, a similar network of fine cracks has been observed in the original tablets.

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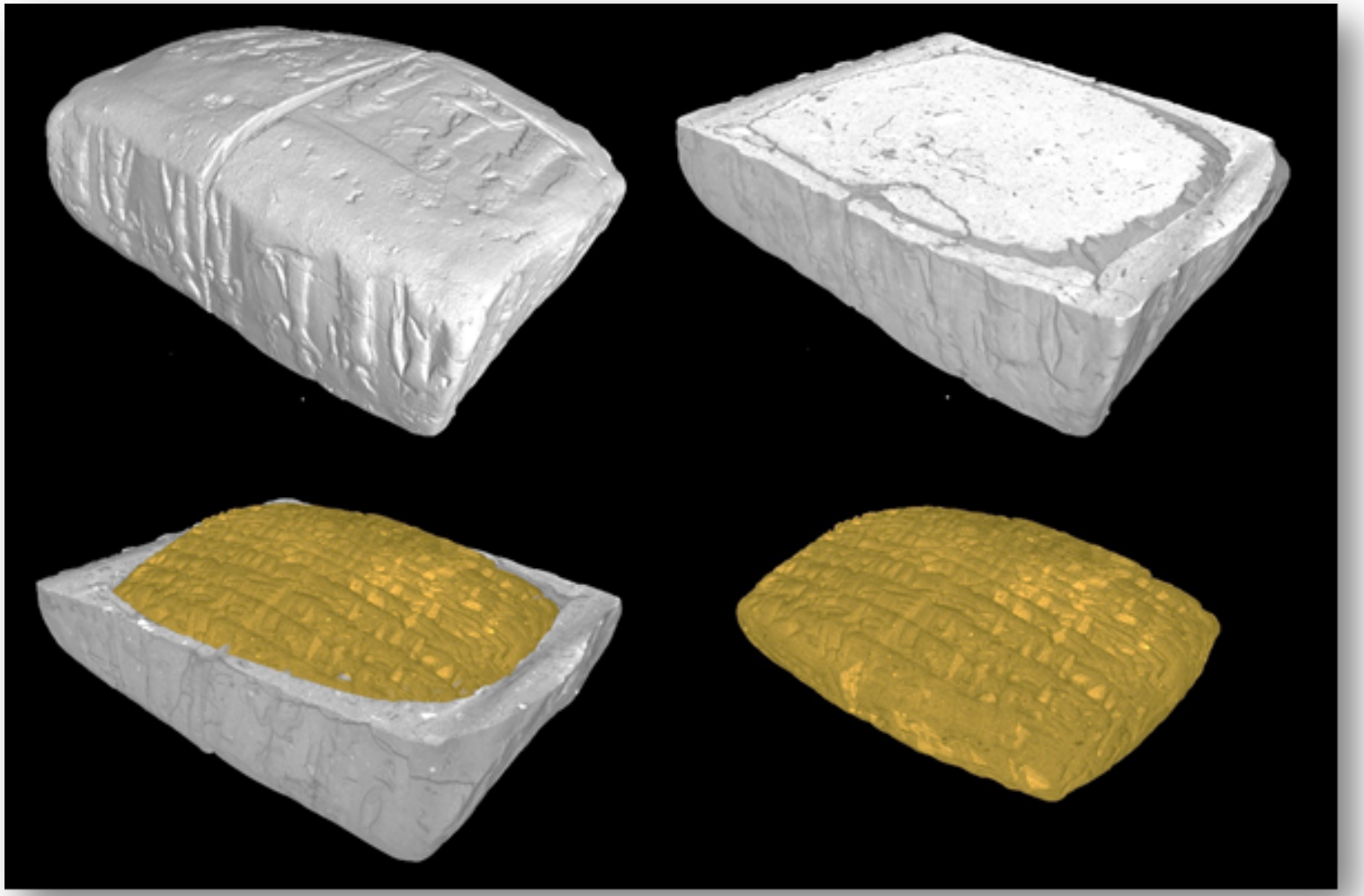
Virtual opening of the I 700 tablet envelope



Top left: a complete reconstruction of the tablet I 700 with the envelope; top right: a virtual cut in half. Both components have the same density and structure.
Below: the reconstruction is virtually decomposed

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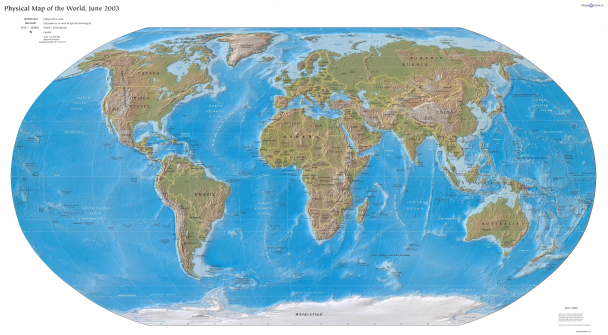
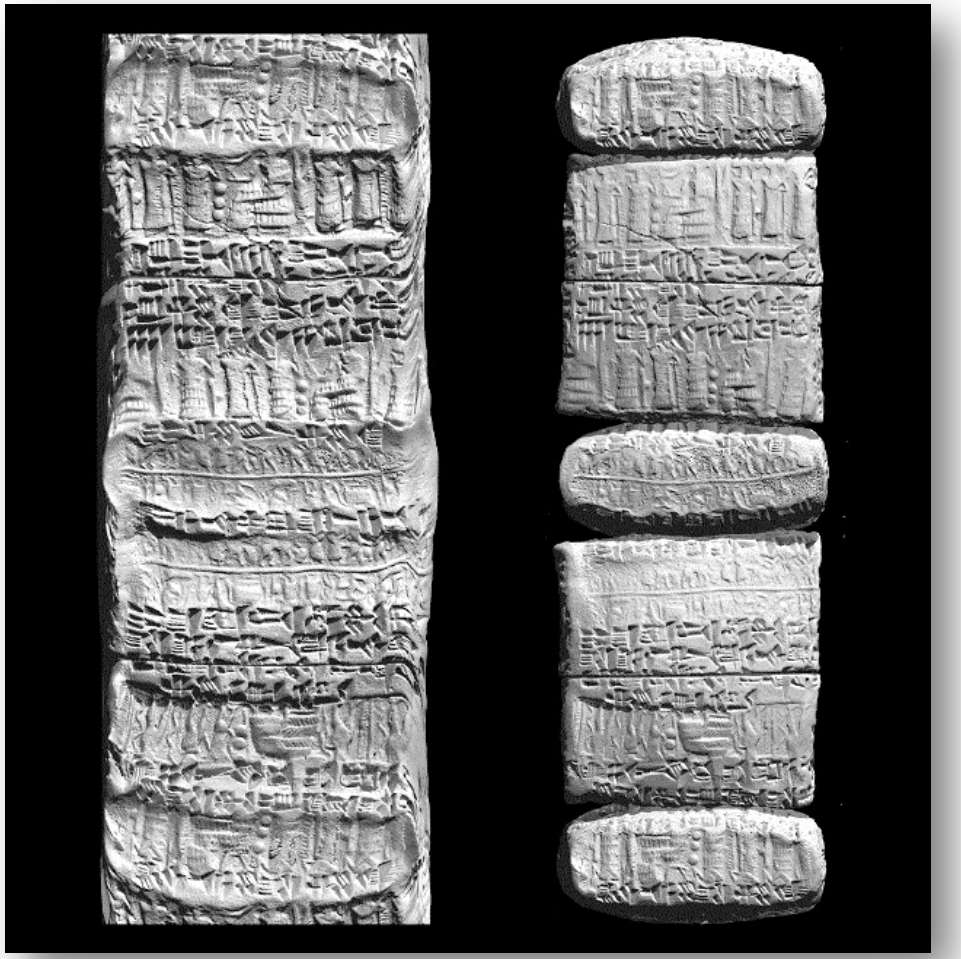
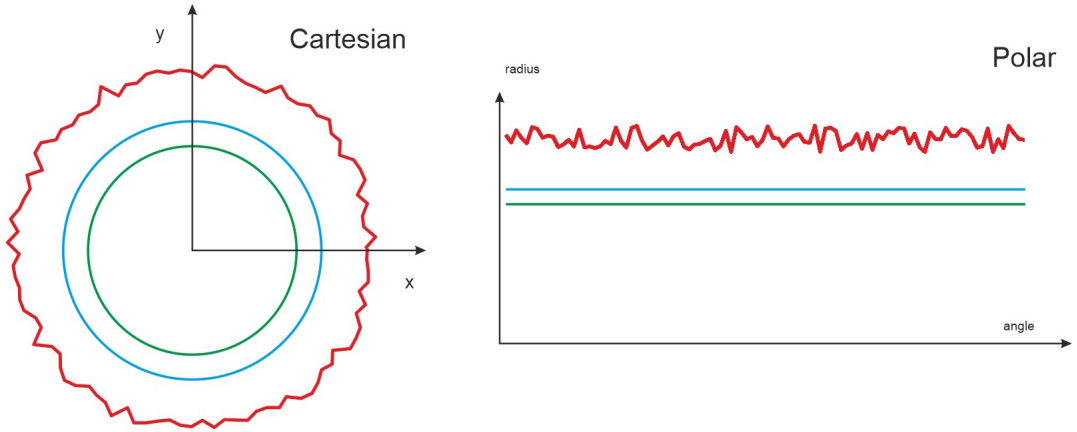


Unwrapping the I 463B envelope surface into a plane





- The reconstructed model can be viewed from all sides by a researcher in a suitable program.
- However, it is not possible to view all the text at once, especially when the text is written on the edges.
- As with the transfer of a globe view of the world to a planar map, it is also possible to unfold the surface of the tablets and their envelopes into a plane.
- For this purpose, it is necessary to describe the outer geometry with sufficient precision, here called hyperellipsis.

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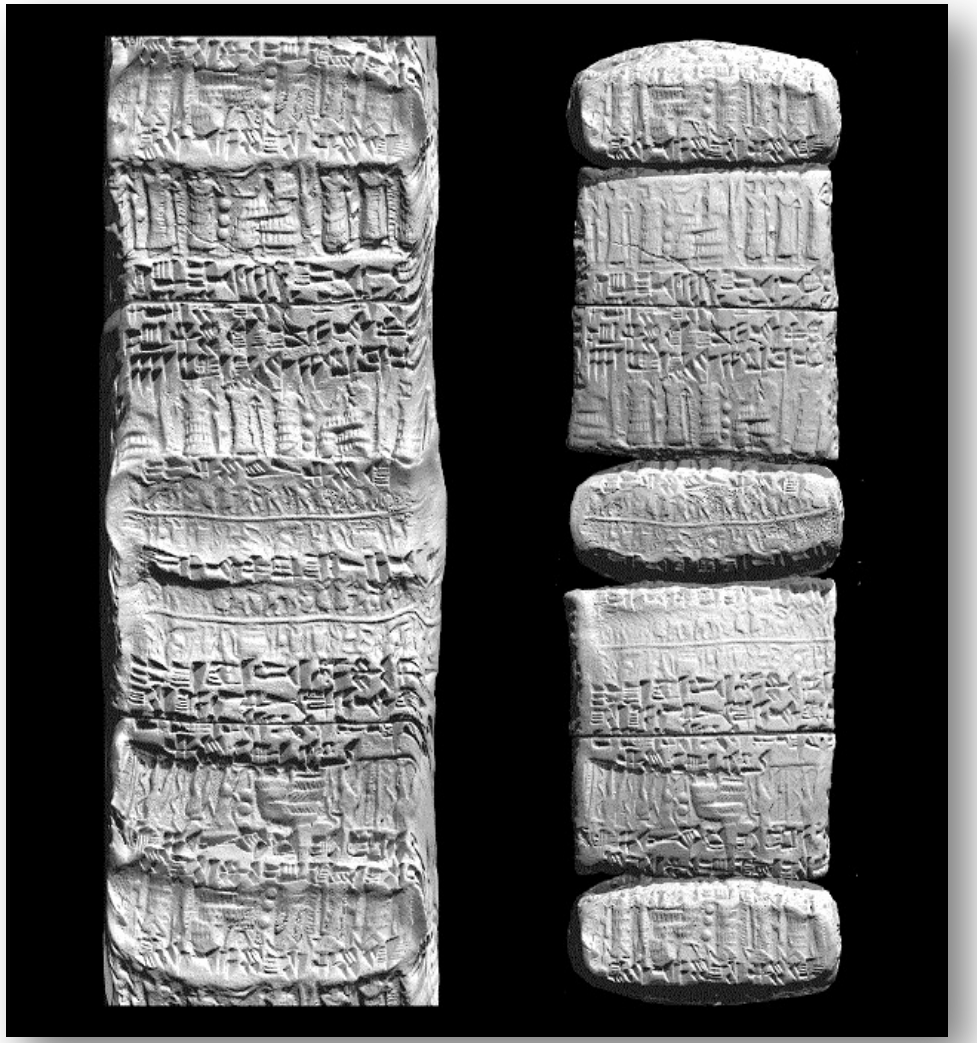
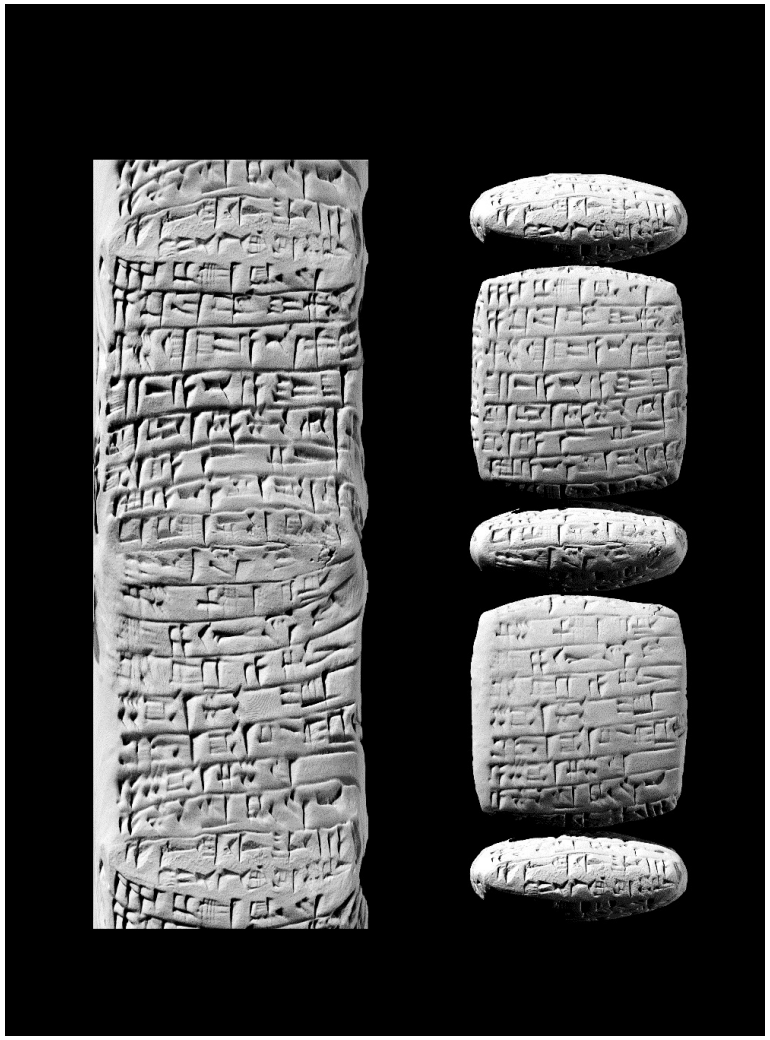
Unwrapping the I 463A, B surface into a planar shape





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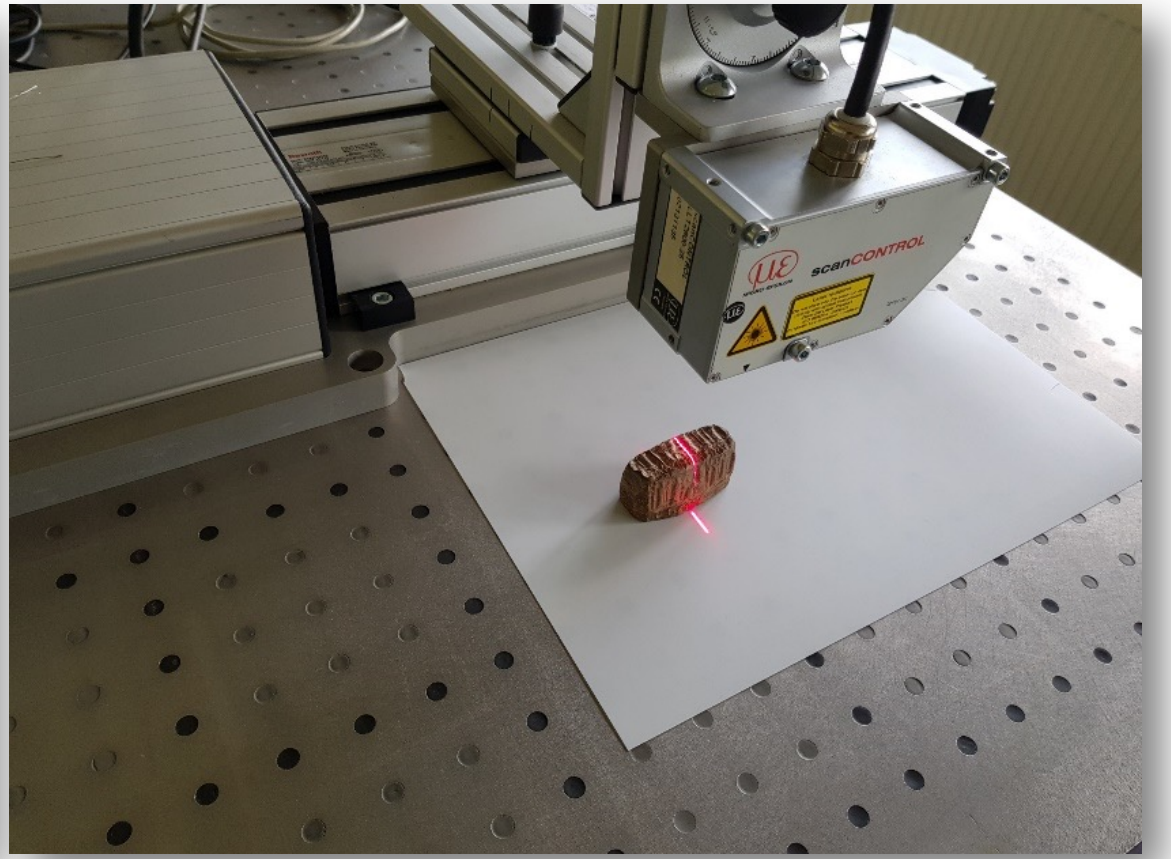
Seal on I 463 envelope and its documentation by means of laser scanning profilometry



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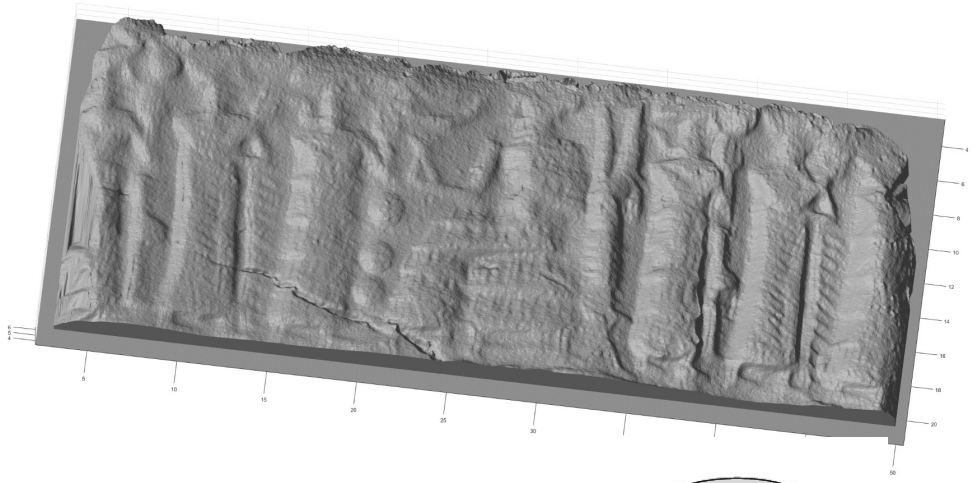
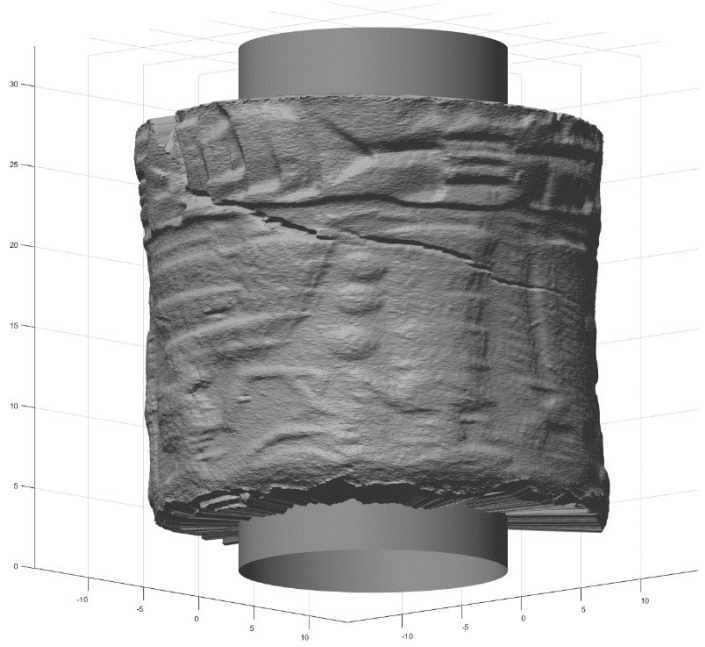
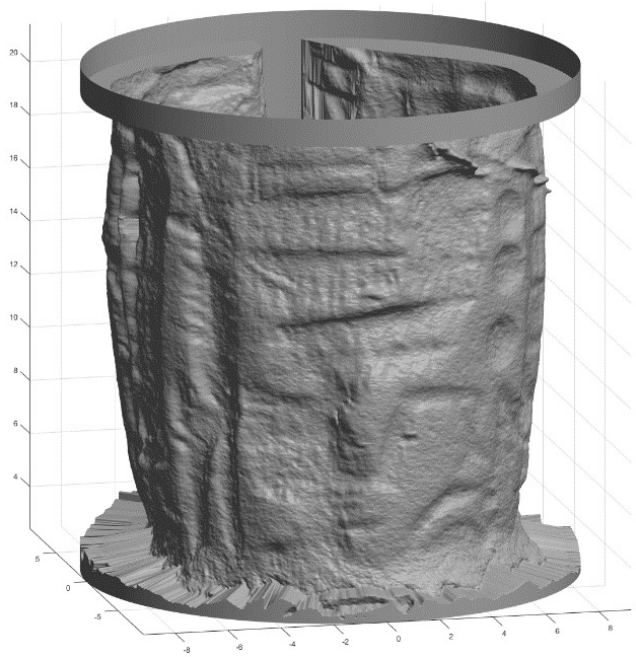
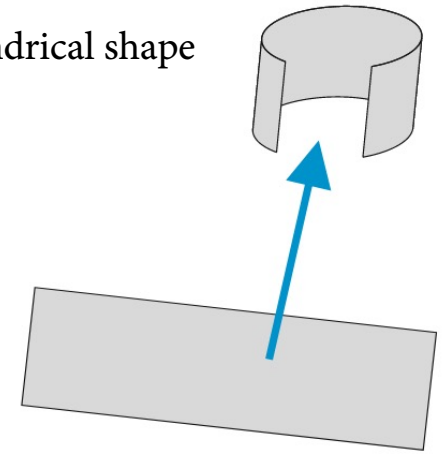
Reverse engineering of a cylinder seal from a digital model of the seal imprint







Wrapping into a cylindrical shape



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From a digital model via a 3D printed object to the seal reconstruction

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Scaled model of I 512 tablet (50x larger than the original)

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Holographic image of I 463 tablet

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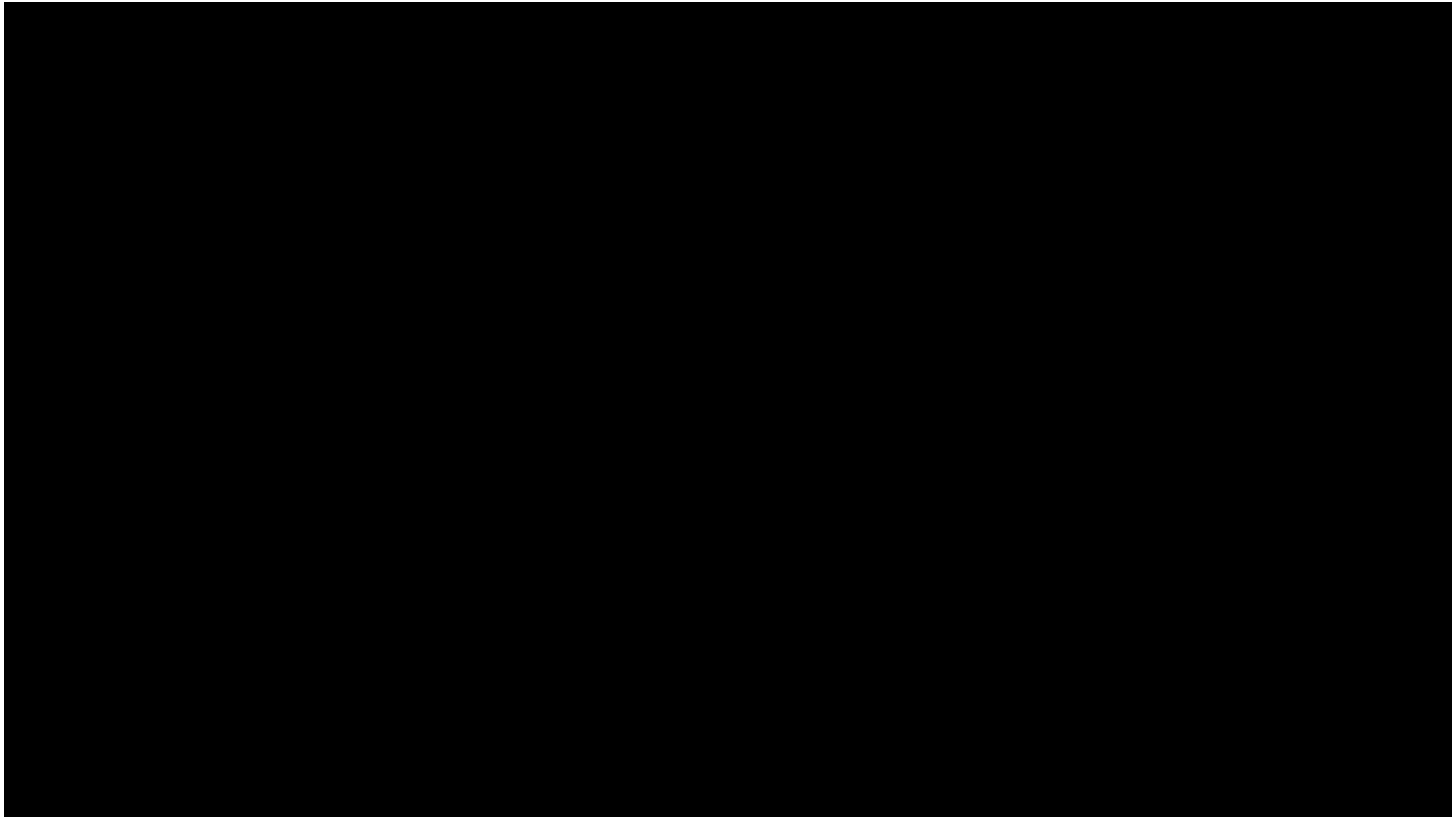

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Conclusions

- In general, the distribution of points in the three-dimensional element diagrams shows that the material of the individual tablets varies quite significantly.
- To some extent, a relationship can be found between the basic structure of the tablet and its composition, but at the same time some of the differences depend on the production method of a particular workshop rather than on the composition of the material, which, however, is an advantage in terms of identifying the place of production.
- Furthermore, it turned out to be possible to virtually open the envelope and remove the tablet. Similarly, it has been documented that unfolding the surface of the envelope into a plane allows the context of the entire text to be well captured.
- Combined with other modern technologies (such as 3D printing), it is then very easy to produce faithful copies of cuneiform tablets from tomographic models (with some appropriate marker that it is a copy).
- It should also be noted that high-resolution tomographic measuring with high-quality data processing are relatively time and equipment intensive. If only digitisation of the external shape and colour is required, without knowledge of the internal structure, it is more appropriate to use optical methods.
- With regard to more accurate determination of chemical composition and technology of production, it will be desirable in the future to use other analytical methods such as X-ray diffraction or detailed Raman spectroscopy.

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