The Credit Cards of the Bronze Age: Indus Seals and the Origins of Institutional Credit

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Abstract

The Indus Valley Civilization (c. 2600–1900 BCE) sustained long-distance trade across five million square kilometers without coinage. This paper proposes that Indus stamp seals functioned as institutional credit instruments—the structural equivalent of modern credit cards—within a guild-backed or administratively backed transaction system. The hypothesis is grounded in five convergent lines of evidence drawn from a prior statistical analysis of 179 Mohenjo-Daro unicorn seal inscriptions (Kriger & Hunt, 2026): (1) near-total sequence uniqueness (98.3%, $p < 0.001$), analogous to unique account numbers; (2) positional entropy profiles consistent with formatted alphanumeric codes rather than natural language; (3) intaglio manufacture enabling impression transfer, functionally identical to embossed credit card imprinting; (4) centralized, tamper-resistant production (steatite fired to enstatite), paralleling institutional card issuance; and (5) archaeological find contexts—minimal wear, personal portability, international transport to Mesopotamia, and burial with the owner—consistent with a non-transferable credential guaranteeing the bearer's creditworthiness. The paper reconstructs a plausible transaction cycle: identification via seal presentation, transaction recording on perishable media or clay tags, and inter-institutional clearing. This interpretation is situated within the broader scholarship on pre-monetary credit, particularly Graeber (2011) and Hudson (2018), who demonstrate that credit systems preceded coinage in the ancient world. The credit-instrument hypothesis is compatible with Mukhopadhyay (2023)'s administrative interpretation and extends the registration-code framework of Kriger & Hunt (2026) by specifying the economic function that the codes may have served. All claims are qualified to the Mohenjo-Daro unicorn subcorpus; generalization requires replication on the full corpus.

Keywords: Indus script, credit instruments, pre-monetary economies, institutional credit, Indus seals, Bronze Age trade, cashless transactions, registration codes, Mohenjo-Daro

Contents

1 Introduction

The Indus Valley Civilization presents a paradox. At its peak (c. 2600–1900 BCE), it was the largest Bronze Age civilization by area, spanning approximately one million square kilometers across what is now Pakistan and northwestern India (Kenoyer, 1998). It maintained standardized weights following a binary ratio system (1:2:4:8:16:32:64), uniform urban planning with sophisticated drainage, long-distance trade networks reaching Mesopotamia, the Persian Gulf, and Central Asia, and professional craft production of remarkable quality (Kenoyer, 1998; Possehl, 2002). Yet it produced no coinage. No currency of any kind has been identified in the archaeological record.

How did a civilization of this scale and complexity conduct trade?

The standard answer—barter supplemented by commodity money (grain, metals weighed against standardized weights)—is not wrong, but it is incomplete. As Graeber (2011) demonstrated in a comprehensive historical and anthropological survey, credit systems preceded coinage in every documented case. Hudson (2018) showed specifically that Bronze Age Mesopotamian economies operated primarily on credit: debts were recorded, tabs were run, and settlement occurred periodically—not at the point of transaction. The idea that barter preceded money, and money preceded credit, is, as both authors argue, a modern myth unsupported by archaeological or ethnographic evidence.

If credit preceded coinage in Mesopotamia—the Indus civilization's contemporary trading partner—then it is reasonable to ask whether the Indus civilization also operated a credit system. And if so, what was the physical instrument of that credit?

This paper proposes that the answer has been in front of us for a century: the Indus stamp seal.

Approximately 4,000 inscribed seal objects have been recovered from Indus sites (Mahadevan, 1977; Parpola, 1994; Wells, 2015). These small steatite squares (2–3 cm per side), carved in intaglio with an animal motif and a short sign sequence, fired to permanent enstatite, fitted with a perforated boss for cord suspension, and carried on the person, exhibit every structural property of a modern institutional credit instrument. A prior statistical analysis (Kriger & Hunt, 2026) of 179 Mohenjo-Daro unicorn seal inscriptions established that the sign sequences function as structured registration codes: unique, positionally constrained, mixed alphanumeric, centrally manufactured, and tamper-resistant. The present paper takes the next step: it asks what *economic function* such registration codes served.

The answer proposed here is that the seal was a credit token—a guild-issued or administratively issued credential that identified the bearer as a member of a solvent institution and guaranteed the bearer's transactions. The seal was not money. It was a claim on money—or, more precisely, a claim on future settlement between institutions. It functioned in the Indus economy as the credit card functions in ours: as a portable, tamper-proof, institutionally backed instrument that enables transactions without the physical transfer of value at the point of sale.

This is not a metaphor. The structural parallels are exact and will be developed formally in Section 9. The paper proceeds as follows: Section 2 maps the logical structure of the argument;

Section 3 reviews the relevant scholarship; Section 4 develops the conceptual framework; Section 5 presents the mathematical and statistical foundations; Section 6 reconstructs the transaction cycle; Section 9 develops the structural parallels with modern credit instruments; Section 10 grounds the hypothesis in archaeological evidence; Section 11 discusses implications; Section 12 acknowledges limitations; and Section 13 identifies future directions.

2 Logical Structure of the Argument

The argument proceeds through seven linked steps:

Step 1: The economic puzzle. The Indus civilization conducted large-scale, long-distance trade without coinage. Barter and commodity money alone cannot account for the scale and regularity of this trade (Section 3).

Step 2: Credit precedes coinage. Historical and anthropological evidence demonstrates that institutional credit systems preceded coinage in every documented ancient economy (Graeber, 2011; Hudson, 2018). The Indus civilization's Mesopotamian trading partners operated on credit. The absence of Indus coinage is therefore not an absence of a monetary system—it is evidence that the monetary system was credit-based (Section 3).

Step 3: The seal as registration code. Statistical analysis of 179 Mohenjo-Daro unicorn seals (Kriger & Hunt, 2026) demonstrates that the inscriptions function as structured registration codes: 98.3% unique, positionally constrained, mixed alphanumeric, with formatted fields. These are the structural properties of an identifier in a registration system (Section 5).

Step 4: Physical properties match credit instruments. The seal's physical characteristics—intaglio carving enabling impression transfer, centralized tamper-resistant manufacture, personal portability, minimal wear—match every design requirement of a credit instrument (Section 9).

Step 5: Transaction cycle reconstruction. The credit-instrument hypothesis generates a specific, testable transaction model: identification $\rightarrow$ transaction recording $\rightarrow$ institutional clearing. This model is consistent with the archaeological evidence of clay sealings at trade sites, the scarcity of transaction records (perishable media), and the find contexts of seals (Section 6).

Step 6: The duplicate problem. The 1.7% of non-unique sequences in the subcorpus are reinterpreted not as system failures but as replacement issuances—new physical seals carrying the same account number, analogous to credit card reissuance (Section 7).

Step 7: International function. Indus seals found at Mesopotamian sites (Ur, Tell Asmar, Bahrain) functioned not as administrative documents (which would have no validity abroad) but as credit credentials—proof of guild membership and payment guarantee, analogous to the international function of modern payment cards (Section 8).

The argument's dependencies are linear: each step depends on the preceding ones. The weakest link is Step 5 (transaction reconstruction), which is necessarily speculative given the absence of perishable records. The strongest links are Steps 3 and 4, which rest on statistical evidence and physical archaeology respectively.

3 Background and Related Work

3.1 The Indus economic puzzle

The Indus civilization's economy was trade-intensive. Archaeological evidence documents the exchange of cotton textiles, carnelian beads, shell bangles, copper, tin, lapis lazuli, timber, and pottery across a network spanning from Shortugai in northern Afghanistan to Lothal on the Gujarat coast (Kenoyer, 1998; Possehl, 2002). Indus artifacts have been found at Ur, Tell Asmar, Kish, and other Mesopotamian sites; Mesopotamian cuneiform texts reference a land called "Meluhha," widely identified with the Indus region, as a source of traded goods (Parpola, 1994).

Standardized cubical chert weights, following a binary-decimal ratio system, have been found across all major Indus sites, indicating centralized regulation of measurement (Kenoyer, 1998). Yet no coins, no tokens interpretable as currency, and no price lists have been identified. The standard interpretation is that trade was conducted through barter supplemented by weighed metals (silver, copper) as commodity money.

3.2 Credit before coinage: the anthropological evidence

The barter-then-money narrative, standard in economics textbooks since Adam Smith, has been comprehensively challenged. Graeber (2011) demonstrated that no anthropological evidence supports the existence of pure barter economies. Instead, credit and debt relations preceded the development of coinage in every documented case. Hudson (2018) showed specifically that Bronze Age Mesopotamian economies operated on institutional credit: temples and palaces extended credit, debts were recorded on clay tablets, and periodic settlement (often at harvest time) substituted for point-of-sale payment. The monetization of grain and silver was "not physical; it was administrative and fiscal" (Hudson, 2018).

Ingham (2004) argued that money is fundamentally a social relation of credit and debt, not a commodity. Wray (2004) developed the "chartalist" or state theory of money, in which money originates as a unit of account for tax obligations, not as a medium of exchange. These frameworks predict that a civilization with taxation (as Mukhopadhyay 2023 argues the Indus system encoded) would necessarily have a credit system—the tax obligation itself is a credit relationship.

3.3 The Indus seal corpus

Approximately 4,000 inscribed objects have been recovered, predominantly steatite stamp seals with inscriptions averaging 4–5 signs (Mahadevan, 1977). Over 400 distinct sign types have been catalogued (Parpola, 1994; Wells, 2015). The seals feature animal motifs (unicorn, bull, elephant, rhinoceros, tiger) and short sign sequences carved in intaglio (mirror image) so that impressions read correctly.

Mukhopadhyay (2023) demonstrated that the inscriptions encode administrative information—taxation, trade licensing, commodity control, and access control. Kriger & Hunt (2026) showed that a subcorpus of 179 Mohenjo-Daro unicorn seal inscriptions exhibits the statistical properties of structured registration codes: 98.3% sequence uniqueness ($p < 0.001$), positional entropy profiles with a low-high-low pattern ($\chi^2(4) = 14.7$, $p = 0.005$), stroke numerals concentrated in penultimate positions, and edge-avoidant near-duplicates. Pillai (2026) independently analyzed the same subcorpus using Mukhopadhyay (2023)'s positional framework and found compatible results, including 63% of signs showing strict zone exclusivity.

3.4 Counterarguments and Responses

Objection: The credit-before-coinage thesis is primarily documented for Mesopotamia and may not apply to the Indus context.

Response: The Indus civilization was a direct trading partner of Mesopotamia. Indus seals have been found at Mesopotamian sites, and Mesopotamian texts document trade with "Meluhha." If the Mesopotamian side of these transactions operated on credit (as Hudson demonstrates), the Indus side must have had a compatible mechanism—otherwise cross-civilizational trade would have been restricted to spot barter, which contradicts the scale and regularity of the documented exchange.

Objection: The absence of coinage does not require a credit system; weighed metals could serve all monetary functions.

Response: Weighed metals function as commodity money for spot transactions. But they cannot efficiently serve long-distance trade where goods move weeks or months before payment, where multiple parties must coordinate, or where risk of loss during transport makes carrying large quantities of metal impractical. These functions require credit—deferred payment guaranteed by an institution. The question is not whether credit existed alongside commodity money (it almost certainly did), but what physical instrument mediated the credit relationship.

3.5 Section Result and Implications

The background establishes three premises: (1) the Indus civilization conducted trade at a scale inconsistent with barter alone; (2) credit systems preceded coinage in every documented ancient economy, including the Indus civilization's primary trading partner; (3) the Indus seal inscriptions function as structured registration codes. The question that remains is whether the registration codes served a credit function. The following sections develop the affirmative case.

4 Conceptual Framework: The Seal as Credit Instrument

4.1 Defining the credit-instrument hypothesis

Definition 4.1 (Credit instrument)**.** *A* credit instrument *is a portable physical object that: (a) bears a unique identifier linking the bearer to an institutional account; (b) is issued by a recognized institution (guild, temple, administrative body); (c) enables transactions without immediate transfer of value; (d) guarantees future settlement by the issuing institution; and (e) is non-transferable—its validity is tied to the registered bearer.*

Proposition 4.1 (Seal–credit-instrument correspondence)**.** *The Indus stamp seal satisfies all five conditions of Definition 4.1.*

Proof. We verify each condition against the archaeological and statistical evidence:

Condition (a): Unique identifier. Kriger & Hunt (2026) demonstrated that 98.3% of sign sequences in the 179-seal subcorpus are unique ($p < 0.001$ against a null model preserving sign frequencies). The sign sequences function as unique account numbers.

Condition (b): Institutional issuance. The manufacturing process—intaglio carving in mirror image, kiln firing at 900–1100°C, standardized dimensions across the civilization—requires professional workshops with specialized skills and equipment (Kenoyer, 1998). Self-production is excluded. Archaeological evidence from Harappa indicates concentrated workshop production (Kenoyer, 1998), consistent with institutional oversight.

Condition (c): Transactions without value transfer. The seal is not itself valuable (steatite is a common, soft stone). Its value lies entirely in the institutional relationship it represents. Presenting a seal at a transaction point transfers no commodity; it authorizes a credit entry.

Condition (d): Institutional guarantee. The seal's function abroad (Mesopotamian find-sites) cannot be administrative—an Indus tax code has no validity in Ur. The only function that survives across civilizational boundaries is reputational: the seal identifies the bearer as a member of a solvent trading institution whose obligations will be honored. This is a credit guarantee.

Condition (e): Non-transferability. Seals are found in graves. A transferable instrument would be inherited or resold. Burial with the owner indicates that the seal's validity died with the bearer—precisely the property of a personal credential, not a commodity or currency. □

The administrative-code hypothesis (designated H2 in the Decision Framework of Kriger 2026) is the most consistently supported by existing evidence. Across all six tests proposed in that framework—inscription–context correlation, animal–prefix correlation, cross-site format consistency, commodity–inscription independence, prefix distribution, and algebraic substitution testing—H2 generates predictions that are either confirmed or untested, while the linguistic hypothesis (H1) produces multiple anomalies. Pillai (2026) independently confirmed this assessment through structural analysis of the same subcorpus using Mukhopadhyay (2023)'s positional framework, finding that 63% of signs exhibit strict zone exclusivity—a near-absolute constraint inconsistent with natural language but predicted by a registration-code system. The credit-instrument hypothesis developed here specifies the *economic function* within this administrative-code framework: the codes served as institutional credit identifiers.

4.2 Counterarguments and Responses

Objection: The seal could be a personal identity document (like a passport) without having a credit function.

Response: A passport identifies a person but does not guarantee transactions. The critical distinguishing feature is the seal's use abroad: at Mesopotamian sites, the seal could not function as an identity document (Mesopotamian authorities had no Indus identity registry). It could function as a trade credential—proof that the bearer's institution would honor obligations. This is a credit function.

Objection: Perhaps the seals were religious or ritual objects, not economic instruments.

Response: The animal motifs may carry symbolic meaning, but the sign sequences—unique, positionally structured, mixed alphanumeric—are inconsistent with religious formulae, which tend to be repetitive and standardized (prayers, invocations, dedications). The 98.3% uniqueness rate rules out formulaic religious content.

4.3 The dual-layer economy

The credit-instrument hypothesis does not require the absence of other forms of exchange. The Indus economy almost certainly operated on multiple layers simultaneously:

Layer 1: Spot exchange. Local, small-scale transactions using barter or commodity money (grain, metals weighed against standardized weights). This layer requires no seals and leaves no seal-related archaeological traces.

Layer 2: Credit transactions. Large-scale, long-distance, or institutionally mediated transactions using the seal as a credit instrument. This layer generates seal impressions on clay tags (recording transactions), seal wear patterns (or lack thereof, indicating occasional use), and seal distribution across trade routes.

The two layers are complementary, not competing. Modern economies operate identically: cash coexists with credit cards, and the existence of one does not preclude the other. The standardized weights served Layer 1 (measuring commodity values for spot exchange) and Layer 2 simultaneously (providing the unit of account for credit entries).

4.4 Section Result and Implications

The conceptual framework establishes a formal definition of credit instruments and demonstrates that Indus seals satisfy all definitional conditions. The dual-layer model situates the credit function within a broader economy that includes spot exchange, resolving the apparent tension between the seal hypothesis and the evidence for barter and commodity money.

5 Mathematical Development

This section formalizes the statistical properties that distinguish a credit-instrument system from alternative interpretations (religious formulae, personal names, commodity labels). The empirical basis is the 179-seal Mohenjo-Daro unicorn subcorpus analyzed in Kriger & Hunt (2026); the mathematical framework extends those results.

5.1 Uniqueness as a design requirement

Definition 5.1 (Uniqueness rate)**.** *For a corpus of N inscriptions, let U be the number of distinct sign sequences. The uniqueness rate is $u = U/N$.*

Proposition 5.1 (Credit instruments require near-total uniqueness)**.** *A system of credit instruments functioning as account identifiers requires $u \to 1$ as the system matures. Duplicate identifiers would permit unauthorized transactions, making uniqueness enforcement a systemic necessity.*

The observed uniqueness rate in the subcorpus is $u = 176/179 = 0.983$. A permutation test (10,000 iterations) against a null model preserving observed sign frequencies and inscription lengths produced a mean uniqueness of 0.912 (95% CI: 0.887–0.935). The observed value exceeds this null at $p < 0.001$ (Kriger & Hunt, 2026).

5.1.1 Counterarguments and Responses

Objection: High uniqueness could arise from personal names or commodity descriptions, not only from designed identifiers.

Response: Personal names in Bronze Age contexts show moderate uniqueness (many individuals share common names), not 98.3%. Commodity descriptions would produce repetition (the same goods would be described identically on different seals). Only designed registration systems enforce near-total uniqueness as a system requirement.

5.2 Positional entropy and formatted codes

The entropy profile of the 179-seal subcorpus reveals a characteristic low-high-low pattern across positions (Kriger & Hunt, 2026):

Table 1: Positional entropy for 5-sign inscriptions ($n = 35$). Adapted from Kriger & Hunt (2026).

Position	Entropy (bits)	Unique signs	Hypothesized role
1	3.13	15	Issuer/category classifier
2	4.44	25	Variable account field
3	4.45	25	Variable account field
4	3.77	20	Tier/class numeral
5	3.98	23	Status/terminal classifier

Proposition 5.2 (Entropy profile matches credit-card format)**.** *The low-high-low entropy pattern is the signature of a formatted identifier code: low-entropy edges encode institutional classifiers (issuer, card type, status); high-entropy middle positions encode unique account numbers. Modern credit card numbers exhibit the identical pattern: the first 6 digits (BIN/IIN) identify the issuer (low entropy across a bank's portfolio), the middle digits encode the unique account (high entropy), and the final digit is a Luhn check digit (deterministic, zero entropy).*

The Friedman test across positions yields $\chi^2(4) = 14.7$, $p = 0.005$ (Kendall's $W = 0.105$), confirming non-uniform entropy (Kriger & Hunt, 2026). This is inconsistent with natural language (approximately uniform entropy across positions in short texts) and with random symbols (uniformly high entropy).

5.3 The Luhn analogy: structural error detection

Modern credit card numbers incorporate a check digit computed via the Luhn algorithm, enabling point-of-sale verification without network access. While we cannot determine whether the Indus system incorporated an analogous mechanism, the low-entropy terminal position (Position 5, Table 1) is consistent with a constrained terminal field that could serve a verification function. The PF2 class of signs identified by Mukhopadhyay (2023)—which shows 100% zone exclusivity in the subcorpus analysis by Pillai (2026)—is restricted exclusively to the final position, consistent with a terminal classifier or verification marker.

5.4 Combinatorial capacity

Kriger & Hunt (2026) estimated the system's combinatorial capacity using a conservative 5-field model:

$$C = n_{\text{prefix}} \times n_{\text{medial}}^{k} \times n_{\text{suffix}} \tag{1}$$

where $n_{\text{prefix}} \approx 10$ (prefix classifiers), $n_{\text{medial}} \approx 30$ (medial signs), $k = 2$ (two medial positions), and $n_{\text{suffix}} \approx 5$ (suffix classifiers). This yields:

$$C \approx 10 \times 30^2 \times 5 = 45{,}000 \tag{2}$$

More generous estimates using the full sign inventory yield $C > 1{,}000{,}000$ (Kriger & Hunt, 2026). Either estimate exceeds Mohenjo-Daro's estimated population (∼40,000) and the civilization's total estimated population (1–5 million), confirming that the system had sufficient capacity to assign unique codes to every economically active individual or entity.

5.4.1 Counterarguments and Responses

Objection: The combinatorial capacity exceeding the population does not prove credit function; any registration system (tax rolls, census records) would have similar capacity.

Response: Correct. The capacity argument does not distinguish between registration functions. It establishes a necessary condition (sufficient unique codes exist) rather than a sufficient condition (the codes must be credit instruments). The credit-instrument interpretation is supported by the convergence of capacity with the other four lines of evidence, not by capacity alone.

5.5 Section Result and Implications

The mathematical analysis establishes that the subcorpus exhibits three properties required by a credit-instrument system: near-total uniqueness (analogous to unique account numbers), a formatted entropy profile (analogous to structured card numbers), and combinatorial capacity exceeding the population (sufficient address space for universal registration). These are necessary conditions, not sufficient ones; the credit-instrument interpretation requires additional support from physical archaeology and transaction-cycle reconstruction.

6 Reconstruction of the Transaction Cycle

6.1 The five-step transaction model

If the seal functioned as a credit instrument, the transaction cycle would have followed a specific sequence. The following reconstruction is explicitly speculative but is constrained by the archaeological and statistical evidence.

Definition 6.1 (Credit transaction cycle)**.** *A credit transaction cycle consists of five stages: (1) issuance—the institution creates and assigns the instrument; (2) identification—the bearer presents the instrument; (3) recording—the transaction is documented with reference to the instrument's identifier; (4) clearing—the issuing institution settles accumulated obligations; (5) retirement—the instrument is decommissioned when the bearer's relationship with the institution ends.*

Proposition 6.1 (Archaeological evidence supports each stage)**.** *Each stage of the credit transaction cycle (Definition 6.1) has at least one line of supporting archaeological or statistical evidence.*

Stage 1: Issuance. Concentrated workshop production at Harappa (Kenoyer, 1998), standardized dimensions across the civilization, and the irreversible firing process (which excludes post-production modification) indicate centralized issuance under institutional oversight. The near-total uniqueness (98.3%) implies a registry maintaining assigned codes.

Stage 2: Identification. The seal was designed for presentation: portable (2–3 cm, fitted with suspension loop), carved in intaglio for impression transfer, and featuring a visually distinctive animal motif recognizable without reading the sign sequence. The unicorn motif—present on approximately 75% of all Indus seals (Frenez, 2018)—may function as an "issuer logo," analogous to the Visa or Mastercard symbol, identifying the institutional network rather than the individual bearer.

Stage 3: Recording. This is the critical stage for which evidence is most fragmentary. Two recording mechanisms are plausible:

Clay impression. The seal was pressed into wet clay to produce a positive-reading impression (sealing). Clay sealings have been found at multiple Indus sites, notably at Lothal, where one-third of sealings bear multiple seal impressions (Frenez, 2020)—consistent with multi-party transactions requiring authorization from more than one account holder.

Inscription on perishable media. The sign sequence was transcribed onto palm leaves, birch bark, cotton cloth, or wooden boards—the standard writing surfaces of South and Southeast Asian civilizations throughout recorded history. These materials do not survive India's monsoon climate, termite activity, and funerary cremation over 4,000 years (Kriger & Hunt, 2026). The near-complete absence of written records from the Indus civilization is consistent with a society that wrote extensively on perishable media, preserving only the durable instruments (seals) and occasional archival records (clay sealings).

Stage 4: Clearing. Inter-institutional settlement would have occurred periodically—at harvest time, at the end of a trading season, or upon the arrival of a caravan. The standardized weights provided the unit of account for clearing: debts denominated in standardized weight units of grain, copper, or silver, settled in kind or by weight. This is precisely the mechanism documented in contemporary Mesopotamian economies (Hudson, 2018).

Stage 5: Retirement. Seals found in graves represent decommissioned instruments. The bearer's institutional account is closed upon death; the physical instrument is retired with the bearer. This explains why seals are not inherited or resold: a credit instrument is valid only for its registered holder. Modern parallels include the cancellation of government-issued credentials upon the holder's death.

6.2 Counterarguments and Responses

Objection: The reconstruction of Stages 3 and 4 is speculative, relying on the assumed destruction of perishable records.

Response: This is acknowledged. The argument from perishable media is an *absence-of-*

evidence argument, which is logically weaker than an evidence-of-absence argument. However, the absence is not unexplained: every South Asian literary and documentary tradition prior to the Common Era was transmitted on perishable materials. The Vedas survived only through oral transmission; the earliest surviving South Asian manuscripts date to the first centuries CE. The systematic absence of Indus written records is consistent with—indeed predicted by—the perishable-media hypothesis.

Objection: Clay sealings might represent commodity-sealing (marking the contents of containers) rather than transaction recording.

Response: Both functions are compatible with the credit-instrument hypothesis. Sealing a container with a credit-holder's seal simultaneously marks ownership, authorizes the transaction, and creates a record. The multiple-seal impressions found at Lothal (Frenez, 2020) are more naturally explained as multi-party authorization (buyer and seller, or multiple co-signers) than as purely commodity-marking.

6.3 Section Result and Implications

The transaction-cycle reconstruction generates a testable model with five stages, each supported by at least one line of evidence. The weakest stages (3 and 4) predict the existence of transaction records on perishable media—a prediction that is difficult to test archaeologically but is consistent with the broader South Asian documentary tradition. The strongest stages (1, 2, and 5) are supported by direct archaeological evidence.

7 The Duplicate Problem: Reissuance, Not Error

Three inscription pairs in the 179-seal subcorpus share identical sign sequences, yielding a uniqueness rate of 98.3% rather than 100%. Under the credit-instrument hypothesis, these duplicates are not system failures but *replacement issuances*: new physical seals carrying the same account number, produced when the original seal was lost, broken, or damaged.

Proposition 7.1 (Duplicate interpretation)**.** *In a credit-instrument system, the duplication rate $d = 1 - u$ represents the replacement rate, not the error rate. The intended uniqueness is 100%; observed duplicates reflect the operational lifetime of instruments, not the design of the code system.*

This interpretation generates testable predictions:

Prediction 1: Physical divergence. If duplicates are replacements, the two physical seals bearing the same code should differ in manufacturing details—carving style, dimensions, wear patterns—reflecting production at different times, possibly by different artisans. Identical manufacturing would instead suggest simultaneous production (batch issuance), which would require a different explanation.

Prediction 2: Stratigraphic separation. If one seal was lost and replaced, the two seals should be found in different archaeological layers or locations—one discarded (the lost original), one in active use or buried with the owner (the replacement). Same-context discovery would weaken the replacement interpretation.

Prediction 3: Institutional record. A replacement system requires a registry that tracks active codes. The existence of such a registry—presumably on perishable media—is independently predicted by the credit-instrument hypothesis (Stage 1 of the transaction cycle).

Modern credit card systems reissue cards with the same account number routinely: when a card expires, is lost, or is compromised, a new physical card is produced with the same number. The physical medium changes; the identifier persists. The three Indus duplicates may represent exactly this process, preserved in steatite rather than plastic.

7.1 Counterarguments and Responses

Objection: Three duplicates in 179 seals could be accidental—two different entities happened to receive the same code by chance.

Response: The permutation test (Kriger & Hunt, 2026) showed that random assignment with observed sign frequencies would produce a mean uniqueness of 91.2%, yielding approximately $179 \times 0.088 \approx 16$ expected duplicates. The observed three is far below this expectation, indicating active duplicate avoidance. The few duplicates that exist are more parsimoniously explained as intentional reissuance than as system failure.

7.2 Section Result and Implications

The duplicate problem, far from weakening the credit-instrument hypothesis, strengthens it. The near-zero duplication rate implies active uniqueness enforcement (a registry), while the small number of duplicates implies a replacement protocol. Both are properties of an administered credit system.

8 International Function: The Seal Abroad

Indus seals and seal impressions have been found at Ur, Tell Asmar, Kish, Nippur, and other Mesopotamian sites, as well as at Bahrain (ancient Dilmun) and Failaka Island in the Persian Gulf (Parpola, 1994; Kenoyer, 1998). This distribution presents a puzzle under purely administrative interpretations: an Indus tax code, commodity license, or municipal registration would have no administrative validity in Mesopotamia. Mesopotamian officials operated under Sumerian and Akkadian bureaucratic systems with cuneiform documentation. An Indus registration number would be meaningless in Ur, just as a Toronto municipal business license is meaningless in Istanbul.

Yet the seals traveled. Why?

Proposition 8.1 (International credit function)**.** *The seal functioned abroad as a credit credential: proof of guild membership and guarantee of payment. The animal motif was visually recognizable without reading the signs; the sign sequence confirmed membership to those within the Indus trading network.*

This interpretation aligns with the documented practices of medieval European merchant guilds. A Hanseatic League merchant's guild seal guaranteed transactions not because foreign counterparts could read the seal's language, but because the guild's reputation—its record of honoring obligations—stood behind it. The seal was a signal of creditworthiness, backed by institutional capital.

The international function also explains why owners carried seals across thousands of kilometers of dangerous travel rather than leaving them safely at home. One does not risk losing an administrative form number in a foreign port. One carries a credential that opens doors—that converts institutional reputation into commercial access.

8.1 The letter of credit analogy

The closest modern financial analogy for the seal's international function is the *letter of credit*: a document issued by a bank guaranteeing that a buyer's payment to a seller will be received on time and for the correct amount. Letters of credit are used primarily in international trade, where the parties may not know each other and where legal enforcement across jurisdictions is uncertain. The Indus seal would have served the same function in a world without banks: the guild or administrative body that issued the seal stood behind the bearer's obligations, and the seal was the physical proof of that guarantee.

8.2 Counterarguments and Responses

Objection: The seals found at Mesopotamian sites could be trade samples, souvenirs, or objects of curiosity rather than functional instruments.

Response: Individual seals as curiosities would not produce the pattern of multiple finds across multiple sites over several centuries. The distribution is consistent with systematic, ongoing use by a trading community, not with incidental collection.

Objection: The seals could have identified the origin of goods ("Made in Meluhha") rather than the creditworthiness of the bearer.

Response: Origin marking would require the seal to remain with the goods, not with the person. The portability design (suspension loop for personal carrying) and the find contexts (not attached to goods but found in residential and commercial areas) indicate personal use. The seal identifies the *bearer*, not the *cargo*.

8.3 Section Result and Implications

The international distribution of Indus seals is most parsimoniously explained by a credit function: the seal guaranteed the bearer's transactions across civilizational boundaries, backed by the reputation of the issuing institution. This function requires no common language, no shared bureaucracy, and no mutual administrative recognition—only mutual recognition of institutional creditworthiness.

9 Structural Parallels with Modern Credit Instruments

The credit-instrument hypothesis gains force when the Indus seal system is compared point-by-point with modern credit technologies. The parallels are not metaphorical; they are structural.

9.1 The embossed credit card

Prior to the chip-and-PIN era, credit card numbers were embossed (raised) on the card surface. This was not decorative. The embossment enabled *mechanical impression transfer*: the card was placed in an imprinter ("knuckle buster"), a carbon-paper slip was laid over it, and a roller was passed across, transferring the raised numbers onto the slip. The slip—bearing the card number, the merchant's information, and the transaction amount—was the *transaction record*. It was sent to the issuing bank for clearing and settlement.

The Indus seal operates identically. The sign sequence is carved in intaglio (recessed) on the seal, producing a positive (raised) impression on clay. The clay impression—bearing the seal's unique code—is the transaction record. It is retained by the receiving party (merchant, port official, warehouse manager) for institutional clearing.

The mechanical correspondence is exact (Figure 1):

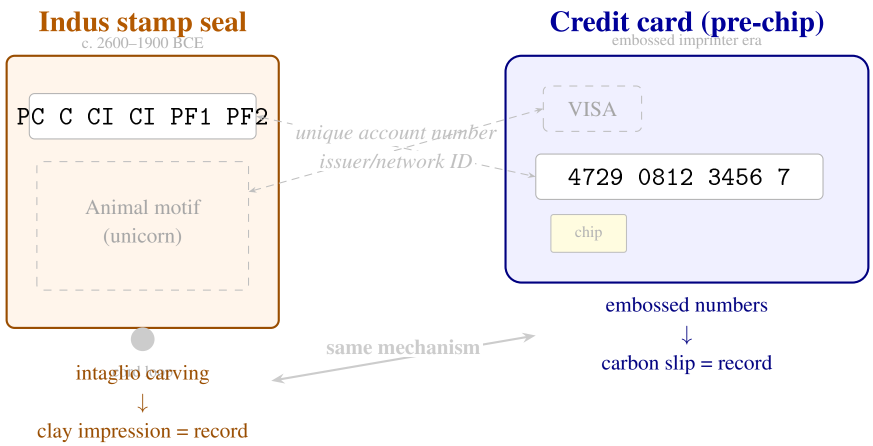

Figure 1: Visual comparison of an Indus stamp seal (left) and a pre-chip embossed credit card (right). The sign sequence corresponds to the card number (unique account identifier); the animal motif corresponds to the issuer logo (network identification). Both objects use relief-based impression transfer to create transaction records: the seal's intaglio produces a clay impression; the card's embossment produces a carbon-paper slip. Both are portable, tamper-resistant, centrally manufactured, and non-transferable.

Table 2: Structural correspondence between Indus seal and embossed credit card.

Credit card (pre-chip)	**Indus seal**
Plastic card, 85×54 mm	Steatite square, 20–30 mm
Embossed (raised) numbers	Intaglio (recessed) carving
Carbon-paper imprint	Clay impression
Unique account number	Unique sign sequence (98.3%)
BIN prefix (issuer ID)	PC class sign (category ID)
Account number (middle)	CI class signs (variable field)
Check digit (terminal)	PF2 class sign (terminal marker)
Issuing bank	Guild or administrative body
Hologram/signature (security)	Fired enstatite (tamper-proof)
Carried in wallet	Suspended on cord
Minimal physical wear	Minimal archaeological wear
Not inherited upon death	Buried with the owner
Reissued when lost	Duplicate seals (1.7%)
Works internationally	Found at Mesopotamian sites

No other proposed interpretation of the Indus seal—personal name, religious token, commodity label, administrative stamp—generates this degree of structural correspondence with any single modern technology. The credit-instrument interpretation aligns with *every* observed property simultaneously.

9.2 The imprinter as transaction technology

The credit card imprinter (mechanical "knuckle buster") was the standard point-of-sale device from the 1950s through the 1990s. Its operating principle was simple: the card's embossed surface was pressed against a carbon-paper slip, producing a legible copy of the card number. The slip was the legal record of the transaction.

The Indus seal's operating principle is identical: the seal's intaglio surface was pressed into wet clay, producing a legible impression of the sign sequence. The clay tag—sometimes found with cord impressions on the reverse, indicating attachment to bundled goods (Frenez, 2020)—was the record of the transaction.

Both technologies share a crucial property: *the recording medium is separate from the instrument*. The credit card is not consumed by the transaction; neither is the seal. The card produces a slip; the seal produces a clay tag. The instrument remains with the bearer; the record remains with the counterparty. This separation of instrument and record is a defining feature of credit systems, distinguishing them from commodity money (where the medium of exchange is consumed by the transaction).

9.3 Counterarguments and Responses

Objection: Structural parallels between ancient and modern technologies can be superficial. The existence of structural similarity does not prove functional equivalence.

Response: This is correct as a general principle. However, the parallels enumerated in Table 2 are not cherry-picked surface resemblances; they constitute a complete mapping across every observable property of both systems. When *every* property of system A maps onto a corresponding property of system B, the hypothesis that A and B serve the same function becomes substantially more parsimonious than the hypothesis that the mapping is coincidental. Functional convergence—different civilizations independently arriving at similar solutions to similar problems—is well documented in the history of technology (Basalla, 1988).

9.4 Section Result and Implications

The structural correspondence between the Indus seal and the pre-chip credit card is comprehensive and exact. Every observable property of the seal maps onto a corresponding property of the credit card. This does not constitute proof of functional equivalence, but it establishes a strong prima facie case and identifies the credit-instrument hypothesis as the most parsimonious interpretation of the combined evidence.

10 Empirical and Data-Grounded Illustrations

10.1 The weight system as unit of account

The Indus weight system followed a binary-decimal ratio: 1, 2, 4, 8, 16, 32, 64, 160, 200, 320, 640, 1600, 3200, 6400, 8000, 12800 units, where the base unit was approximately 0.86 grams (Kenoyer, 1998). The most common weight was 16 units (≈13.7 g), close to the half-ounce used in later South Asian metrology.

In a credit system, weights serve a different function than in a spot-exchange economy. In spot exchange, weights measure the commodity being traded. In a credit system, weights define the *unit of account*—the denomination in which debts are recorded and settled. The distinction matters: the weight is not the money; the weight is the ruler by which money (credit) is measured. This is precisely how weights functioned in contemporary Mesopotamia, where the shekel was simultaneously a weight unit and a unit of account (Hudson, 2018).

The standardization of Indus weights across the entire civilization—from Shortugai to Lothal, from Mohenjo-Daro to Dholavira—implies not merely uniform measurement but a *shared unit of account*: debts recorded in one city could be settled in another because both used the same denomination. This is a prerequisite for an inter-city credit system.

10.2 The digit "2" anomaly

Kriger & Hunt (2026) found that the stroke-numeral "2" constitutes 66.9% of all numeral occurrences in the subcorpus ($\chi^2(4) = 198.3$, $p < 0.001$ against a uniform distribution). This anomaly excludes the encoding of naturally distributed quantities (which would follow Benford's law or a uniform distribution) and is consistent with categorical or ordinal encoding.

Under the credit-instrument hypothesis, the dominance of "2" may reflect a tier or grade system: most account holders belong to the second tier (standard membership), with fewer in the first tier (premium) and fewer still in higher tiers. This mirrors the distribution of modern credit card tiers: the majority of cardholders hold standard cards, with smaller fractions holding gold, platinum, or elite cards. A frequency distribution dominated by one tier is exactly what one expects from a stratified membership system.

10.3 Near-duplicates as account variants

Eight inscription pairs differ by exactly one sign (Hamming distance = 1), with variation restricted to middle positions (never edges) (Kriger & Hunt, 2026). Under the credit-instrument hypothesis, these near-duplicates may represent accounts within the same institutional category (same prefix and suffix = same issuer and status) but assigned to different holders (different middle field = different account numbers). They are, in effect, cards issued by the same bank: structurally similar but individually unique.

The twenty-eight prefix-sharing groups identified by Kriger & Hunt (2026)—groups of inscriptions sharing identical first two signs with divergent endings—are similarly interpretable as accounts within the same institutional branch, sub-guild, or commodity class.

10.4 Section Result and Implications

The empirical evidence—standardized weights as unit of account, the digit "2" anomaly as tier distribution, and near-duplicates as account variants—is consistent with the credit-instrument hypothesis and difficult to explain under alternative interpretations. No single piece of evidence is decisive; the strength of the case lies in convergence across multiple independent lines.

11 Discussion

11.1 What the hypothesis explains

The credit-instrument hypothesis provides a unified explanation for a set of otherwise disparate observations:

The absence of coinage. Not a deficiency but a design choice: the economy operated on institutional credit, rendering coinage unnecessary.

The standardized weights. Not merely measuring tools but the unit of account for a credit system, enabling inter-city debt settlement.

The seal's unique sign sequences. Account numbers linking the bearer to an institutional ledger.

The seal's physical properties. Engineered for a credit instrument's requirements: portable, tamper-proof, impression-capable, durable.

The minimal wear. The seal was presented, not applied repeatedly—shown to authorize transactions, not stamped onto goods daily.

The find contexts. Personal carrying (cord suspension), international transport (Mesopotamian finds), and burial with the owner (non-transferable credential).

The scarcity of written records. Transaction records were written on perishable media (palm leaves, bark, cloth); only the durable instruments (seals) and occasional archival records (clay sealings) survived.

The duplicate seals. Replacement issuances, not system errors.

The absence of monumental architecture and royal imagery. A civilization organized through institutional credit rather than royal decree would appear egalitarian in visible expression and sophisticated in invisible infrastructure—precisely what the archaeology reveals.

11.2 Relationship to Mukhopadhyay's administrative interpretation

Mukhopadhyay (2023) demonstrated that Indus inscriptions encode taxation, trade licensing, commodity control, and access control. The credit-instrument hypothesis is fully compatible with this finding: every function Mukhopadhyay identifies is a function that registration-based credit instruments serve. Tax codes are account identifiers. Trade licenses are credit authorizations. Commodity control is inventory management within a credit system. Access control is authorization verification. The credit-instrument hypothesis does not replace Mukhopadhyay's analysis; it identifies the *economic mechanism* that connects all four functions.

The Decision Framework proposed in Kriger (2026) formalizes the criteria by which the administrative-code hypothesis (H2) can be distinguished from the linguistic hypothesis (H1) and the metrological-hybrid hypothesis (H3). That framework establishes *which* hypothesis the evidence supports; the present paper addresses the next question: *what economic function* does the administrative code serve? The answer—institutional credit—transforms H2 from a structural description into a functional explanation with predictive content.

11.3 Relationship to Graeber and Hudson

Graeber (2011) and Hudson (2018) demonstrated that credit preceded coinage in the ancient world. The present paper provides a candidate physical instrument for the Indus credit system—the first such identification for any pre-monetary civilization. If confirmed, the Indus seal would be the oldest known credit instrument: a physical technology of credit predating Mesopotamian clay-tablet debt records (which document credit but are not themselves credit instruments) by virtue of being designed to be carried and presented, not merely stored.

11.4 Implications for the "information civilization" thesis

Kriger & Hunt (2026) characterized the Indus civilization as potentially "the world's first known information civilization"—a society whose administrative backbone was structured information encoding rather than phonetic writing. The credit-instrument hypothesis adds an economic dimension to this characterization: the Indus civilization may have been the first to develop an *institutional credit technology*—a physical instrument encoding a credit relationship in a structured, language-independent format. This would place the Indus civilization at the origin of two fundamental technologies: information architecture and institutional credit.

11.5 Counterarguments and Responses

Objection: The hypothesis is unfalsifiable because the key evidence (perishable transaction records) has been destroyed.

Response: The hypothesis generates several testable predictions that do not depend on perishable records: (1) cross-site replication of the uniqueness and entropy patterns; (2) physical divergence between duplicate seals (different artisan, different wear); (3) clay sealings at trade sites should show patterns consistent with multi-party transactions; (4) the animal motif should function as a categorical classifier (different motifs = different institutional networks); (5) comparison with Mesopotamian sealing practices should reveal structural parallels. These predictions are testable with existing or obtainable archaeological data.

Objection: The hypothesis projects modern economic concepts onto an ancient civilization.

Response: The concepts of credit, debt, and institutional guarantee are not modern. Graeber (2011) and Hudson (2018) document their existence in every known ancient civilization. The structural properties of the Indus seal (unique identifier, institutional issuance, impression capability, tamper resistance) are objective physical facts, not projections. The interpretation as a credit instrument is the most parsimonious explanation of these facts taken together.

11.6 Phonetic vocalization: how the code was spoken

A credit-card number must be communicable. When a merchant in Mohenjo-Daro needed to record a transaction without the seal physically present—to relay an account number to a scribe, to confirm a code across a warehouse, to dictate it for inclusion in a ledger written on perishable media—the sign sequence had to be spoken aloud.

This observation reconciles the credit-instrument hypothesis with the phonetic readings proposed by Parpola (1994) and Mahadevan (2014). The reconciliation is not a compromise; it is a structural clarification. *The code was vocalized, but the vocalization was not what the code encoded.* One reads a credit-card number aloud—“four-seven-two-nine”—without the spoken words constituting a sentence, a name, or any linguistic content. The number “4729” does not *mean* “four-seven-two-nine”; it identifies an account. The phonetic realization is a communication convenience, not a semantic layer.

The critical implication is that the phonetic realization of a given sign sequence would have varied—by region, by language community, by historical period—without affecting the code’s function. As argued in Kriger & Hunt (2026), the Chinese writing system provides the strongest existing demonstration of this principle: the character for “water” is read as *shuǐ* in Mandarin, *séui* in Cantonese, *chúi* in Hakka, *sui* in Japanese on’yomi, and *mizu* in Japanese kun’yomi. The character is identical; the phonetic realizations are entirely different words in mutually unintelligible languages. If the Indus civilization spanned linguistically diverse communities—as archaeological and genetic evidence suggests—a code vocalized differently in Mohenjo-Daro, Harappa, Lothal, and Dholavira would still function identically as an account identifier at every site.

This has a direct consequence for the credit-instrument hypothesis. A transaction in Lothal might be recorded by a scribe who spoke a Dravidian language; the same account code presented at Mohenjo-Daro might be vocalized in a different language entirely. The code does not care. It identifies the account, not the language. The institutional clearing system operates on the code, not on its pronunciation—just as a modern bank processes “4729” identically regardless of whether the cardholder dictated it in English, Hindi, or Finnish.

Parpola’s Proto-Dravidian readings may therefore capture a *genuine phonetic tradition*—real vocalizations used by real speakers in a specific region and period—without this constituting evidence that the script encodes Dravidian. The readings are real; the inference that the script is phonetic writing does not follow. Searching for the "correct" phonetic reading of an Indus seal inscription is like searching for the "correct" name of the @ symbol: every language assigns one, all are legitimate, none is canonical, and the symbol's function is independent of all of them (Kriger & Hunt, 2026).

11.7 Section Result and Implications

The credit-instrument hypothesis provides a unified, parsimonious explanation for the major features of the Indus seal system and the Indus economy. It is compatible with existing administrative, non-linguistic, and information-theoretic interpretations. It generates testable predictions. Its principal weakness is the reliance on the perishable-media hypothesis for the absence of transaction records.

12 Limitations

1. **Subcorpus restriction.** All statistical claims derive from 179 Mohenjo-Daro unicorn seals (3–4% of known inscriptions). Generalization to the full corpus requires replication.
2. **No direct evidence of credit transactions.** No clay tablet, sealing, or inscription has been identified as a credit record. The transaction-cycle reconstruction (Section 6) is inferential.
3. **Perishable-media argument.** The absence of written records is explained by the perishable-media hypothesis, which is plausible but not directly testable.
4. **Functional inference from structure.** The argument infers economic function from physical and statistical properties. This is standard archaeological reasoning but carries inherent uncertainty.
5. **No bilingual text.** Without a bilingual inscription or a clear phonetic decipherment, the semantic content of the sign sequences remains unknown. The hypothesis specifies the format and function of the codes but not their content.
6. **Modern analogy risk.** Structural parallels with modern technologies can produce false familiarity. The Indus credit system, if it existed, may have operated under principles without modern analogues.

13 Future Directions

Full-corpus replication. The most important next step is replication of the uniqueness and entropy analyses on the complete ICIT corpus (∼5,500 inscriptions) with site and animal-type metadata.

Animal-motif analysis. If the animal motif functions as an "issuer logo," different motifs (unicorn, bull, elephant) should correspond to distinct sign vocabularies or entropy profiles—analogous to different card networks having different BIN ranges.

Clay sealing analysis. Systematic analysis of Lothal and other site sealings for evidence of multi-party transactions (multiple seal impressions on single tags) would test the credit-authorization model.

Mesopotamian cross-reference. Cuneiform texts referencing "Meluhha" trade should be examined for evidence of credit or deferred-payment arrangements with Indus merchants.

Duplicate-seal physical analysis. High-resolution comparison of duplicate-code seals for manufacturing differences (carving style, dimensions, clay composition) would test the reissuance hypothesis.

Comparative analysis with Mesopotamian sealing practices. Formal comparison of Indus and Mesopotamian administrative sealing patterns could establish whether the two civilizations used compatible credit protocols for cross-border trade.

Computational modeling. Agent-based models of credit-based trade networks could test whether a guild-backed credit system with the observed seal properties could sustain the scale and geographic range of documented Indus trade.

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The author gratefully acknowledges Professor Asko Parpola (University of Helsinki), whose half-century of foundational work on the Indus script made the present analysis possible. In a personal communication with T. A. Hunt, Professor Parpola described the non-phonetic approach as "a welcome exception to the papers now poured on the decipherment of the Indus script," while maintaining his commitment to phonetic decipherment. This generous engagement with an alternative framework exemplifies the scholarly openness that the field requires, and the present paper's reconciliation of phonetic vocalization with non-linguistic encoding (Section 11) is offered in the same spirit: not to displace phonetic research, but to show how it captures a genuine layer of a multi-layered system.

The author thanks Treasure A. Hunt, co-author of the statistical analysis (Kriger & Hunt, 2026) on which the present paper builds, for developing the constraint-governed analytical framework and the structure-first interpretive methodology that underpin the registration-code hypothesis, and for the information-theoretic foundation connecting the script's structure to Indus social organization (Hunt, 2025a,b).

The author thanks Karan Damodaram Pillai for sharing his independent structural analysis of the Indus sign system (Pillai, 2026), for detailed comments on the relationship between linguistic and non-linguistic interpretations, and for the observation—developed in his published work on the hybrid origin of Brāhmī (Damodaram Pillai, 2023)—that sign-system hybridity has documented precedent in South Asia. His algebraic substitution method, in which putative linguistic values are assigned to individual signs and tested across multiple inscriptions, provided independent confirmation that the Indus system does not encode natural language and informed the development of Test 6 in Kriger (2026).

The author thanks Richard Sproat (Google) for extensive and detailed comments on the Decision Framework (Kriger, 2026) that informed the methodological foundations of the present work. His published critique of entropy-based methods (Sproat, 2010) and his analysis of nonlinguistic symbol systems (Sproat, 2023) collectively defined the methodological challenges that the credit-instrument hypothesis was constructed to address.

The author thanks the developer of the digitized Indus corpus (`https://github.com/mayig/indus-valley-script-corpus`) for making the data publicly available under a CC-BY-4.0 license. The reproducibility of all statistical results cited in this paper depends on this open-access resource.

Statistical computations underlying the quantitative results cited in this paper were performed using Claude Opus 4.6 (Anthropic, 5 February 2026) as a computational tool, as described in Kriger & Hunt (2026). All hypotheses, interpretations, and claims are the sole responsibility of the human author.

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A Appendix: Computational Notes

All statistical results cited from Kriger & Hunt (2026) were computed using Python 3 (standard library only) on the open-access corpus available at `https://github.com/mayig/indus-valley-script-corpus`. The analysis pipeline included:

1. Sign frequency computation (global and per-position).
2. Shannon entropy per position for fixed-length subsets ($n = 5,6,7$).
3. Sequence uniqueness with permutation test (10,000 iterations).
4. Bigram co-occurrence matrix and sparsity analysis.
5. Stroke-sign identification from corpus metadata.
6. Digit frequency tested against uniform distribution (χ^2 test).
7. Hamming distance for all same-length pairs.
8. Prefix-sharing group identification.

Scripts are provided as Supplementary Information to Kriger & Hunt (2026) and are reproducible from the public corpus by any researcher with Python 3 and an internet connection.

No new statistical computations were performed for the present paper. All quantitative claims reference Kriger & Hunt (2026). The present paper contributes interpretive analysis (the credit-instrument hypothesis), not new data.