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Commenting on the Computational Processing of the Two Cypriot Signaries of Bronze Age

Evangelos Papakitsos
** School of Physics, University of the Witwatersrand, Johannesburg, South Africa,*

Abstract: *The present study is focused on the similarities of the two Cypriot pre-alphabetic scripts of Bronze Age, that is the Cypro-Minoan and the Cypriot Greek syllabaries. The paper presents the mainstream views on the nature of these scripts that the former is considered undeciphered, their decipherment attempts by linguists, and the computational approaches for this purpose. Subsequently, two linguistic theories are discussed for the scripts' nature and the assignment of the corresponding phonetic values, namely, the Cretan and the Cypriot Protolinear scripts. The former theory is the most complete, detailed, comprehensive and well-documented theory on the descent of the Cypriot scripts. Accordingly, Cypro-Minoan probably renders an Akkadian dialect, while the grids (i.e., the two-dimensional alphabetic ordering of their signs' phonetic values regarding consonants' and vowels' sounds) of both Cypriot scripts are presented and compared, as a prerequisite for computational processing.*
Keywords: *Aegean scripts, Cretan Protolinear, Cypriot Protolinear, Cypro-Minoan, Cypriot Greek Syllabary, decipherment.*

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I. INTRODUCTION

During the Bronze and Early Iron Ages, Mainland Greece, Crete, and Cyprus were dominated by a closely related group of writing systems that predated the classical Greek alphabet [1]. Uncovered largely by Sir Arthur Evans at the beginning of the 20th century, these writing systems are categorized as the Aegean scripts [2]. This family of scripts illustrates a remarkable history of linguistic and technological adaptation; as regional populations shifted and new societies emerged, existing writing systems were systematically modified to document entirely distinct languages [3], [4].

The Aegean script family comprises five distinct pre-alphabetic writing systems that function primarily as syllabaries; within these systems, individual characters denote consonant-vowel combinations (such as *ci*, *to* or *pa*) as opposed to isolated phonetic letters [5]. Chronologically, Cretan Hieroglyphic is recognized as the earliest script in this lineage. It was succeeded by Linear A, which in turn served as the parent script for both Linear B and Cypro-Minoan, while the Cypriot Greek Syllabary is firmly established as the final development in the family. Yet, recent studies rearrange this ordering according to the Cretan Protolinear Script theory [6], as it will be explained next.

II. HISTORICAL CONTEXT

This study adopts the Cretan Protolinear Script theory [7], which posits a foundational script of 120 syllabograms from which Linear A, Linear B, and Cretan Hieroglyphics (grouped here as "Cretan" scripts to differentiate them from Cypriot variants) originally diverged [8]. This shared repertoire encompasses all Linear A and B syllabograms, regardless of whether they are common to both writing systems [9]. Consequently, this perspective challenges the orthodox view by framing Linear A and B as sibling scripts rather than a parent-child lineage (see also [10]). Furthermore, it treats Cretan Hieroglyphics simply as an ornamental and ritual variant of the Cretan Protolinear Script [11].

Methodologically, this theory dictates how phonetic values are assigned to the syllabograms. Unlike Near Eastern scripts, the phonetic values of Aegean signs were not immediately linked to their pictorial origins following their initial discovery. This disconnect persists in modern computational processing, reflecting a broader omission of comparative linguistics. Kenanidis [12], [13] first noted that the phonetic value of each sign corresponds to the Archaic Sumerian word for the object abstractly depicted, operating on the rebus principle [14], [15]. For numerous signs, the visual and vocalic links to their mainly pre-cuneiform Sumerian equivalents are clear and undeniable [9]. Although mainstream archaeology continues to overlook this linguistic and pictorial affinity to Archaic Sumerian despite supporting independent studies, these findings demonstrate that Archaic Sumerian served as the model language for the creation of the Cretan scripts, even if it was not necessarily the language they ultimately recorded (as seen in Linear B).

Considering the above notion of Archaic Sumerian, it should be stressed that anthropological and genomic analyses of the Minoan population indicate two primary human phenotypes: a Neolithic Mediterranean type (85%) and an Iranian/Armenian type (15%), derived from dozens of skeletons excavated across several ancient cemeteries [16]. This demographic diversity aligns with accounts by Homer and Strabo, who noted that multiple nations speaking various languages inhabited Minoan Crete [17]. Regarding the archaeological corpus, roughly 90% of the approximately 1,500 Linear A artifacts consist of administrative clay documents, with the remainder comprising formulaic religious inscriptions on diverse materials. Although Linear A fragments appear sporadically outside Crete, nearly 90% of the recovered tablets originate from a single southern Cretan site: the settlement of AgiaTriada.

Given the multi-ethnic environment described by ancient scholars, the inhabitants of AgiaTriada may have spoken a different language than those in other major centers like Phaistos, Khania, Zakros, Knossos, or Malia. Furthermore, the overwhelmingly administrative and commercial nature of these inscriptions suggests that foreign traders and delegates—representing different cultures and anthropological types—frequented these trading posts without leaving a lasting genetic imprint due to the transient nature of their stay. Even within a single site like AgiaTriada, the tablets could record multiple languages if the settlement served as a regional hub for compiling administrative reports. This phenomenon is mirrored in later Linear B tablets, which record both Greek and non-Greek personal names. Consequently, because Linear A functioned primarily as an administrative tool, it may have rendered multiple languages across Crete [18]. Viewed this way, the administrative tablets might not reflect a single, unified spoken language, but rather a standardized, cross-linguistic code for record-keeping.

Accordingly, the most detailed linguistic approach on the linguistic affinity of the rendered so-called Minoan language is that of Hurrian [19]. Hurrian is a member of the Hurro-Urartian (Vannic) language family, a group originally spoken throughout ancient northern Mesopotamia, Syria, and southeastern Anatolia, with a highly specific phonology that modern linguists have thoroughly mapped. Interpreting Linear A as a dialect or variant of Hurrian—an ancient, agglutinative, non-Indo-European language famously tied to the Mitanni Kingdom—represents an active, highly detailed decipherment hypothesis. Far from relying on broad "macro-family" comparisons, this framework analyzes exact morphological structures and onomastics (naming conventions) to link the Minoan clay tablets to cuneiform records excavated across Syria and Anatolia. Proponents argue that Linear A shares distinct grammatical and phonological traits with Hurrian, a language that became significantly more accessible to structural analysis following the 1983 discovery of the Hurrian-Hittite bilingual tablets at Boğazkale [8].

Considering the domination of the Sumerians' religion in Central Eurasia [20], a probable historical scenario hypothesized herein is that Hurrian populations migrated to Crete between 2700-2600 BCE, bearing the Sumerians' religion and culture. Given the historical reality that literacy was almost a monopoly of the clergy, the Hurrian clerics designed the Cretan Protolinear script based on their sacred language (Archaic Sumerian) to render other languages, including their own (i.e., Hurrian).

Subsequently and according to Kenanidis [13], the Cypriot Protolinear Script was developed concurrently with the Cretan Protolinear Script—a process attributed here to the Sumerian clergy of Cyprus—utilizing the same underlying principles, which accounts for their pictorial resemblance. The Cypro-Minoan script represents the evolutionary remnant of this original writing system. A detailed study [21] elucidates the structural nature of its syllabograms and offers a decipherment of texts that appear to record an Akkadian dialect. The historical presence of Akkadians in Cyprus, dating back to the reign of King Sargon the Great in the 23rd century BCE, is well-documented in the Mari Tablets [16], as is their established Sumero-Akkadian bilingualism [22].

III. CYPRO-MINOAN SYLLABARY

Dating from approximately 1550 to 1050 BCE, the Cypro-Minoan script of the Late Bronze Age is generally understood to have evolved from Linear A. Modern computational analyses have sparked intense debate regarding whether the script encodes a single, cohesive language or a network of distinct but closely related dialects [23]. Decipherment efforts are severely hindered by a scarce epigraphic record, which comprises fewer than 300 total inscriptions primarily found on clay balls, ceramic vessels, and cylinder seals [24]. Nevertheless, since the initial application of the comparative method in the early twentieth century, scholars have consistently maintained rigorous, systematic efforts to decode the script.

Initial progress toward decoding the script focused on establishing its genealogical roots rather than achieving an immediate translation. Following his discovery of pre-alphabetic writing systems on Crete, Sir Arthur Evans (in 1909) examined Bronze Age artifacts from Cyprus and identified structural parallels between the Cretan and Cypriot scripts. Ultimately, Evans introduced the term "Cypro-Minoan," positing that the writing system developed as a regional variant derived from Minoan Linear A [25], [26].

Johannes Sundwall (in 1915) provided another early attempt at phonetic mapping, utilizing a straightforward comparative framework to read the script. This methodology rested on the assumption that because George Smith had successfully deciphered the Iron Age Cypriot Greek Syllabary in 1871, any visual identity between a Bronze Age Cypro-Minoan character and an Iron Age Cypriot sign implied an identical phonetic value. On this basis, Sundwall published a comparative table in 1915 that paired 30 Cypro-Minoan signs with their presumed Classical equivalents to decipher isolated words. However, this approach faced heavy criticism for failing to account for centuries of paleographical evolution and script divergence [27].

A major methodological shift occurred with the work of John Franklin Daniel (in 1941), who recognized that establishing a standardized sign list is a prerequisite for any successful decipherment. Previously, researchers had failed to differentiate between random isolated marks, stamps, and actual multi-sign inscriptions [26]. Daniel introduced a rigorous scientific framework in his seminal 1941 paper, "Prolegomena to the Cypro-Minoan Script" [27]. By separating genuine writing from simple "potmarks" used merely for cargo or ownership identification, he cataloged a clean signary of 73 distinct characters. Furthermore, he proposed tentative phonetic values for 26 of these signs by tracing geometric evolutionary paths from Linear A down to the later Cypriot Syllabary [27], [28]. Regrettably, Daniel's sudden death in the field prevented him from testing his matrix against the larger tablet discoveries of the late 1940s and 1950s.

The mid-twentieth century was marked by post-Linear B decipherment efforts and the development of the Hurrian Hypothesis (1950s–1970s). Michael Ventris' successful 1952 decipherment of Linear B using an algebraic grid sparked widespread optimism, prompting scholars to apply his grid and phonetic values directly to Cypro-Minoan. This approach rested on the assumption that the underlying language might represent an archaic dialect of Greek or a known ancient Near Eastern tongue [26]. Extending the work of Ventris and John Chadwick, researchers shifted their focus to newly excavated clay tablets from Enkomi and Ugarit (Syria), which offered longer, more complex Cypro-Minoan texts [24]. Although Ventris and Chadwick conducted rigorous structural analyses—tracking sign frequencies and mapping prefixes and suffixes—they ultimately concluded that the available dataset was too limited to build a reliable, independent internal grid.

In the 1970s, French epigrapher Emilia Masson introduced the Hurrian Hypothesis, fundamentally altering the field by categorizing the script into three distinct sub-classes based on geographical provenance and palaeographical variations. These classifications included CM1 (the general Cypriot corpus), CM2 (dense, specialized tablets excavated at Enkomi), and CM3 (inscriptions recovered from the Syrian trading hub of Ugarit). Masson then attempted a linguistic decipherment by concentrating specifically on the CM3 texts. Given Ugarit's status as a multi-ethnic diplomatic center, she posited that Cypro-Minoan was utilized to record Hurrian, an established, non-Indo-European language of the ancient Near East [29]. Although she successfully isolated recurring character sequences that aligned with Hurrian onomastic (naming) patterns, she ultimately acknowledged that her efforts produced only sporadic readings rather than a comprehensive, systemic decipherment [28].

Isolated attempts at full decipherment persisted into the late twentieth and early twenty-first centuries, including Jan Best and Fred Woudhuizen's proposal of a Semitic/Luwian hybrid language, alongside various attempts to interpret the text as Eteocypriot—the indigenous, unclassified pre-Greek language of Cyprus [30]. However, contemporary linguistic consensus, championed by epigraphers and computational specialists such as Silvia Ferrara and Philippa Steele, treats all comprehensive decipherment claims with deep skepticism, viewing them as premature and highly improbable [26]. Consequently, modern scholarship has largely moved away from direct translation efforts. Instead, current research prioritizes advanced 3D imaging, digital palaeography, and structural analyses of the script's socio-economic functions within Late Bronze Age Mediterranean trade networks [31], [32].

Concurrently, innovative computational techniques are being applied to Cypro-Minoan scholarship. It is vital, however, to clarify the exact scope of these digital initiatives: given that the total corpus is exceptionally restricted—comprising fewer than 300 inscribed artifacts [33] — current computational linguistics and artificial intelligence applications do not aim to actively "decipher" or translate the underlying language. Rather, they are designed to resolve the fundamental architectural and palaeographic prerequisites necessary for any future decipherment. To date, the primary computational breakthroughs and methodologies applied to Cypro-Minoan include the following three techniques:

3.1 Unsupervised Deep Learning & Sign Reclassification

Historically, the Cypro-Minoan script was divided into three distinct sub-scripts (CM1, CM2, and CM3) under the suspicion that they recorded separate languages. A primary obstacle to decipherment involved distinguishing true graphemes (distinct signs) from allographs (stylistic variations produced by different scribes). To address this without human bias, a landmark 2022 study utilized an unsupervised convolutional neural network (CNN) rooted in computer vision and natural language processing. The deep learning model mapped sign drawings into a vector space while integrating sequence data to analyze character contextual

interactions. The model revealed that the physical inscription medium—whether clay balls, tablets, or metallic vessels—severely distorted sign morphology. Once this "medium bias" was computationally corrected, the neural network demonstrated that Cypro-Minoan constitutes a single, unified writing system rather than three separate sub-groups [33]. By resolving this issue, the study provides paleographers with a standardized signary, establishing a critical foundation for eventual linguistic decipherment.

To understand how the unsupervised neural network grouped these characters, it is useful to examine its dual-architecture design. The 2022 study by Corazza et al. [33] neutralized subjective human preconceptions by processing sign data through a deep learning pipeline that integrated computer vision with natural language processing (NLP). Lacking any semantic knowledge of the script, the AI evaluated the data strictly based on visual properties and positional distribution. This methodology relied on a two-pronged pipeline that categorized each character using two distinct vectors:

- Visual Geometry (Morphological Analysis): A Convolutional Neural Network (CNN) processed digitized illustrations of the signs by decomposing their strokes, curves, and angles. It then plotted each character into a geometric vector space, ensuring that visually analogous signs clustered in close spatial proximity.
- Contextual Environment (Distributional Analysis): Utilizing a language modeling technique similar to Word2Vec, the algorithm analyzed every occurrence of a sign across the entire corpus. By tracking adjacent characters, the model effectively mapped out the sequential behavior and environmental patterns of each sign.

Overcoming “medium bias” represented a primary objective of this research. Historically, the foremost obstacle for epigraphers stems from the diverse materials utilized to record Cypro-Minoan; a scribe lightly incising wet clay produces an entirely different line quality than one incising a rigid bronze vessel or rolling a cylinder seal. Human researchers, misled by these stylistic variations, classified the script into three separate corpora (CM1, CM2, and CM3). Conversely, the unsupervised model cross-referenced overlapping geometric traits with contextual distributional data. It mathematically demonstrated that these discrepancies were entirely environmental—determined by the material and document type—rather than linguistic. Upon clustering the data, the model revealed that morphologically distinct signs from CM1 and CM2 yielded nearly identical contextual neighbor scores. Consequently, the AI proved that these variants were identical characters executed in divergent scribal hands.

3.2 Cross-Script Target Modeling

Given that Cypro-Minoan is traditionally modeled as a transitional evolutionary link between Cretan Linear A and the later, deciphered Cypriot Greek Syllabary, computational linguists have leveraged these known systems to map the unknown script. Recent doctoral and institutional initiatives have focused on training unsupervised models using the structural framework of the Cypriot Greek Syllabary as a known target. By programming algorithms to recognize the syllabic mechanics of this geographical descendant, researchers use artificial intelligence to reconstruct disputed allographs within Cypro-Minoan and map structural, statistical pathways connecting the two writing systems [23].

3.3 Algorithmic Combinations & Similarity Metrics

Alternative computational pipelines evaluate Cypro-Minoan’s parent script, Linear A, utilizing feature-based similarity metrics to mathematically map characters against known writing systems like the Carian alphabet and the Cypriot Greek Syllabary. By constructing algorithmic models that quantify graphic proximity and phonological probability across these interconnected script families, researchers aim to eliminate the human error of retrofitting phonetic values where they do not belong [34]. Nevertheless, as argued herein, geometric simplicity inherently diminishes a grapheme's diagnostic utility when analyzed in isolation from its contemporary cultural context.

Both domains offer valuable insights into the intersection of modern data science and classical historical linguistics. Having outlined the classification mechanics of the unsupervised neural network, attention now turns to the structural relationship between Cypro-Minoan and its presumed parent script, Linear A. Conventionally classified as a direct offshoot of the Cretan system, Cypro-Minoan emerged when Bronze Age Minoan merchants established dense maritime trade routes with Cyprus, prompting local populations to adopt and modify the script to record their indigenous language (frequently termed “Eteocypriot”). Both systems share a deep linguistic architecture, and they can be compared in several critical areas:

- Syllabic Architecture: Both scripts function primarily as syllabaries rather than alphabets, where individual signs typically represent open consonant-vowel combinations (e.g., ta, ma, ri).
- Visual Cognates: Roughly half of the signs within the Cypro-Minoan corpus possess clear visual equivalents in Linear A, suggesting that core graphemic shapes migrated directly from Crete to Cyprus.

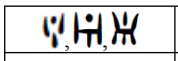
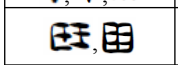
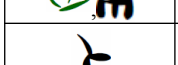
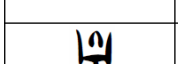
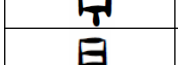
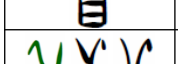
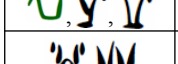
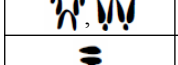
- Logographic Divergence: Linear A relies heavily on logograms or ideograms to signify whole lexical items (e.g., "wine", "wheat", or "person"). Conversely, Cypro-Minoan almost entirely lacks these symbols, operating on a nearly pure phonetic baseline.
- Functional Distribution: While Linear A served a predominantly administrative purpose dedicated to economic accounting and ritual libation formulas, Cypro-Minoan is highly varied, appearing on personal possessions, prestige goods, clay balls, and monumental architecture.
- Palaeographical Simplification: Linear A retains intricate, pictorial flourishes inherited from its hieroglyphic ancestry. In contrast, Cypro-Minoan features drastically simplified character forms with reduced stroke counts designed for rapid incising or stamping.

This structural lineage introduces a compelling paradox for computational models. Because the historical successor to Cypro-Minoan—the Cypriot Greek Syllabary—is fully deciphered, researchers can reliably extrapolate the phonetic values of many Cypro-Minoan characters. Yet, even if an artificial intelligence successfully reconstructs the exact phonology of the script, the underlying language itself remains entirely unclassified.

3.4 The Cypriot Protolinear Script Theory

Probably, the latest decipherment attempt of historical linguistics is that of IoannisKenanidis [21]. Subsequently, as posited by Kenanidis [13], the Cypriot Protolinear script developed alongside its Cretan counterpart—a divergence here attributed to a Sumerian priesthood on Cyprus—utilizing identical structural principles to explain their close pictorial similarities. From this perspective, the Cypro-Minoan (CM) script survives as the evolutionary remnant of that foundational system. A detailed examination elucidates the precise structural mechanics of these syllabograms (Table 1) and offers a decipherment of texts that seemingly record an Akkadian dialect.

Table 1 The Cypro-Minoan syllabary's provisional grid [35]

	A	E	I	O	U	Ə	Ø	Y
-								
B								
C								
D								
G								
H								
J								
L								
M								
N								
P								
Q								
R								
S								
T								
V								
W								
Z								
Θ								

This linguistic assignment aligns with the historical presence of Akkadians on Cyprus, which dates to the reign of King Sargon the Great in the twenty-third century BCE and is attested both by the Mari Tablets [16] and their established Sumero-Akkadian bilingualism [22]. Yet, this original decipherment attempt lacks a grid, which is a two-dimensional table where the syllabograms are placed according to their preceding consonantal phoneme (sound) and the following vowel. In the next provisional grid (Table 1), based on this decipherment [21], each row contains all the syllabograms that start with the same consonant in standard alphabetical order, and each column contains all the syllabograms with the same vowel following the preceding consonant. The first row is an exception that lists the single-vowel syllabograms (i.e., there is no preceding consonant). The signs are taken from [35].

The grid of Table 1 includes 100 alternative signs for 73 attested phonetic values. In the alphabetical order, G denotes Ĝ (ŋ), H denotes IPA's /x/ (not /h/), and Z denotes IPA's /ɕ/ (SH). Many CM syllabograms (30) are either identical or obvious pictorial simplifications of the equivalent Cretan Protolinear script's (Linear A/B's) syllabograms (i.e., same phonetic value) [13], as presented in Table 2.

Table 2 The common signs between Cretan Protolinear (Cretan) and Cypro-Minoan (CM) scripts

Syllabary	A	CA	CI	DA	DE	DI	JA	LA	LO	LƏ
Cretan										
CM										
Syllabary	NA	NE	PA	PI	PO	PU	QO	RA	RE	RO
Cretan										
CM										
Syllabary	RU	RƏ	SA	SE	SI	TE	TI	TO	WA	WE
Cretan										
CM										

The grid of Table 1 is not complete according to the Cypriot Protolinear Script Theory.

IV. CYPRIOT GREEK SYLLABARY

The field of modern historical linguistics was built on the successful decipherment of two readable ancient scripts: Linear B and the Cypriot Greek Syllabary. In 1871, English Assyriologist George Smith fully cracked the Cypriot Greek script using a bilingual stone inscription found in Idalium (modern-day Dali, Cyprus). The artifact featured matching texts in both the Phoenician consonantal alphabet (abjad) and the Cypriot Greek Syllabary. Because the script turned out to record the Greek language, it conclusively proved for the first time that a syllabic writing system could be used to express Indo-European languages [1].

Attested during the Iron Age (c. 1100–300 BCE), the Cypriot Greek Syllabary descended from the Cypro-Minoan script and coexisted alongside the early Greek alphabet [23]. While primarily employed to record the Arcado-Cypriot dialect of Greek, this writing system was also occasionally used to write Eteocypriot, an indigenous and still poorly understood language of ancient Cyprus [1]. The corresponding grid is presented in Table 3 [36].

Table 3 The Cypriot Greek syllabary's grid

	A	E	I	O	U			A	E	I	O	U
-												
J							R					
K							S					
L							T					
M							X					
N							W					
P							Z					

The grid of Table 3 contains 56 signs for equal number of syllabograms and their corresponding phonetic values. An excellent explanation of the sketches of signs and their rendered phonetic values, according to the rebus principle, is available in [21]. Many Cypriot Greek syllabograms (28) are either identical or obvious pictorial simplifications of the equivalent Cypro-Minoan syllabograms of Table 1 (i.e., same phonetic value), as presented in Table 4.

Table 4 The common signs between Cypro-Minoan (CM) and Cypriot Greek (CG) scripts

Syllabary	A	I	CI/KI	QO/KO	LA	LE	LI	LO	MU	NA
CM										
CG										
Syllabary	NE	PA	PO	PU	RA	RE	RO	SA	SE	SI
CM										
CG										
Syllabary	SO	TA	TI	TO	WE	WI	WO	ΘA/ZA		
CM										
CG										

The long-observed affiliation of the two Cypriot scripts is thereby verified. Furthermore, 19 signs of the above are indirectly equivalent to the Cretan Protolinear script's syllabograms through their Cypro-Minoan resemblance (A, KI/CI, KO/QO, LA, LO, NA, NE, PA, PO, PU, RA, RE, RO, SA, SE, SI, TI, TO and WE), while four (4) of the signs in Table 3 are directly equivalent to the simplified Cretan Protolinear script's syllabograms (Table 5).

Table 5 Some common signs between Cypriot Greek (CG) and Cretan Protolinear (Cretan) scripts

Syllabary	NO/GO	PE/BE	TE
CG			
Cretan			

Thus, the pictographic affiliation of the two Protolinear scripts (Cretan and Cypriot) is confirmed.

V. CONCLUSION

This study examines the structural similarities between Cyprus' two Bronze Age pre-alphabetic writing systems: Cypro-Minoan and the Cypriot Greek Syllabary. After reviewing mainstream consensus regarding the undeciphered status of the former, alongside previous linguistic and computational decipherment attempts, this paper evaluates two supplementary theories on their nature and phonetic values: the Cretan and the Cypriot Protolinear Script hypotheses. Of these, the Cretan Protolinear Script theory offers the most thorough, detailed,

and robustly documented account of the scripts' lineage, proposing that Cypro-Minoan likely records an Akkadian dialect. Finally, to facilitate future computational processing, this paper presents and compares the sign grids, mapping the two-dimensional consonantal and vocalic phonetic values for both Cypriot scripts.

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