



The Evolution and Current State of Digital Tools in Epigraphy: Documentation, Analysis, and Infrastructure

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The Evolution and Current State of Digital Tools in Epigraphy: Documentation, Analysis, and Infrastructure

Epigrafide Dijital Araçların Evrimi ve Güncel Durumu: Belgeleme, Analiz ve Altyapı

Eren NACAK*

Abstract: Digital epigraphy spans imaging, three-dimensional documentation, machine learning, and linked open data, warranting critical review to situate recent claims within the discipline. The article traces the evolution of epigraphic documentation from paper squeezes to AI-assisted tools and surveys the methods and infrastructures shaping the field. Successive sections address documentation history, RTI, SfM photogrammetry, multispectral and hyperspectral imaging, deep learning systems including Pythia, Ithaca, and Aeneas, digital databases, the EpiDoc standard, and the FAIR/IIIF/Linked Open Data infrastructure, with problems and shortcomings discussed thereafter. Peer-reviewed independent replication studies auditing the reported accuracy of AI epigraphy tools remain limited, and these tools perform unevenly between formulaic and poorly attested inscriptions, where expert input is most critical in the second group. The concentration of computational epigraphy on Greek and Latin marginalises geographically more diverse epigraphic traditions, including those of Türkiye. Database sustainability, interoperability, and FAIR compliance recur as structural problems. AI-assisted tools should function as decision-support systems, not verified methodological revolutions.

Keywords: Digital Epigraphy, RTI, Photogrammetry, Deep Learning, EpiDoc, Epigraphic Databases

Öz: Dijital epigrafi; görüntüleme, üç boyutlu belgeleme, makine öğrenimi ve bağlantılı açık veriyi kapsamakta olup, güncel iddiaların disiplin içindeki yerini belirlemek adına eleştirel bir değerlendirmeyi gerekli kılmaktadır. Makale, epigrafik belgelemenin kâğıt estampajlardan yapay zekâ destekli araçlara uzanan evrimini incelemekte; alanı şekillendiren yöntem ve altyapıları tanıtmaktadır. Sırasıyla belgeleme tarihi, RTI, SfM fotogrametrisi, multispektral ve hiperspektral görüntüleme, Pythia, Ithaca ve Aeneas gibi derin öğrenme sistemleri, dijital veri tabanları, EpiDoc standardı ve FAIR/IIIF/Bağlantılı Açık Veri altyapısı ele alınmakta; mevcut sorun ve eksiklikler tartışılmaktadır. Yapay zekâ epigrafi araçlarının bildirilen doğruluk oranlarını denetleyen hakemli ve bağımsız yineleme çalışmaları literatürde sınırlı kalmaktadır. Bu sistemler, kalıplaşmış (formüler) ile az tanıklanmış yazıtlar arasında düzensiz performans göstermekte; uzman katkısı özellikle ikinci grupta kritik önem taşımaktadır. Hesaplamalı epigrafinin Hellence ve Latince üzerine yoğunlaşması, Türkiye'deki veriler dâhil, coğrafi bakımdan daha çeşitli epigrafik gelenekleri ikincil konuma itmektedir. Veri tabanı sürdürülebilirliği, birlikte çalışabilirlik ve FAIR uyumluluğu yinelenen yapısal sorunlardır. Yapay zekâ destekli araçlar, henüz doğrulanmış metodolojik devrimler olarak değil, karar destek sistemleri olarak konumlandırılmalıdır.

Anahtar Kelimeler: Dijital Epigrafi, RTI, Fotogrametri, Derin Öğrenme, EpiDoc, Epigrafik Veri Tabanları

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Introduction

Since 2018, digital epigraphy has gained momentum and has been undergoing a paradigm shift at the intersection of advances in imaging techniques, three-dimensional documentation, machine learning, and linked open data standards. Reflectance Transformation Imaging (RTI) and photogrammetry have become routine documentation tools, deep learning systems such as Pythia, Ithaca, and Aeneas have begun to assist specialists in the restoration, chronological attribution, and geographical attribution of texts, and the EpiDoc XML standard, which may be regarded as the common language of linked epigraphic database networks, has become widely used¹. Although epigraphic research, long conducted through paper squeezes and hand-drawn facsimiles, has today evolved into a research field supported by computational methods and operating with large datasets, these still-maturing methods have not yet reached a level at which they can replace the expertise of a real specialist. Research indicates that the future of epigraphic studies will be shaped by work related to the transition from analogue to digital documentation².

This study is a critical review, not an exhaustive systematic survey. The literature discussed below was identified through Google Scholar, Lens.org, and the Scopus Preview, supplemented by the ACL Anthology and arXiv for work published in computational venues and by TR Dizin and DergiPark for Turkish-language scholarship. The search strategy combined field-level expressions (“digital epigraphy”, “computational epigraphy”), method- and task-level expressions (“artificial intelligence”, “machine learning”, “deep learning”, “neural networks”, “OCR”, “HTR”, “text restoration”, “decipherment”, “translation”), and script- or language-specific expressions (“Greek inscriptions”, “Latin inscriptions”, “cuneiform tablets”, “Egyptian hieroglyphs”, “Lycian inscriptions”, “Lydian inscriptions”, “Phrygian inscriptions”). These groups were cross combined where relevant, especially in searches testing whether dedicated artificial intelligence or machine learning systems existed for Anatolian epigraphic material. The survey concentrates on the period from 2019 to 2025, when deep learning most visibly reshaped the field, while earlier studies are included where they provide necessary historical or methodological background. Studies were retained when they presented a tool, method, dataset, or substantive critical discussion. General press coverage and works without technical or scholarly content were excluded. Where the review notes the absence of work on a given script, as with Lycian, Lydian, and Phrygian, this indicates that no dedicated system was identified in the accessible academic literature surveyed, rather than a claim of exhaustive coverage.

The Evolution of Documentation in Epigraphy

The methods used to document inscriptions have passed through major technological stages that have changed how researchers see, record, and share inscriptions. Paper squeezes, produced by pressing moistened paper onto an inscribed surface, were used from the 19th century onward as a principal portable recording medium (Fig. 1)³. Major squeeze archives include the BBAW archive, with approximately 70,000 squeezes⁴, the CSAD archive at the Centre

¹ As of March 2026, EpiDoc version 9.8 is available. For a detailed discussion, see Bodard 2010; Elliott et al. 2026.

² Seales & Chapman 2023, 137.

³ Petrie 1904, 62-64.

⁴ Berlin-Brandenburgische Akademie der Wissenschaften 2019. Funke (2019, 21) states that the IG archive contains a larger collection, with approximately 90,000 squeezes.

for the Study of Ancient Documents in Oxford, with approximately 25,000 squeezes⁵, the Meritt Collection at the Institute for Advanced Study in Princeton, with at least 25,000 squeezes⁶ and the archive of the Académie des Inscriptions et Belles-Lettres in Paris. These collections continue to retain their scholarly value and have become direct subjects of digitisation projects⁷.

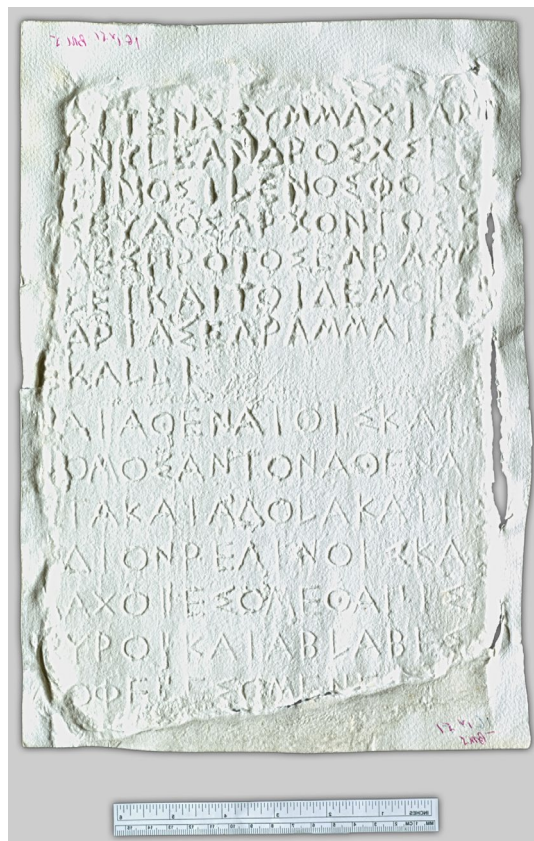


Fig. 1: Paper squeeze of the Athenian decree on the alliance with Rhegion (IG I³ 53), 433/432 BCE.

Source: University of British Columbia Library, Malcolm F. McGregor Squeeze Collection (Digital Identifier IG_I3_0053. No known copyright restrictions. Credit: UBC Library). Access: <http://digitalcollections.library.ubc.ca/cdm/ref/collection/squeezes/id/35>

The use of photography in epigraphic studies began to appear from the mid-19th century onward⁸. James Henry Breasted pioneered the Chicago House Method in Luxor, combining photography with hand drawn epigraphic records⁹. By developing a method based on the systematic comparison, directly before the monument wall, of pencil drawings made over photographs by epigraphists and artists, Breasted established a norm for documenting damaged relief details that photography alone could not capture. This hybrid approach was widely accepted and used as a standard for much of the 20th century¹⁰. The Leiden Conventions, systematised by van Groningen in 1932, standardised the system of signs used in epigraphic transcription, while EpiDoc is an application framework developed for digital editions of ancient documents, making these conventions encodable in a TEI-based XML environment¹¹.

⁵ Centre for the Study of Ancient Documents 2020.

⁶ Habicht 2010, 6; Howe et al. 2025.

⁷ Brunet 2019; Chastel et al. 2023.

⁸ Breasted 1927.

⁹ For one of the earliest examples, see Du Camp 1852.

¹⁰ Johnson 2000, 3.

¹¹ Van Groningen 1932; Bodard 2010, 6.

The stages of digitisation accelerated toward the end of the 20th century. The process began in the 1980s with the establishment of the Epigraphik-Datenbank Clauss-Slaby (EDCS), followed by the Epigraphische Datenbank Heidelberg (EDH) in 1986 and both were gradually brought online during the 1990s¹². A turning point occurred between 2000 and 2004, when the first EpiDoc guidelines were published and tested in the “Inscriptions of Aphrodisias” and “Vindolanda Tablets Online” projects¹³. Malzbender and colleagues developed polynomial texture mapping, regarded as a precursor of RTI, thereby preparing the beginning of a new phase in surface visualisation¹⁴. By the 2010s, Cultural Heritage Imaging (CHI) had introduced the open source Reflectance Transformation Imaging (RTI) method, while the Digital Epigraphy and Archaeology (DEA) project at the University of Florida digitised its squeezes¹⁵. Between 2013 and 2016, the EU funded EAGLE (Europeana Network of Ancient Greek and Latin Epigraphy) best practice network constituted one of the first examples of bringing hundreds of thousands of inscriptions together in a single portal¹⁶. Since 2018, the establishment of the Epigraphy.info community, the launch of the FAIR Epigraphy project, and the development of deep learning systems including Pythia, Ithaca, and Aeneas have brought this transformation to its current pace¹⁷.

Reflectance Transformation Imaging (RTI)

Reflectance Transformation Imaging (RTI) improves the legibility of worn details by modelling how a surface responds under different light directions. The technique works by taking dozens of photographs from a fixed camera position under changing illumination angles and analysing the reflective properties of the surface through pixel based mathematical models¹⁸. The resulting interactive image allows researchers to relight the surface virtually, thereby revealing incisions that would normally remain invisible¹⁹. Since Malzbender’s PTM algorithm, the technology has developed considerably²⁰. In 2008, PTM was superseded by Hemispherical Harmonics (HSH) fitting. Over time, portable equipment has become increasingly widespread, ranging from hand-held flash systems, reflective spheres, and setups costing under USD 1,000 to precise dome systems equipped with 48–128 LEDs controlled by Arduino microcontrollers²¹.

The software ecosystem is currently undergoing an active transition. Following CHI’s original RTIBuilder²² and RTIViewer²³ software, RelightLab²⁴, and OpenLIME²⁵, developed by the Visual Computing Laboratory of CNR-ISTI in Pisa, have begun to be used. RelightLab supports multiple basis functions, including RBF, PTM, HSH, SH, and bilinear models, and produces outputs in web

¹² Kolb & Speidel 2025, 10.

¹³ Malzbender et al. 2000; 2001.

¹⁴ Earl et al. 2010; Bozia & Barmpoutis 2015.

¹⁵ Mudge et al. 2008; Bozia & Barmpoutis 2015, 30-32.

¹⁶ Orlandi et al. 2014.

¹⁷ Feraudi-Gruénais & Grieshaber 2016; Assael et al. 2019; 2022; 2025; Heřmánková et al. 2022.

¹⁸ Malzbender et al. 2001, 2; Piquette 2014; Seales & Chapman 2023, 131-133.

¹⁹ For examples of its use in surface analysis more generally, see Zendagui et al. 2021.

²⁰ Mudge et al. 2008, 20.

²¹ Akçay 2016; Lech et al. 2024. The “superdome” system developed at Oxford for the Bloomberg tablets uses 128 LEDs concentrated at low elevation angles in order to capture paleographic detail (MacDonald et al. 2019). The Vorderasiatisches Museum in Berlin has used a 64-LED dome system for cuneiform tablets, while the Multi-Spectral Portable Light Dome developed at KU Leuven combines RTI with infrared, visible, and ultraviolet bands in a single device (Kinsman 2016; Diara et al. 2024).

²² Cultural Heritage Imaging 2011; Mytum & Peterson 2018.

²³ Cultural Heritage Imaging 2010.

²⁴ Ponchio 2024.

²⁵ Ponchio et al. 2025.

ready formats²⁶. OpenLIME, as a modern ES6/WebGL viewer, has replaced the earlier relight.js library and now supports DeepZoom, IIIF tiling, annotations, and measurement functions²⁷. Its core compression algorithm optimises the balance between quality and file size by using PCA based data reduction and Gaussian RBF interpolation, making it possible to relight high resolution inscriptions interactively and directly within web browsers²⁸. The impact of RTI can be observed through case studies. Research conducted at the ancient city of Phaselis has shown that RTI increased the legibility of most previously unreadable Greek and Latin inscriptions²⁹. In another research, when RTI was applied to amphora stamps from Tanais, previously unnoticed details were revealed³⁰. The InscriptiFact database developed at USC contains more than 40,000 RTI images of cuneiform tablets, Dead Sea Scroll fragments, and coins³¹. In 2025, a new workflow introducing an improved dome design for imaging epigraphic squeezes with RTI was published in IEEE Access³².

Photogrammetry and 3D Scanning Methods

Structure-from-Motion (SfM) photogrammetry has become one of the most widely adopted documentation methods for inscriptions because it offers low cost, high portability, and superior texture quality³³. In the standard workflow, numerous overlapping photographs are taken, followed by feature matching, dense point cloud generation, mesh construction, and texturing. Software like Agisoft Metashape, RealityCapture, the open source COLMAP, and Apple's Object Capture API is used for these processes³⁴. In the post processing stage, MeshLab and CloudCompare are commonly used for mesh cleaning, deviation analysis, and visualisation³⁵.

Photogrammetric accuracy is increasing with the development of new algorithms. Tests using focus stacked macro images have shown that photographs taken at very close range can capture seals measuring 1 to 3 centimetres with an accuracy at the level of one hundredth of a millimetre, producing results comparable to industrial laser scanning (LiDAR) outputs³⁶. The conversion of point clouds into 2.5D raster format through orthographic projection enables inscriptions to be analysed epigraphically and visualised in a more legible form suitable for publication³⁷. Structured light and SfM can be combined as complementary methods.

²⁶ Ponchio et al. 2019, 29.

²⁷ Ponchio et al. 2025.

²⁸ Ponchio et al. 2019.

²⁹ Önen et al. 2017.

³⁰ Lech et al. 2021, 6.

³¹ Hunt et al. 2005; 2006. Since 2022, the project could no longer be continued because of insufficient hardware and budgetary resources. Although the existing archive has been preserved, updates have ceased. See Zuckerman et al. 2014 for its developmental process.

³² Gotsikas et al. 2025.

³³ Carrero-Pazos & Espinosa-Espinosa 2018; Ravanelli et al. 2022; Nazim et al. 2025.

³⁴ For a comparative analysis of the usability of Agisoft Metashape and RealityCapture software in cultural heritage research, see Kingsland 2019. Both software packages produce similar results, although differences exist in interface design and cost. Although COLMAP and Object Capture API are free, Object Capture API runs only on Apple-developed devices and has been reported to produce faster and better results than COLMAP. Object Capture API does not require masking and processes an average of 100 photographs in less than 10 minutes. See Hurst et al. 2024 for further details. For a detailed comparison of the two, see Van Vlasselaer et al. 2024.

³⁵ For an example of the combined use of both, see Probst et al. 2018, 4.

³⁶ Ravanelli et al. 2022.

³⁷ The method made a substantial contribution to resolving a 150-year-long debate by assisting in the reading of an inscription on the Temple of Apollo at Syrakousai. For further information, see Sapirstein 2019.

Structured-light scanning is an active scanning method that calculates the three dimensional geometry of an object by projecting patterned light onto a surface and recording, through cameras, the deformation of that pattern on the surface³⁸. Hand held devices, for example the Artec Space Spider, provide consistent results (Fig. 2)³⁹. Studies show that both structured-light scanning and SfM are applicable to worn Greek inscriptions, although SfM is markedly cheaper and faster⁴⁰.



Fig. 2: Three dimensional close range LiDAR scan model of the Aurelius Kougas inscription from Phaselis (TAM II/3 1207; Bérard 1892, 445 no. 95; Laum 1914, II 124 no. 142). (Model: Author)

For the dissemination of the models produced, several platforms have been developed to enable the interactive distribution of epigraphic material, as well as cultural heritage assets more broadly. 3DHOP, which uses WebGL for web based visualisation, is one of these platforms and is widely preferred⁴¹. Sketchfab is another widely recognised platform and hosts the 3D models of inscriptions from the Epigraphia 3D project⁴². Within the scope of the DEA project, the Digital Epigraphy Toolbox was developed for 3D visualisation and analysis and was presented as the first online 3D epigraphic library⁴³.

Multispectral Imaging (MSI) and Hyperspectral Imaging (HSI)

Multispectral Imaging (MSI) enables the visualisation of various wavelength bands ranging from ultraviolet (UV) to near infrared, whereas Hyperspectral Imaging (HSI) produces a denser dataset by combining hundreds of contiguous narrow bands⁴⁴. Both methods are non invasive and effective in revealing ink traces, pigments, and surface features that are not fully visible to the naked eye. The landmark Archimedes Palimpsest project established the basic framework of this method⁴⁵. Multispectral imaging

was carried out with narrow band LED illumination, and the data were processed using Principal Component Analysis (PCA) and Independent Component Analysis (ICA) in order to distinguish the spectral traces of Archimedes' ink from the later overtext⁴⁶. A similar method combining LED illuminators and narrow band filters has also been tested in the imaging of the Oxyrhynchus papyri and the Dead Sea Scrolls⁴⁷. Multispectral imaging of the Arad Ostrakon, which had been

³⁸ Geng 2011.

³⁹ Diara 2023.

⁴⁰ Papadaki et al. 2015.

⁴¹ Potenziani et al. 2015. For the comparative limitations, strengths, and weaknesses of prominent platforms used in the field of cultural heritage, see Champion & Rahaman 2020.

⁴² Ramírez-Sánchez et al. 2015.

⁴³ Barmpoutis & Bozia 2023.

⁴⁴ Picollo et al. 2020.

⁴⁵ Knox et al. 2001.

⁴⁶ Salerno et al. 2007.

⁴⁷ Easton et al. 2011.

displayed at the Israel Museum for more than 50 years, revealed three previously invisible lines on the verso, which had been thought to be blank, and four new lines on the recto⁴⁸.

Spectral RTI, which combines spectral imaging and RTI, represents the most advanced form of the method. The open source, ImageJ-based SpectralRTI_Toolkit creates extended spectrum and PCA false colour RTI images applicable to cuneiform tablets, coins, and funerary inscriptions by combining colour and luminance information obtained from approximately 20 different wavelengths with reflectance information derived from 30 to 50 different lighting positions⁴⁹.

Machine Learning (ML)

Artificial intelligence now contributes to epigraphic work in several distinct ways, and its adoption has been rapid. The systems discussed below are examined by the function each performs, and each is assessed in relation to three questions: what the tool actually does, how representative and well prepared the data behind it are, and where such evidence exists, whether its performance has been independently confirmed. Seen in this way, the figures cited in the following pages indicate what a tool can do on a particular task rather than marking successive steps on a single scale of progress.

The task based taxonomy proposed by Sommerschild and colleagues provides a useful point of departure for organising the discussion, since it distinguishes between digitization, restoration, attribution, linguistic analysis, textual criticism, translation, and decipherment as separate but related areas in which machine learning has been applied to ancient texts⁵⁰. Within this framework, the sequence from Pythia (2019) to Ithaca (2022) is significant not because it represents a linear increase in accuracy, but because it shows the expansion of machine learning tasks from textual restoration to combined restoration and attribution. Pythia, based on a bidirectional long short term memory (LSTM) architecture, was designed specifically for the restoration of damaged Greek inscriptions and was evaluated through character level error rates on the PHI-ML corpus⁵¹. Ithaca, by contrast, uses a transformer architecture to combine three related but distinct tasks: textual restoration, geographical attribution, and chronological attribution⁵². Its reported results therefore belong to a broader task setting than Pythia's and should be read as evidence of assisted attribution within a defined Greek inscription corpus, not as a directly comparable improvement in general reliability. Ithaca's datings for the "Athenian Decrees" are consistent with redating studies⁵³.

Aeneas marks a further stage in this development. Developed as a multimodal neural network for Latin inscriptions, Aeneas can process text and images together, restore gaps of unknown length, and identify textual and contextual parallels within the Latin Epigraphic Dataset (LED), which contains 176,861 inscriptions. In automated evaluation, when the restoration length was provided, Aeneas achieved a character error rate of 40.5% and a Top-20 prediction accuracy of 46.5%. When the gap length was unknown, the character error rate was reported to be only 15% higher. For geographical attribution, the model reached 72% accuracy

⁴⁸ Faigenbaum-Golovin et al. 2017. For details on the current capabilities of HSI, see Cheng et al. 2025. For an example of its use from Egypt, see Cucci et al. 2024.

⁴⁹ Hanneken 2016.

⁵⁰ Sommerschild et al. 2023.

⁵¹ Assael et al. 2019, 6368.

⁵² Assael et al. 2022.

⁵³ Assael et al. 2019, 6368; Assael et al. 2022, 282-283. Reported metrics include a 30.1% character error rate on PHI-ML, compared with 57.3% for human epigraphists.

across 62 Roman provinces, while its chronological attribution placed texts within an average distance of approximately 13 years from the ground truth ranges⁵⁴. When evaluated by epigraphists, Aeneas was found useful as a research starting point in 90% of the cases. In the dating task, Aeneas achieved a distance of 12.8 years from the ground truth ranges, while historians working with Aeneas' parallels and predictions reduced their distance to 14.1 years⁵⁵. The system was tested on the *Res Gestae Divi Augusti*, where it correctly identified dating features, orthographic clues, and political ideology⁵⁶. This example is useful because it shows the strongest side of these models: they work best when the inscription belongs to a well documented textual and historical tradition against which the model can compare its suggestions.

The distinction here is important because not all AI-assisted recoveries of ancient texts involve the same kind of evidence or the same scholarly task. As an example, the Vesuvius Challenge illustrates a neighbouring but distinct use of machine learning for ancient texts⁵⁷. In this case, artificial intelligence assists the virtual unwrapping and reading of carbonised Herculaneum papyri, whereas Aeneas works on already visible inscriptions by proposing restorations, parallels, dates, and geographical attributions.

Advances in AI-assisted tools extend beyond Greek and Latin. Most of this work, however, takes the form of single task systems built for one script or corpus, and a large share of it is devoted to producing the annotated datasets they depend on, not on decipherment as such. DeepScribe achieved 80% end-to-end Top-5 classification accuracy in the detection of Elamite cuneiform signs from the Persepolis Fortification Archive, providing a useful example of this pattern⁵⁸. As the system was trained and evaluated on this single administrative archive, the figure reflects one corpus and a limited range of scribal hands rather than Elamite cuneiform as a whole. Other cuneiform projects show the same movement toward narrowly defined visual tasks, especially sign detection, classification, and the production of machine readable datasets⁵⁹. GigaMesh was developed as a solution capable of extracting cuneiform characters automatically from 3D scans more rapidly than manual drawing, even on eroded tablets. With GigaMesh, it has been shown that 3D scans are more suitable than photographs for sign detection using CNN/RepPoints, with the best results obtained from datasets combining 3D scans and photographs⁶⁰. In this context, GigaMesh is better understood as an enabling 3D processing and rendering framework than as an interpretive AI system⁶¹. These experiments suggest that rendered 3D data can improve sign detection when compared with photographs

⁵⁴ Assael et al. 2022. The stated figures refer to Aeneas' own automated evaluation settings and should not be directly generalised beyond the dataset, task definitions, and metrics used in that study.

⁵⁵ It was tested with the participation of 23 epigraphists in total. For further details, see Assael et al. 2025, 144-145.

⁵⁶ The stated rates refer to Top-20 accuracy. The accuracy rates given represent performance metrics reported within the respective studies' own datasets, task definitions, and experimental settings, and should not be directly generalised to the field as a whole. For Top-1 and Top-3 statistics and further details, see Assael et al. 2025, 144-145.

⁵⁷ The prize was awarded to the young students Youssef Nader, Luke Farritor, and Julian Schilliger, who deciphered more than 2,000 characters revealing a previously unknown Epicurean text focused on pleasure; see Parsons et al. 2023. For details of the underlying technology, see Bukreeva et al. 2016.

⁵⁸ Williams et al. 2025.

⁵⁹ Bogacz & Mara 2022.

⁶⁰ Mara et al. 2010; Stötzner et al. 2023.

⁶¹ Bogacz & Mara 2022.

alone, especially when combined with mapped photographic data.

Other attempts address the same preparatory problem from the textual side, using existing transliterations, legacy editions, and large image collections to make cuneiform material usable for machine learning. One study attempted sign detection in Neo-Assyrian tablets by using existing transliterations as weak supervision data⁶². Deep-learning OCR has been applied to older edition materials through CuReD,⁶³ and more than 94,000 CDLI images have been used to classify tablets from silhouettes⁶⁴. The CuneiML dataset offers 38,947 high resolution photographs paired with transliterations for machine learning training⁶⁵. Taken together, these studies show that the most consequential advance in cuneiform oriented machine learning at present lies not in autonomous interpretation, but in the infrastructural conversion of heterogeneous evidence, including 3D scans, legacy editions, transliterations, and tablet images, into aligned, annotated, machine readable corpora on which future interpretive systems will depend.

A second group of cuneiform applications moves from visual recognition toward linguistic processing, where the object is no longer the detection or preparation of signs but the computational treatment of already transcribed language. BabyLemmatizer, an NLP pipeline focused on POS tagging and lemmatisation for Akkadian and other cuneiform languages, has been tested on Neo-Assyrian, Babylonian, Sumerian, and Urtian, while another solution, BabyFST, has been specifically customised for Babylonian⁶⁶. These tools therefore form an intermediate stage between dataset preparation and full translation. They shift the emphasis from identifying signs to analysing language after transcription, but remain dependent on well prepared corpora and language specific customization.

In tests aimed at translating Akkadian tablets into English, scores of 36.52 BLEU4 for cuneiform to English and 37.47 BLEU4 for transliteration to English (T2E) may be regarded as relatively strong for an early stage machine translation system⁶⁷. Even so, scores near 37 remain well below those of mature translation systems and yield drafts that require substantial expert post editing, not finished translations. Taken together, the cuneiform applications surveyed here, spanning sign detection, lemmatisation, and translation, advance task by task rather than as a single integrated system, and each remains bound to the corpus and preparation effort behind it.

Beyond cuneiform, comparable single script efforts have emerged for other writing systems. For Egyptian hieroglyphs, the dedicated Glyphnet convolutional network reached about 97.6% sign classification accuracy, while a separate Deep Metric Learning approach reported 97.70% and recognised a larger set of signs under class imbalance⁶⁸. Both figures concern the classification of already segmented signs, however, and leave the harder tasks of detecting and isolating hieroglyphs on running monuments largely unaddressed. A related limitation appears in restoration oriented systems, where high performance also depends on controlled training conditions. DeepHadad is another example of a tool that uses artificially generated erosion data to train neural networks for the visual

⁶² Dencker et al. 2020, 10-11.

⁶³ Gordin et al. 2024.

⁶⁴ Kapon et al. 2024.

⁶⁵ Chen et al. 2023; 2024.

⁶⁶ Sahala et al. 2020; 2021; Sahala et al. 2022; Sahala & Lindén 2023. See also, Punia et al. 2020 for the first neural machine translation system for further details.

⁶⁷ Guthertz et al. 2023.

⁶⁸ Barucci et al. 2021; Fuentes-Jimenez et al. 2025.

restoration of heavily damaged Aramaic inscriptions⁶⁹ and the reported results are best read as evidence of task specific feasibility, not as proof that such tools can move easily from experimental settings to the complex surfaces and fragmentary contexts encountered in epigraphic practice.

The pattern becomes still clearer when the survey moves from individual scripts to the wider field of experimental workflows across Tamil, Armenian, Greek, Latin script, and Maya materials, where projects usually establish feasibility within a single corpus or benchmark instead of converging on shared tools or standards. A system combining advanced preprocessing with a neural network has been developed for reading Tamil temple inscriptions through deep learning⁷⁰. a detection and decipherment pipeline using YOLO and Vision Transformer has been proposed for medieval Armenian inscriptions⁷¹. and a new benchmark dataset named Bessarion has been published for medieval Greek inscriptions⁷². Comparative evaluations of HTR engines, including PyLaia, TrOCR-f, and Transkribus' transformer based Titan model, have shown that Titan and TrOCR-f provide the strongest zero-shot performance on Latin script documents, whereas PyLaia, IDA, and HTR+ stand out in certain non Latin or more specialised datasets, particularly when properly trained.⁷³ In experiments on Maya hieroglyphs, deep learning models including LeNet, Sketch-a-Net, and ResNet-50 have been tested, while the Segment Anything Model (SAM) has been specifically configured for the segmentation of hieroglyphic blocks in the Maya Vase Database⁷⁴. This group of studies is therefore important less because it offers a unified solution than because it shows how different scripts are being tested through separate experimental workflows.

A further group of examples concerns boundary cases between recognition, decipherment, and language modelling, where reported success depends heavily on whether the target script already has a readable ground truth. In a deep learning system developed for the Indus Valley script, YOLOv3 based sign detection and MobileNet based classification were combined, achieving an accuracy of 94.5%⁷⁵. A model designed to minimise the cost of deciphering unknown languages was tested on Ugaritic and Linear B, reaching an accuracy of 67.3%⁷⁶. Crucially, this result was obtained by treating two already deciphered languages as controlled test cases, so it measures the method against known answers, rather than its performance on a genuinely undeciphered script. KuroNet, developed for Kuzushiji among early Japanese scripts, has also demonstrated accuracy above 90% on benchmark datasets⁷⁷. This figure refers to character recognition on benchmark images and does not extend to rendering the text into modern Japanese, so a gap remains between recognition and a readable transcription.

PhiloGPT is the first specialised large language model developed for ancient Chinese manuscripts, but in this context it is best treated as another script bound experiment rather than as evidence of a general model for ancient language interpretation⁷⁸. Across these scripts the work remains fragmented, in that most systems are built and tested on a single corpus and few

⁶⁹ Aioanei et al. 2026.

⁷⁰ Bhuvaneswari & Kathiravan 2024.

⁷¹ Vidal-Gorène & Decours-Perez 2024.

⁷² Sfikas et al. 2024.

⁷³ Romein et al. 2025.

⁷⁴ Can et al. 2018; Shivam et al. 2024.

⁷⁵ Dixit et al. 2025.

⁷⁶ Luo et al. 2019.

⁷⁷ Clanuwat et al. 2018.

⁷⁸ Zhang et al. 2024a.

are designed to transfer to other languages or to integrate into a shared workflow.

The most active technical frontier in the application of artificial intelligence to ancient textual material lies in optical character recognition (OCR) and handwritten text recognition (HTR), especially where inscriptions, papyri, and manuscript images can be treated as visual recognition problems. The ICDAR 2023 competition produced significant results through glyph detection and recognition experiments on papyrus images derived from Homer's *Iliad*. The winning system combined YOLOv8 detectors with DeiT and SimCLR, achieving 93.2% detection mAP and 74.7% recognition mAP at the relaxed IoU threshold of 0.5, with these figures falling to 51.4% and 42.2% respectively at the stricter IoU range of 0.5–0.95, thereby establishing a viable basis for automated papyrology⁷⁹.

The ICDAR example belongs to a broader shift in the field. Beyond the performance of individual systems, the evaluation of these methods has increasingly been organised through community competitions and shared tasks. Workshops such as ML4AL, LT4HALA, and ALP, organised within the frameworks of ACL, LREC-COLING, and NAACL in Bangkok, Turin, and Albuquerque, together with associated shared tasks such as EvaCun, EvaHan, and EvaLatin, show that the use of artificial intelligence for text analysis, lemmatisation, punctuation, and named entity recognition in ancient languages such as Greek, Latin, Sumerian, Akkadian, and Ancient Chinese has become an international, competition based research effort⁸⁰. This is one of the few areas in which comparison is methodologically stronger, because shared tasks define a common dataset and evaluation procedure. However, even there the results remain valid primarily within the limits of the specific task and corpus.

Named Entity Recognition (NER) forms part of a broader linguistic analysis layer that follows recognition and transcription, where models are used not to read signs but to identify entities, assign grammatical categories, and detect textual or scribal irregularities. Transformer based NER models for Greek using XLM-R and Ancient Greek BERT have achieved F1 scores above 90%⁸¹. For Latin, the LatinCy system has reached 97.41% accuracy in part of speech tagging⁸². A noteworthy finding is that ChatGPT can achieve F1 scores of 0.87 for personal names, 0.84 for group entities, and 0.81 for geographical entities in NER tasks on known Latin texts, whereas this performance declines markedly on new and unfamiliar texts⁸³. GrēBERTa, an architecturally ambitious language model, has outperformed previous models for Greek⁸⁴. Logion, a BERT based system developed at Princeton and Cambridge, detects scribal errors in Greek manuscripts and offers correction suggestions⁸⁵. The pattern is therefore similar to that observed in restoration and attribution. That is, performance is strongest where the language, script, and textual tradition are already well represented in the training data.

Work on damaged and fragmentary texts shows a related pattern. Reported advances are strongest where the problem can be reframed as controlled data generation, classification, or restoration rather than open ended interpretation. Deep Aramaic, a project that approaches damaged Aramaic letters through classification rather than visual restoration, generated

⁷⁹ Seuret et al. 2023; Turnbull & Mannix 2025.

⁸⁰ Pavlopoulos et al. 2024; Sprugnoli & Passarotti 2024; Anderson et al. 2025.

⁸¹ Yousef et al. 2023.

⁸² Burns 2023.

⁸³ Woodrum et al. 2025.

⁸⁴ Riemenschneider & Frank 2023.

⁸⁵ Cowen-Breen et al. 2023; Battezzato et al. 2025.

photorealistic letter data consisting of 250,000 training images and 25,000 validation images simulating texture, lighting and damage (Fig. 3), and a ResNet classifier trained on this dataset achieved 95% accuracy on real letter images from the Hadad statue inscription⁸⁶. This result shows that procedurally generated training data can help overcome the fundamental data scarcity bottleneck in machine learning. A similar logic underlies work on ancient Chinese oracle bone⁸⁷ inscriptions, where generative approaches have been used to support inpainting and restoration⁸⁸.

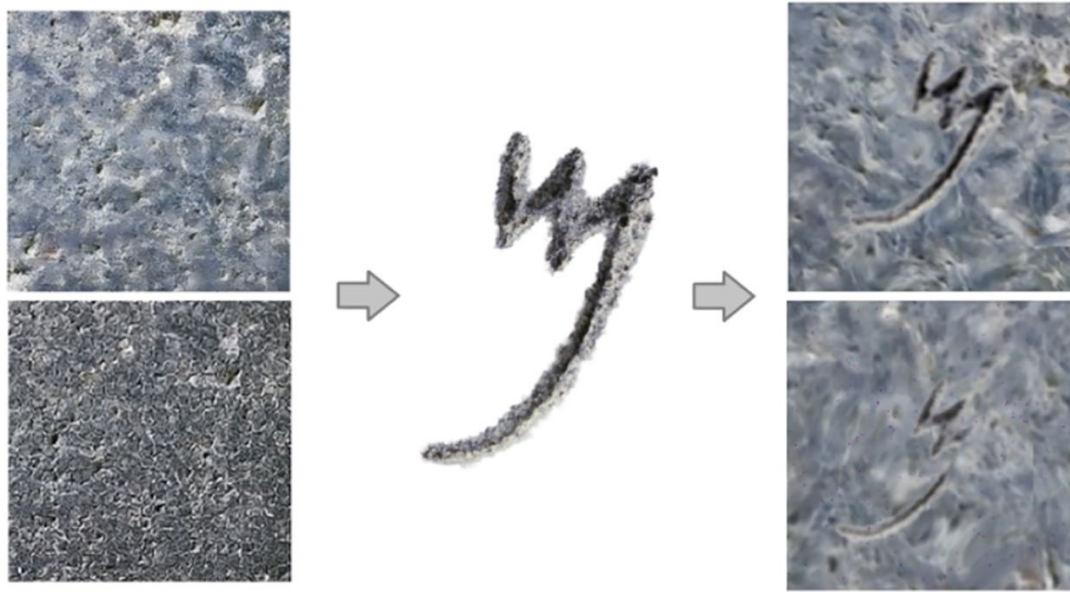


Fig. 3: Synthetic training data generation workflow for Old Aramaic letters. Textural, lighting, and damage augmentations applied to a few real letter forms produce the large dataset (all 22 letter classes) used to train a ResNet classifier for heavily damaged inscriptions. Source: Aioanei et al. 2024, “Deep Aramaic: Towards a Synthetic Data Paradigm Enabling Machine Learning in Epigraphy”. *PLoS ONE* 19/4, e0299297, fig. 12 (CC BY 4.0). Access: <https://doi.org/10.1371/journal.pone.0299297>

A separate but related issue appears in palaeographic dating. In particular, a multi stage deep learning pipeline developed for Greek papyrus fragments has reached 79% accuracy in predicting two century date ranges at the fragment level for well preserved fragments, even though its underlying character level models averaged only 35–45%⁸⁹. This contrast between fragment level and character level performance is a useful reminder that a high headline figure may depend on the unit of evaluation chosen by the study.

The same questions about task specificity, corpus preparation, and specialist dependence also appear in current work from Türkiye. One of the current examples is the project “Three Dimensional Scanning of the Cuneiform Tablets in the Museum of Anatolian Civilizations and the Reading of the Boğazköy Tablets by Artificial Intelligence (Fig. 4)”, conducted in collaboration

⁸⁶ Aioanei et al. 2024. It is warned that scarce labelled data constrain current techniques and have caused tool development for languages such as Old Aramaic to lag behind (Aioanei et al. 2024, 26).

⁸⁷ Oracle bone inscription recognition constitutes one of the most computationally advanced examples outside ancient Greek and Latin. The Oracle Bone Inscription Image Restoration Model (OraGAN), developed for decipherment, operates especially through alignment and multi-scale restoration modules, whereas diffusion models generate oracle bone inscriptions that remain structurally faithful. For further information, see Ma et al. 2025 and Zhang et al. 2025.

⁸⁸ Wang et al. 2024; Zhang et al. 2024b.

⁸⁹ West et al. 2024.

with the Ministry of Culture and Tourism and Ankara University. Within the scope of this project, 1,954 Hittite tablets in the inventories of the Museum of Anatolian Civilizations, the Istanbul Archaeological Museums, and the Çorum Museum were digitised, transfer learning based ResNet, DenseNet, EfficientNet, and ConvNeXt models were tested, and an accuracy rate of 89% was achieved through an ensemble model approach⁹⁰. Another example from Türkiye, although not directly related to ancient texts, stands out as a noteworthy artificial intelligence application in the field of historical text recognition. This application aimed to automatically transcribe Ottoman Turkish texts from Arabic script into Latin script and, through deep learning technology, achieved a low character error rate of 6.59%⁹¹. As a parallel example in the field of text recognition in Türkiye, the Akis transcription software has been evaluated for the transcription of Ottoman Turkish texts⁹². In his evaluation of technologies used in archaeological studies, Tetiker also addressed artificial intelligence tools, stating that although useful tools exist, they do not constitute final solutions capable of replacing the specialist and should be treated only as supportive instruments⁹³. Together, these examples suggest that machine learning applications in Türkiye are currently most visible in cuneiform tablet recognition and historical text transcription, and not across the full range of Anatolian epigraphic traditions.



Fig. 4 Akkadian cuneiform tablet preserving the Hittite version of the Egyptian–Hittite peace treaty, commonly known as the Treaty of Kadesh. The tablet was discovered at Boğazköy/Hattuša and is kept in the Museum of the Ancient Orient, Istanbul Archaeology Museums. Source: Wikimedia Commons, “Treaty of Kadesh.jpg”; photo by locanus, CC BY 3.0. Access: https://commons.wikimedia.org/wiki/File:Treaty_of_Kadesh.jpg

⁹⁰ Takan et al. 2024. For an international study addressing the processing of Hittite tablets for machine learning, see Yavasan & Gordin 2025.

⁹¹ Taşdemir et al. 2024.

⁹² Akcan et al. 2022.

⁹³ Tetiker 2025, 113.

The contrast becomes clearer when Anatolian material is considered more broadly. RTI has been applied to the Luwian inscriptions at the Hittite Sacred Spring Pool of Yalburt⁹⁴. Hittite cuneiform aside, however, no dedicated artificial intelligence or machine learning system targeting the indigenous Anatolian scripts such as Luwian, Lycian, Lydian, or Phrygian has been identified in the accessible academic literature surveyed. This contrast is important since it shows that the regional gap is not an absence of epigraphic material or digital documentation, but the absence of AI-ready datasets and dedicated models for these scripts.

Taken together, these applications show that artificial intelligence has become a genuine working tool in epigraphy, but not in the form of a single, uniformly advancing technology. Its strongest results appear where the scholarly problem can be translated into a clearly bounded computational task, whether restoration, attribution, detection, recognition, lemmatisation, translation, dating, or transcription.

The accuracy figures reported above should therefore be read as task specific results, not as directly comparable measures of reliability. They rest on different languages, corpora, metrics, and evaluation settings, and, as the independent re-evaluation of Ithaca makes clear, results obtained on a system's own benchmark may overstate performance on unfamiliar material.⁹⁵ Seen in this context, these systems are most convincing not as replacements for the epigraphist but as decision support tools that narrow the possibilities and propose readings for expert judgement. The recurring problems of circularity, data bias, and limited independent validation reinforce that conclusion.

Digital Databases and Encoding Standards

Digital databases and encoding standards provide important methodological infrastructures for contemporary epigraphic research. EpiDoc, a subset of TEI XML specifically developed for inscriptions, papyri, and similar documents, has gained international acceptance⁹⁶. More than 100 projects worldwide use this standard⁹⁷. The EFES (EpiDoc Front-End Services) platform has made it easier for projects lacking dedicated digitisation support to publish searchable EpiDoc editions⁹⁸. The encoding logic can be followed in a single example: the diplomatic text of a statue base from Aphrodisias (Fig. 5), its TEI XML markup (Fig. 6), and the EpiDoc encoding of its English translation (Fig. 7).

1 ΟΔΗΜΟΣ
2 ΤΟΝΤΡΩΙΛΟΝΚΑΙ
3 [.] ΠΟΝΚΑΙΤΟΝΑΧΙΛΛΕΑ

Fig. 5: Diplomatic text of a statue base honouring Troilos, the horse and Achilles, Aphrodisias (Karia), showing the lost letters in line 3. Source: *I.Aphrodisias* 2007, 12.10 (CC BY 2.0 UK).

⁹⁴ Durusu-Tanrıöver 2020.

⁹⁵ Cullhed 2026.

⁹⁶ Bodard 2010.; Elliott et al. 2026.

⁹⁷ Bodard & Yordanova 2020.

⁹⁸ Bodard & Yordanova 2020.

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▼<div type="edition" lang="grc">
  <head lang="en">Edition</head>
  ▼<ab>
    <lb n="1"/>
    <w lemma="ὁ">ὁ</w>
    <w lemma="δῆμος">δῆμος</w>
    <lb n="2"/>
    <w lemma="ὁ">τὸν</w>
    ▼<persName type="other">
      <name>Τρωῖλον</name>
    </persName>
    <w lemma="καί">καὶ</w>
    <lb n="3"/>
    ▼<w lemma="ὁ">
      <supplied reason="lost">τὸν</supplied>
    </w>
    ▼<w lemma="ἵππος">
      <supplied reason="lost">ἵπ</supplied>
      πον
    </w>
    <w lemma="καί">καὶ</w>
    <w lemma="ὁ">τὸν</w>
    ▼<persName type="other">
      <name reg="Ἀχιλλεύς">Ἀχιλλέα</name>
    </persName>
  </ab>
</div>

```

Fig. 6: EpiDoc TEI XML encoding of the inscription above (Fig. 5), showing <persName> tagging for Τρωῖλον and Ἀχιλλέα, and <supplied reason="lost"> marking the letters lost in line 3. Source:

I.Aphrodisias 2007, 12.10 (CC BY 2.0 UK). Access: <https://insaph.kcl.ac.uk/iaph2007/xml/iAph120010.xml>

```

▼<div type="translation">
  <head>Translation</head>
  ▼<p>
    The People
    <supplied reason="subaudible">set up the statue of</supplied>
    Troilos and the horse and Achilles.
  </p>
</div>

```

Fig. 7: EpiDoc TEI XML encoding of the English translation, with <supplied reason="subaudible"> marking the verb implied but not present in the Greek text. Source: *I.Aphrodisias* 2007, 12.10 (CC BY 2.0 UK). Access: <https://insaph.kcl.ac.uk/iaph2007/xml/iAph120010.xml>

Major databases collectively contain more than one million records, although overlaps between them must be taken into account. EDCS (Clauss-Slaby) is the largest single collection, with more than 500,000 Latin inscription records⁹⁹. PHI (Packard Humanities Institute) contains the full texts of 178,551 Greek inscriptions¹⁰⁰. EDH (Heidelberg) covered 81,882 Latin and bilingual inscriptions, but its funding ended in 2021, while its data continue to remain openly

⁹⁹ Kolb & Speidel 2025.

¹⁰⁰ Iversen 2007; Assael et al. 2022.

accessible under a CC BY-SA 4.0 licence¹⁰¹. EDR (Rome) contains more than 71,000 inscriptions from the Italian Peninsula. I.Sicily, within the framework of the ERC CROSSREADS grant, includes approximately 3,300 records covering all languages and periods of ancient Sicilian epigraphy¹⁰². IG Online offers the digital edition of *Inscriptiones Graecae* at the BBAW in Berlin and has made the TEI/EpiDoc encoded texts of eleven volumes available with German and English translations under a CC-BY 4.0 licence¹⁰³. Trismegistos, in turn, provides unique and persistent TM numbers for each text and offers application programming interfaces (APIs) with cross references across all major databases¹⁰⁴.

The EAGLE network brought together 593,597 objects and 474,577 texts, 90% of which are stored in TEI/EpiDoc format¹⁰⁵. After the end of EU funding, the International Digital Epigraphy Association (IDEA) has continued to maintain the portal and provides grant support for early career researchers¹⁰⁶. The FAIR Epigraphy project also has published standardised epigraphic vocabularies as RDF Turtle files with stable URIs integrated with Wikidata¹⁰⁷.

Developments have also occurred in the visualisation infrastructures of databases. EDH implements IIIF manifests for high resolution image display¹⁰⁸ and France's *Bibliissima+* consortium has made the CIFM inscription volumes accessible through the *Mirador IIIF* viewer¹⁰⁹. I.Sicily provides links via GitHub to the *Pleiades* gazetteer, EAGLE vocabularies, and *Trismegistos* identifiers¹¹⁰. The *PATRIMONIVM* editor of the Ausonius Institute offers online TEI/EpiDoc editing integrated with a multilingual thesaurus¹¹¹.

Problems, Shortcomings, and Criticisms

Criticisms exist especially concerning the levels of consistency displayed by AI-assisted tools. One of these is the problem of circularity. AI models are trained on corpora that include the hypothetical restorations of earlier scholars. The developers of *Aeneas* explicitly acknowledge this issue. Previous editors' restorations of lost text were retained in the training data, and an additional experiment excluding conjectured restorations produced performance differences of less than 5%, with the model trained without them underperforming across all tasks¹¹². Datasets derived from PHI, such as I.PHI, display a markedly imbalanced distribution caused by quantitative overrepresentation in favour of Attica, and the database carries the accumulated bias of decades of scholarship¹¹³. Classical period data are dominant when compared with Hellenistic, Roman, and Late Antique data¹¹⁴. An analysis based on PHI disk archive data suggests that inscriptions associated with Attica may constitute approximately 10–20% of all published Greek inscriptions, while the geographical distribution map of I.PHI shows the greatest regional

¹⁰¹ Elliott 2014; Feraudi-Gruénais & Grieshaber 2016.

¹⁰² Prag & Chartrand 2018.

¹⁰³ Berlin-Brandenburgische Akademie der Wissenschaften 2019.

¹⁰⁴ Depauw & Gheldof 2013.

¹⁰⁵ Orlandi et al. 2014; De Santis & Rossi 2018.

¹⁰⁶ Liuzzo 2019.

¹⁰⁷ Heřmánková et al. 2025.

¹⁰⁸ Grieshaber 2019.

¹⁰⁹ Turcan-Verkerk 2022, 4.

¹¹⁰ Bodard et al. 2017; Prag & Chartrand 2018.

¹¹¹ Heřmánková et al. 2025.

¹¹² Assael et al. 2025, 149.

¹¹³ Hedrick 1999, 390–392; Assael et al. 2022.

¹¹⁴ Assael et al. 2022, 283; Sommerschild et al. 2023, 720–727.

concentration in Attica¹¹⁵. These figures reflect both ancient inscriptional practices and the structure of modern publication processes, including repetitions caused by discovery, excavation, and republication¹¹⁶. Chronologically, Attica related inscriptions show a marked increase in the IV. century BCE, whereas the epigraphic curves of the eastern Mediterranean appear to rise between the III. century BCE and the II. century CE¹¹⁷. In addition, a significant portion of chronological data at the scale of PHI is either missing or not processable by machine learning methods¹¹⁸. This is one of the factors that makes it difficult to draw generalisable temporal conclusions for the entire PHI corpus. Similarly, the fact that Aeneas was tested on the *Res Gestae Divi Augusti*, a source for which abundant references and contextual information exist, indicates the need for testing on less well known or newly discovered inscriptions. The lack of interpretability forces epigraphists to accept or reject AI suggestions without understanding the model's reasoning process, creating an "explanation gap" that is incompatible with scientific practice¹¹⁹.

Another issue concerns accessibility and reproducibility. Although the code for Pythia and Ithaca has been shared on GitHub, preparing data derived from the PHI database in a raw and machine processable form suitable for machine learning requires specialist knowledge and additional processing stages. In the accessible literature, there are almost no independent replication studies that systematically audit these systems at the level of peer-reviewed publication. An independent comparative study measured Ithaca's Top-1 restoration accuracy at 46.5% on recently published inscriptions absent from its training data, compared with 60.9% for Ithaca on the shared test set used in the same study¹²⁰. By comparison, progress has accelerated in recent years through open source academic competitions and shared tasks.

These criticisms are not confined to Pythia, Ithaca, and Aeneas. They apply to the wider field of AI-assisted ancient text analysis, where reported accuracies often derive from isolated corpora, controlled benchmarks, and non comparable evaluation metrics. A similar caution should extend to the tools developed for scripts other than Greek and Latin, whose reported figures have so far escaped comparable scrutiny. The high accuracies cited for these models rest on metrics and test conditions that are rarely comparable with one another. DeepScribe's 80% is an end-to-end Top-5 result that falls considerably at Top-1 and weakens further on the low frequency signs most important for transcription. Glyphnet's figure of roughly 97.6% was obtained on a small, augmented and class balanced set of isolated hieroglyphs rather than on running text. KuroNet's accuracy above 90% reflects page level recognition on clean competition images rather than on degraded or sealed manuscripts. For genuinely undeciphered scripts the difficulty is sharper still, since the 94.5% reported for the Indus pipeline measures grapheme classification against modern annotations rather than decipherment, there being no ground

¹¹⁵ Hedrick 1999, 390-391; Assael et al. 2022, 280-283.

¹¹⁶ Hedrick 1999, 388-390. Hedrick states that Attic inscriptional production was "overdetermined" and must therefore be explained through multiple factors (Hedrick 1999, 388); for duplicate records and republications in PHI-6, see Hedrick 1999, 390-391.

¹¹⁷ Hedrick 1999, 391-392; Nawotka et al. 2022, 8. For the Hadrianic-period, see also Nawotka et al. 2022, 40-41. The number of inscriptions produced during Hadrian's reign exceeds that of any other emperor, with Trajan ranking second (Grzesik 2020, 59).

¹¹⁸ During the preparation of I.PHI, well-defined date ranges could be produced for 60% of the material, while the remaining 40% was reported to have chronological data that were either missing or not machine-readable (Assael et al. 2022, 283).

¹¹⁹ Berry 2022, 445.

¹²⁰ Cullhed 2026.

truth reading against which the output could be validated. Almost none of these systems has undergone the kind of independent replication that revised Ithaca's accuracy downward, and each is trained and tested on its own corpus, so their headline figures cannot be read as a common measure of reliability. Applied consistently, the critical standard that this study brings to Pythia, Ithaca, and Aeneas tempers the apparent success of the wider field rather than confirming it. This concentration is also visible in scholarly output, where machine learning research clusters on a few well documented languages while most scripts attract little or no work, largely as a function of data availability (Fig. 8).

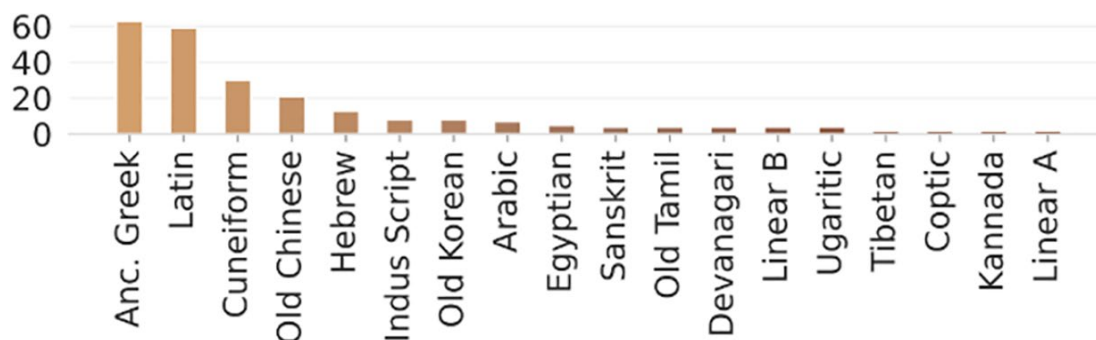


Fig. 8: Distribution of scholarly publications in machine learning by ancient language, showing the pronounced imbalance of the field, in which a few well resourced languages attract most of the work while many scripts remain underrepresented owing to differences in data availability. Source: Aioanei et al. 2024, “Deep Aramaic: Towards a Synthetic Data Paradigm Enabling Machine Learning in Epigraphy”. *PLoS ONE* 19/4, e0299297, (CC BY 4.0). Access: <https://doi.org/10.1371/journal.pone.0299297>

The long term sustainability of digital epigraphic infrastructure constitutes one of the field's most concrete problems. Although EDH is one of the world's most important databases, with approximately 80,000 Latin inscription records, the end of funding from the Heidelberg Academy of Sciences at the close of 2021 caused it to lose all full time staff capacity and to shift from active curation to an archival state¹²¹. The EAGLE project experienced a similar trajectory. After EU funding ended in 2016, the International Digital Epigraphy Association (IDEA) was established in order to sustain the project's outcomes¹²². It has been observed that almost all of the approximately 100 digital humanities projects inherited by King's Digital Lab have struggled to survive because of financial and technical problems, including epigraphic projects such as Inscriptions of Roman Tripolitania (IRT) and Inscriptions of Aphrodisias (InsAph)¹²³. Otis has argued that digitisation projects should be treated like automobiles: they may function for five to seven years at minimal cost, but as time passes, dramatic failures begin to occur¹²⁴. Studies of how digitisation projects decay when updates cease have shown that their “shelf life” is approximately five years and that abandonment results not only in system shutdown, but also in broken links, altered directories, interrupted updates, and the loss of content validity¹²⁵.

The lack of interoperability between databases is another fundamental problem. Major databases such as EDCS, EDH, EDR, EDB, PHI, Trismegistos, and I.Sicily each have their own

¹²¹ Feraudi-Gruénais & Grieshaber 2016; Orlandi 2021.

¹²² Liuzzo 2019, 216–230.

¹²³ Smithies et al. 2019.

¹²⁴ Otis 2023.

¹²⁵ Meneses & Furuta 2019, i129–i134; Otis 2023.

storage structure, data identification system, and conceptual model for defining what constitutes an epigraphic record. Although the EAGLE consortium uses a shared data schema, the participating databases continue to preserve differing understandings¹²⁶. In harmonisation processes, there are basic disagreements over what the “cultural heritage object” actually is. Some studies foreground the inscribed object, others the text, while another group adopts more holistic approaches¹²⁷. There is increasing uncertainty concerning digitisation, and this should be characterised less as a technical problem than as a cultural one¹²⁸.

There are marked differences between awareness and implementation in compliance with the FAIR principles¹²⁹. According to the results of the FAIR Epigraphy scoping survey, 27% of digital epigraphy projects are no longer active, while 23% have no access to technical support¹³⁰. The majority of digital epigraphic data do not meet FAIR requirements, different scholarly traditions diverge in their classification of inscription types, material supports, and writing techniques, and even basic comparative questions require manual reconciliation¹³¹. The adoption of EpiDoc is also hindered by the need for technical skills and by the initial learning barrier¹³².

Conclusion

Since the 19th century, epigraphic documentation has undergone methodological transformations through paper squeezes, photography, digital databases, and AI-assisted analysis. Each stage has contributed to progress in the field, but has also introduced its own problems. RTI and SfM have today become routine tools, the software ecosystem is continuously renewed and while databases have gained scale, dependence on funding and maintenance gaps create chronic fragility. The accuracy rates claimed in the literature for AI tools, which have been added as the most recent link in this chain, have not resolved the existing problems of the field, because they have often been presented without an established verification infrastructure. Rather, they have brought these problems back into discussion in a different form. None of these methods is sufficient on its own. The strongest results are obtained when the tools complement one another. RTI makes illegible surfaces visible, SfM photogrammetry produces measured and shareable models, and multispectral imaging reveals traces invisible to the eye, such as ink or pigment. Just as these methods are insufficient when used in isolation, none of the outputs acquire meaning without specialist interpretation. AI tools such as Aeneas have provided concrete contributions in specific tasks such as chronological and geographical attribution for well documented inscriptions, yet the literature states that they must be tested again on material from less well known regions. This caution is not limited to Greek and Latin focused tools. The high accuracy rates reported for single script or corpus bound systems such as DeepScribe, Glyphnet, and KuroNet must likewise be evaluated within their own datasets, task definitions, metrics, and test conditions. These tools should therefore be positioned not as independently verified methodological solutions, but as a decision support layer whose limits have not yet been fully defined. Their limited interpretability reinforces this position. Since the

¹²⁶ Álvarez et al. 2011, 225.

¹²⁷ Liuzzo 2015.

¹²⁸ Bodel et al. 2024, 91–117.

¹²⁹ Findable, Accessible, Interoperable, Reusable. For more information, see Wilkinson et al. 2016.

¹³⁰ Although 73% of survey respondents were familiar with the FAIR principles, the number of projects using RDF or other standards was very low (Heřmánková et al. 2022, 15–16).

¹³¹ Heřmánková et al. 2025.

¹³² Álvarez et al. 2010, 222–234; Bodard & Stoyanova 2016, 51–68; Bodard & Yordanova 2020, 17–35.

reasoning behind a model's suggestion usually remains opaque, the decision to accept or reject a proposed reading must rest with the epigraphist rather than with the system. The concentration of AI applications on Greek and Latin indicates not merely a technical preference, but a structural inequality within the discipline. While AI projects developed through Hittite tablets in Türkiye and RTI applications at Yalburt point to active movement, no dedicated artificial intelligence or machine learning system targeting Luwian, Lycian, Lydian, or Phrygian inscriptions was identified in the accessible academic literature surveyed.

The progress of the field depends largely on the sustainability of its data infrastructure. The gap between completing a digitisation project and keeping it alive for years has not yet been closed. Compliance with the FAIR principles, the wider adoption of the EpiDoc standard, and interoperability between databases constitute the technical side of this gap, while the inclusion of new languages and the participation of researchers from different regions in international projects are equally decisive. As long as the published literature lacks systematic analyses of failure rates, ethical frameworks, and performance studies comparing AI-assisted tools with senior specialists under realistic conditions, such tools will continue to reproduce the limitations of the existing material. This review is itself necessarily partial. It rests on the literature reachable through the databases and search terms set out above rather than on an exhaustive survey, and the rapid pace of the field means that some very recent work will inevitably have escaped it. For this reason, the use of AI tools in digital epigraphy remains not a verified methodological revolution, but an experimental research field with considerable promise and a still weak evidential foundation.

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