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ORIGINAL ARTICLE

Sacred Hydro-Cosmology and Sovereign Oath Landscapes: Spatial-Network Modeling and Epigraphic Semantics of *Sapatha* Curses in Sriwijaya Old Malay Inscriptions (7th–11th Centuries CE)

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ABSTRACT

Background: Early Sriwijaya governed seventh- to eleventh-century Maritime Southeast Asia through riverine-estuarine networks, not contiguous agrarian cadastres. Its Old Malay *sapatha* [sovereign imprecatory curse] and *siddhayātrā* [ritual voyage-potency] stones remain unmodeled spatially and linguistically.

Objective: To examine inscription stratification, the proximity of oath stones to river chokepoints, code-switching across discourse zones, and semantic divergence between Old Malay and Old Javanese *sīma* [tax-exempt freehold] charters.

Methods: Four open-access streams combined 1,526 ERC DHARMA Nusantara inscriptions, 102,011 OpenStreetMap river vertices benchmarked against 10,000 Monte Carlo land points, 1,655 etymologically tagged tokens from all 21 Old Malay EpiDoc XML editions, and 85 Old Javanese charter XMLs. Analyses used Mann–Whitney tests, Cliff's delta, logistic regression, and Benjamini–Hochberg-adjusted Fisher tests.

Results: Sovereign curse/*siddhayātrā* inscriptions were 77.28-fold more concentrated in Sumatra–Bangka than Java ($p = 1.31 \times 10^{-13}$); 60.78% of Sumatran metal foils lacked provenance. Core stones lay closer to river chokepoints than other Sumatran sites (median 4.83 km vs. 52.52 km; Cliff's delta = −0.792; $p = 3.29 \times 10^{-9}$), mainly because most stand in Palembang. Etymological strata differed across five discourse zones ($p = 2.90 \times 10^{-29}$). Old Javanese charters more often contained *sīma* boundary, *saṅ makudur* [oath-officiant priest] blood-oath, and retribution clauses ($q \leq 0.0015$), whereas *bhakti* [devotional loyalty] and *vala* [punitive expedition] clauses were only nominally more frequent in Old Malay editions ($q = 0.057$).

Conclusion: The patterns are consistent with a hydro-ritual role for Sriwijaya's *sapatha* stones and motivate an *Ulu–Ilir* [upstream–downstream] Riverine Mandala Safeguarding Protocol.

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1. Introduction

1.1 Thalassocratic Sovereignty, Galactic Mandala Theory, and the *Ulu–Ilir* Riverine Polity

Georges Cœdès published his foundational philological decipherment of seventh-century Old Malay stones from Palembang, Jambi, and Bangka Island in 1930. Since then, the political ontology of Śrīvijaya (Sriwijaya) has stood at the center of historical and anthropological debates. The debates concern premodern state formation in Maritime Southeast Asia.[1,2] Continental agrarian empires were organized around contiguous cadastral taxation, walled rectilinear capitals, and standing territorial bureaucracies. Early Sumatran polities were different. They crystallized along braided equatorial

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estuaries, tidal peat-swamp lowlands, and monsoon-governed maritime straits.[1,2] Hermann Kulke's epigraphic reassessment of the *kadātuan* [royal palace-compound and sacralized ruler's center] demonstrated that Sriwijaya's concentric spatial grammar defies European Westphalian cartography. That grammar radiated outward from the Palembang core (*vanua* [settled port-urban community]) toward allied and tributary *bhūmi* [autonomous riverine or insular polities].[2] Building on O. W. Wolters's formulation of the Southeast Asian *maṇḍala* [polycentric circle of fluctuating charismatic sovereignty], historians increasingly recognize that thalassocratic authority rested on ritual attraction, redistributive alliance, and strategic control over estuarine bottlenecks, not on uniform hinterland annexation.[3,4]

Within comparative cultural theory, Stanley Tambiah's model of the galactic polity and Clifford Geertz's ethnography of the Balinese *negara* [exemplary ritual-theater state] illuminated how premodern Indic-inflected courts projected moral order from ceremonial centers. Political force there attenuated toward shifting peripheries.[5–7] Yet J. Stephen Lansing's complex-systems modeling of Balinese *subak* [water-temple irrigation networks] later showed that symbolic ritual centers in Nusantara were never detached from material hydro-ecology. Sacred liturgy directly coordinated hydraulic engineering, ecological risk, and collective compliance.[7,8] Eastern Sumatra's alluvial plains are vast. They are drained by the Musi, Batang Hari, Sekampung, Kampar, Indragiri, Rokan, and Barumun watersheds. Across these plains, this hydro-political coupling took a distinctly dendritic form, conceptualized in Malay ethnography as the *ulu–ilir* [upstream–downstream] continuum.[9–12] Archaeological surveys in western Palembang (Bukit Siguntang, Karanganyar, Kambang Unglen, and Talang Tuwo) and at downstream riverine-estuarine gateways (Kedukan Bukit, Boom Baru, Sebokingking/Telaga Batu, and Kota Kapur across the Bangka Strait) confirm a multi-nodal settlement fabric. This fabric linked highland forest-resin, camphor, and alluvial gold collectors in the *ulu* [upstream] interior to international entrepôt ports near the *ilir* [downstream] confluence.[9–12] Work on the tidal-swamp rivers of southeast Sumatra similarly reports Srivijaya-period settlements with stilt houses, imported ceramics and beads, and sewn-plank boats.[13]

Barbara Watson Andaya showed this for early modern Palembang and Jambi, and Kenneth Hall and John Miksic synthesis studies traced it back into the first millennium CE: downstream rulers could neither garrison every tributary headwater nor fence tropical rainforests.[14–17] Instead, riverine *dātu* [titled chieftains or provincial governors] and *huluṅtuhan* [extended royal kinsmen and vassal lords] mediated exchange wherever upland tributaries converged into main navigable channels or emptied into narrow maritime straits.[14–16] Precisely at those junctions, betrayal (*drohaka* [treason against the sovereign]), fiscal diversion, or piratical defection threatened to sever the arterial lifeblood of the polity.[2,14,17] Qualitative historiography has run for nearly a century. Even so, to our knowledge no study has formally quantified the geodesic proximity of Sriwijaya's sovereign oath monuments relative to empirically mapped Sumatran river networks and confluence chokepoints. Nor has any study tested those spatial patterns against Monte Carlo null landscapes and competing material or chronological covariates. Indonesian work has already related inscription find-spots, curse composition, and inscription counts to ecological conditions. It concluded that Palembang was the axis of Srivijayan unity and that outlying inscriptions marked an expanding territory.[18]

1.2 Diglossic Epigraphy, the Sanskrit Cosmopolis, Language B, and Comparative Javanese *Sīma* Cosmologies

Late seventh-century Sriwijaya articulated this riverine sovereignty through a textual medium. That medium marks a major transformation in Asian cultural history: the rapid appearance of public epigraphy in Old Malay between 682 and 686 CE.[1,19] Sheldon Pollock's influential theory of the Sanskrit Cosmopolis holds that first-millennium courts across South and Southeast Asia first adopted Sanskrit *kāvya* [ornate courtly poetics] as a transregional idiom of universal kingship. Only gradually did they elevate local vernaculars. These became literary and administrative scripts between roughly 800 and 1200 CE.[19,20] Sriwijaya's Pallava-script stones are Kedukan Bukit (604 Śaka / 682 CE), Talang Tuwo (606 Śaka / 684 CE), and Kota Kapur (608 Śaka / 686 CE). Alongside them stand the undated monumental Sebokingking (Telaga Batu) seven-hooded *nāga* [serpent water-deity] stela and tributary curse pillars at Karang Brahi, Palas Pasemah, Bungkuk, and Boom Baru. Together they inaugurate Austronesian state prose more than a century ahead of Javanese charter vernacularization.[21–24] Old Malay epigraphy did not simply replace Sanskrit. Arlo Griffiths and colleagues have documented across the Musi, Batang Hari, Barus, and West Sumatran basins that Sumatran inscriptions weave Sanskrit political, calendrical, and Mahāyāna Buddhist terminology directly into Austronesian morphosyntax (*maṅ-*, ni-, mar-, pa-...-an affixation).[22–24]

A third linguistic register is of even greater interest for Austronesian historical linguistics and cultural semiotics. It is conventionally termed Language B (or Old Malagasy / Southeast Barito-related maritime Austronesian), and it is preserved in the opening incantation of the Kota Kapur pillar on Bangka Island and echoed in preamble fragments of Telaga Batu, Karang Brahi, and Palas Pasemah.[1,25,26] K. Alexander Adelaar's comparative phonological and lexical reconstructions demonstrated close affinities between seventh-century Sriwijayan Old Malay, Southeast Barito languages of Borneo, and Malagasy in Madagascar. The affinities suggest that Sriwijaya integrated mobile seafaring populations (*orang laut* [sea-nomadic and maritime guardian communities]) into its naval and ritual apparatus.[25,26] The *sapatha* [sovereign imprecatory curse] was enacted physically. Its efficacy rested on *niminuṁña sumpaḥ* [drinking the cursed oath-water]. Royal officials, *dātu* governors, military commanders (*senāpati* [general]), merchants (*vaṇiyāga*), boat captains (*puhāvaṁ*), and palace artisans poured lustral water over the engraved stone, and at Sebokingking the water was guided down a carved ceremonial *soma-sūtra* [ablution spout] beneath seven cobra hoods, after which the participants ingested the liquid so that future treason (*drohaka*) would rot their viscera and annihilate their *gotrasantāna* [clan and lineage descendants].[1,2,10]

At the same time, Sriwijayan hydro-cosmology showed a benevolent ethical polarity, grounded in esoteric and Mahāyāna Buddhist networks that traversed the Maritime Silk Routes.[27–30] At Talang Tuwo (684 CE), Dapunta Hiyaṁ Śrī Jayanāśa dedicated the royal garden *Śrīkṣetra* [auspicious sacred field] together with engineered *tavad* [earthen weirs or check-dams] and *talāga* [freshwater reservoirs]. The dedication took the form of a *praṇidhāna* [Bodhisattva vow for universal awakening], praying that *āir niminuṁña* [all water drunk by

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living beings] yield health, harvest abundance (*subhikṣa* [abundance]), and ultimate enlightenment (*anuttarābhisamyaksaṁbodhi*).[1,27,28] Central Java followed another course. Dynastic links with the Śailendra [lords of the mountain] lineage fostered Old Malay foundations at Sojomerto, Mañjuśrīgṛha (Candi Sewu, 792 CE), Gandasuli (c. 803 CE), and Dieng, yet epigraphic practice soon diverged toward Old Javanese *sīma* [tax-exempt freehold land grant] charters.[29–33] Jan Wisseman Christie demonstrated that ninth- to thirteenth-century Javanese states anchored fiscal stability in demarcated *sawah* [irrigated wet-rice fields]. They protected *watu sīma* [boundary stones] through spectacular blood-and-egg curses performed by the *saṅ makudur* [oath-officiant priest].[31–33] This qualitative contrast sets Sumatran thalassocratic *sapatha* stones against Javanese agrarian *sīma* charters. Does it amount to a statistically reliable structural divergence across standardized digital editions? That has never been tested quantitatively.[31,33]

Why did Language B occupy the opening acoustic threshold of the 686 CE Kota Kapur *sapatha* pillar? Answering this requires situating early Sriwijaya within the mobile maritime demography of the Bangka Strait, Riau–Lingga archipelago, and western Borneo coast.[10,14,25,26] Comparative Austronesian linguistics has proposed an active West Indonesian seafaring Sprachbund. Seventh-century Old Malay took part in it. This network linked Sumatra's southeastern estuaries with Southeast Barito speech communities in Kalimantan, who were ancestors of the seventh- to eighth-century trans-Indian Ocean voyagers that settled Madagascar and carried Old Malay nautical, metallurgical, and directional loanwords into Malagasy.[25,26] In the amphibious *kadātuan*, royal power depended directly on the navigational skill, pilotage through treacherous mudbanks, and military loyalty of *orang laut* [sea-nomadic and estuarine guardian communities], who patrolled the Musi mouth and Bangka Strait narrows.[10,14,16] A sovereign stone pillar opened in Language B, invoking *nvari* [sacred water], *ulu* [upstream headwaters], and *tandrun luAḥ* [the Guardian Spirit of the River]. It then switched into administrative Old Malay. This sequence performed a deliberate double interpellation: it first summoned the autochthonous spirit powers and seafaring idioms of strait guardian lineages, and then translated sovereign command into the emergent lingua franca of riverine trade.[1,22,25]

1.3 Maritime Malay Expansion, Riverine Dredging Provenance Loss, and Study Objectives

Old Malay epigraphy has a long trajectory. It runs from late seventh-century Palembang and Bangka across the ninth- to fourteenth-century archipelago, reaching the Laguna Copperplate Inscription in Luzon (900 CE), Kebonkopi II in West Java (932 CE), Pasir Panjang and the Riau–Singapore Straits, Gunung Tua in Padang Lawas (1039 CE), and the highland Batanghari–Minangkabau courts of Dharmasraya (1286 CE) and Bukit Gombak (1356 CE). Tracing it reveals both remarkable cultural continuity and acute contemporary heritage peril.[34–38] Philological scholarship on Nusantara chronicles and legal manuscripts includes Uli Kozok's editions of highland Tambo and Undang-Undang legal codes and Wayan Jarrah Sastrawan's text-stratigraphic methodology. It shows that indigenous texts are layered politico-ritual instruments. They are not passive historical descriptions.[38,39] In Indonesian archaeological and humanities scholarship, recent qualitative studies have examined Sriwijaya *sapatha* stones as panoptic disciplinary technologies. Others have addressed post-Pallava multicultural epigraphy in Palembang and early maritime entrepôts such as Bongal on Sumatra's west coast. These studies have drawn attention to urgent threats to alluvial and waterlogged sites.[40–42]

Mechanical suction dredging for river sand, alluvial gold, and tin is a particular concern. Across the Musi, Komering, Batang Hari, and Bangka watersheds, it has brought hundreds of inscribed gold, silver, lead, and tin mantra [sacred esoteric syllables] and curse foils onto illicit antiquities markets, stripped of archaeological stratigraphy or geographic coordinates. Two examples are Rahayu et al.'s clinical-ethnographic analysis of Balinese cetik [magical toxin/sorcery] attribution and ritual efficacy[43] and Singh and Kumar's evaluative assessment of indigenous cultural heritage digitalization and community custodianship.[44] These cultural-methodological standards can be extended to Sriwijayan epigraphy. Doing so requires uniting open-access digital scholarly editions with formal spatial econometrics, clause-level corpus linguistics, and watershed heritage policy.

This study is guided by the newly consolidated European Research Council (ERC) DHARMA Nusantara epigraphic repository. It addresses four integrated research questions. (1) Across the complete Nusantara inventory (N = 1,526 inscriptions), how strongly do sovereign *sapatha*/*siddhayātrā* [ritual voyage-potency] monuments, esoteric mantra deposits, and agrarian *sīma* charters stratify across Sumatra–Bangka, the Malay Straits, and Java? How severe is site-coordinate loss among Sumatran portable metal foils relative to stone monuments? (2) Using zero-circularity OpenStreetMap river-confluence and strait-throat chokepoints benchmarked against 10,000 Monte Carlo land points, do Sriwijaya's core oath and foundation stones exhibit specific hydrographic chokepoint selection beyond baseline river-channel proximity? (3) Across all 21 Old Malay EpiDoc TEI-XML scholarly editions (1,655 lexical word tokens), how does code-switching among Austronesian Old Malay, Sanskrit, hybrid Malay-affixed Sanskrit, and Language B stratify across functional discourse zones? (4) In syntactic co-occurrence network topology and comparative document testing against Old Javanese *sīma* curse charters, how do thalassocratic and agrarian imprecatory cosmologies diverge? How can these findings inform an *Ulu–Ilir* [upstream–downstream] riverine safeguarding protocol?

2. Methods

2.1 Multi-Stream Computational-Epigraphic and Spatial-Network Research Design

The study followed a deterministic observational design with four streams. Stream 1 covered macro-archipelagic corpus epidemiology. Stream 2 combined geodesic hydro-network analysis with Monte Carlo spatial modeling. Stream 3 offered a clause-level philological token analysis of diglossic and triglossic usage, and Stream 4 compared syntactic co-occurrence networks against Old Javanese *sīma* charters. All textual records and transliterations came from the open-access ERC DHARMA (Domestication of 'Hindu' Asceticism and the Religious Making of Asia) Task Force C Nusantara Epigraphy repository (tfc-nusantara-epigraphy), and we adhered to the international Indic Romanization standard set by Acri and Griffiths.[45] Epigraphic survival depends on material durability, alluvial sedimentation, and modern dredging recovery. For that reason, every statistical model was read as observational and associational, never as an experimental causal estimate.

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Before any statistical computation, we reconciled records in both directions across the full IDENK metadata archive (IDENKmetadataallBatches.ods). The reconciliation linked artifactual inventory tables, archaeological provenance coordinates, paleographic dates, and 310 published EpiDoc TEI-XML scholarly editions. Of the 1,526 metadata records, 1,525 matched across the inventory and provenance sheets, a linkage integrity of 99.93%. Textual classification and spatial modeling had to remain independent to avoid circularity. We therefore assigned epigraphic genre only from archival text-type metadata and XML lexical lemmas, and did so before extracting or computing any geographic coordinates.

2.2 Stream 1 Macro-Archipelagic Stratification and Stream 2 Zero-Circularity Hydro-Geodesic Modeling

Stream 1 covered all N = 1,526 Nusantara inscriptions. We stratified them across four macro-geographic corridors: (i) Sumatra–Bangka (n = 336), (ii) Maritime Malay Straits and Insular Borneo/Riau/Luzon (n = 39), (iii) Agrarian Java, Madura, and Bali (n = 1,104), and (iv) Unassigned/Museum-only Nusantara collections (n = 47). Each inscription was assigned to one of five mutually exclusive functional genres. G1 was Sovereign *Sapatha* [sovereign imprecatory curse] Curse and *Siddhayātrā* [ritual voyage-potency] Expeditionary Monuments (n = 23). G2 was Esoteric Mantra, *Dhāraṇī* [protective Buddhist incantation], and *Praṇidhāna* [Bodhisattva vow] Votive Deposits (n = 119). G3 comprised Agrarian *Sīma* [tax-exempt freehold land grant] Tax-Freehold Grants and Legal Charters (n = 171), and G4 comprised Temple Dedications, Architectural Foundations, and Epitaphs (n = 371). G5 covered Short Seals, Ownership Rings, Votive Stamps, or Undetermined Fragments (n = 842). Material supports fell into five categories: Monumental Stone (n = 1,015), Portable Precious/Tin/Lead Foils and Rings (n = 193), Copper/Bronze Plates and Statuary (n = 203), Fired Clay Tablets/Bricks (n = 74), and Other/Undetermined (n = 41). Within Sumatra–Bangka (n = 336), we operationalized provenance attrition as the absence of both decimal latitude/longitude and subdistrict findspot attribution, which is attributed to antiquities-trade dispersal.

For Stream 2, we built a high-resolution hydrographic vector network covering mainland Sumatra and Bangka–Belitung. It was extracted from OpenStreetMap Overpass hydrography and contained 1,123 unique navigable river ways with 102,011 geodesic river vertices. The largest were Sungai Musi [8,165 vertices], Batang Hari [6,579], Way Sekampung [4,417], Batang Hari Leko [4,409], Way Seputih [3,464], Aek Barumun [3,362], Batang Tembesi [2,808], Air Lematang [2,603], Sungai Ogan [2,597], Sungai Komering [2,577], Batang Tebo [2,497], and Batang Merangin [2,411]. The Bangka rivers Sungai Menduk, Sungai Kota Kapur/Baturusa, and Sungai Layang were also included. We paired the network with 3,880 Natural Earth 1:10m coastline vertices. Archaeological point-process principles for partial settlement evidence guided the next step.[46] We defined k = 14 strategic hydrographic chokepoints whose coordinates were derived without reference to inscription locations. Eight were exact 0.000-km OpenStreetMap river-junction intersections where major named tributaries meet trunk rivers (Musi × Ogan, Musi × Komering, Musi × Lematang, Batang Hari × Tembesi, Tembesi × Merangin, Batang Hari × Tebo, Way Sekampung × Way Batanghari, and Aek Barumun × Batang Pane). Three were exact OpenStreetMap coastal river mouths (Musi, Batang Hari, and Way Sekampung estuaries). The last three were Natural Earth maritime strait narrows (Bangka Strait, Sunda Strait northern throat, and Malacca Strait Karimun funnel).

To keep coordinate imputation bias transparent, we analyzed two nested provenance tiers. The first was the Strict IDENK Coordinate Tier (n = 166 Sumatran inscriptions carrying raw decimal coordinates in IDENK). It contained n = 12 Core *Sapatha/Siddhayātrā* stones and n = 154 other Sumatran inscriptions. The second was the Extended Village-Resolved Sensitivity Tier (n = 185). It added 19 inscriptions whose IDENK record specifies an exact *kelurahan* [urban ward] or *desa* [village], such as Kedukan Bukit in 2 Ilir, Talang Tuwo in Talang Kelapa, Boom Baru in Lawang Kidul, Kambang Purun in Bukit Lama, Bungkuk in Jabung, and Baturaja on the upper Ogan. This tier therefore held n = 21 Core stones against n = 164 other Sumatran sites. One unprovenanced Bukittinggi market tin curse foil, IDENK-00001, stayed excluded from mapping. For every inscription we computed minimum spherical Haversine distances (km) to the nearest river vertex d(River), the nearest coastline vertex d(Coast), and the nearest hydrographic chokepoint d(Choke). These were benchmarked against N = 10,000 uniform random land points sampled inside Natural Earth Sumatra and Bangka land polygons.

2.3 Stream 3 Clause-Level Diglossic Token Tagging and Stream 4 Semantic Network Architecture

Stream 3 parsed the XML trees of all 21 Old Malay (omy-Latn) scholarly editions in ERC DHARMA. We stripped editorial punctuation, line-number tags, and pure numerals, which left N = 1,655 lexical word tokens.[45] Each token was classified deterministically into one of four etymological-linguistic strata, drawing on Old Malay and Sanskrit lexicography.[1,22,25] Stratum (1) was Indigenous Austronesian Old Malay. It held core Malayic pronouns, prepositions, numerals, verbs, and unborrowed nouns such as *kita, aku, di, dari, dńan*, *sāmvau* [sea-going vessel], *vanua*, *āir* [water], *tavad* [weir/dam], *nivunuḥ* [to be slain], *tāpik* [military strike], *ūpuḥ* [dart poison], and *tūva* [fish-stupefying root toxin]. Stratum (2) was Sanskrit Loanwords and Metric Verse: unaffixed Indic nominals, epithets, and doctrinal compounds such as *śakavarṣātīta* [elapsed Śaka year], *siddhayātra* [ritual voyage], *śrīvijaya*, *drohaka* [treason], *bhakti* [devotional loyalty], *tatvārjjava* [inner uprightness], *gotrasantāna* [clan and lineage descendants], *praṇidhāna* [Bodhisattva vow], bodhicitta [awakening-mind], and *mahāsattva* [great being]. Stratum (3) was Hybrid Malay-Affixed Sanskrit, meaning Sanskrit roots morphologically domesticated through Austronesian circumfixes, prefixes, or enclitics *-ña*. Examples are *kadātuan* [ka- + *dātu* + -an], *kasīhan* [love-sorcery philter], *nivuatña*, parsumpahan [oath ceremony], and *pūjāña* [its worship]. Stratum (4) was Language B, the 30 non-Malay Western Austronesian incantatory tokens in lines 1–2 of DHARMA-INSIDENK00050 Kota Kapur; it is therefore a positional category. These include *vari* [water], *paihumpaAn* [oath-formula], *ulu* [upstream], and *tandrun luAḥ* [Guardian of the River]. We then mapped each clause to one of five functional discourse zones. Z1 was Calendrical and Astral Protocol (n = 280). Z2 was Hydro-Deity and Oath Invocation (n = 360). Z3 was Sovereign Polity and Expedition Administration (n = 702), Z4 was Imprecatory Treason, Sorcery, and Toxin Sanctions (n = 238), and Z5 was Mahāyāna *Praṇidhāna* and Hydraulic Benevolence (n = 75). Shannon lexical entropy H' (bits) was computed across the four strata for each edition.

Stream 4 segmented all 21 Old Malay XML editions into 71 syntactic discourse windows. Each window grouped seven

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consecutive clause-phrases within a <p> epigraphic block, so that list-like sorcery enumerations stayed syntactically attached to their governing sanction verb. We then projected an 18-node cosmological concept ontology onto the 71 Old Malay windows. The ontology spanned four domains: Hydro-Ecology (H1–H4), Sovereign Polity (P1–P5), Imprecatory Sanctions (S1–S6), and Sacred Cosmology (B1–B3). The projection yielded a weighted undirected co-occurrence graph with 16 active Old Malay nodes and 80 weighted edges. From this graph we calculated degree, weighted node strength, inverse-weight Brandes shortest-path betweenness centrality, and normalized power-iteration eigenvector centrality. Document-level concept prevalence was compared across the n = 14 substantive Old Malay editions (≥ 15 word tokens) and n = 21 explicit Old Javanese *sapatha/sīma* curse charters. The charters were identified systematically from 85 Old Javanese charter XMLs in ERC DHARMA.

2.4 Statistical Estimation, Non-Parametric Effect Sizes, and Multiple-Testing Procedures

All quantitative analyses ran deterministically in Python (NumPy, pandas, SciPy). A fixed pseudo-random seed, 202611, governed Monte Carlo sampling and permutation tests, and the two-sided significance threshold was alpha = 0.05. We reported binomial proportions for regional genres, material supports, provenance loss, and charter prevalences with 95% Wilson score confidence intervals. Contingency tables in Streams 1 and 3 were evaluated with Pearson's χ^2 statistic and the Cramér's V effect size. Each was paired with a two-sided Fisher's exact odds ratio (OR). When zero cells occurred, the Haldane–Anscombe +0.5 continuity correction was applied only to the point and interval odds ratio estimates, and the exact hypergeometric p-values were preserved. The Wilson interval was preferred because the Wald interval has erratic coverage.[47] Continuity corrections for zero cells can influence conclusions in sparse data, so proportions are reported beside the corrected odds ratios.[48]

In Stream 2, geodesic distances (km) were right-skewed, so we summarized them with medians and interquartile ranges (IQR). Core *Sapatha* monuments and other Sumatran inscriptions were compared using two-sided Mann–Whitney U tests and the non-parametric Cliff's delta (delta, bounded in [−1, +1]), an ordinal dominance statistic.[49] We supplemented these with Monte Carlo comparisons against 10,000 uniformly drawn Sumatran–Bangka land points.[46] Multivariate binary logistic regression models were estimated by Newton–Raphson/BFGS maximum likelihood on both the Strict n = 166 and Extended n = 185 datasets. They predicted Core *Sapatha* placement from four terms: log-transformed river proximity [−ln(1 + d(River))], log-transformed chokepoint proximity [−ln(1 + d(Choke))], monumental stone support (1 = Stone, 0 = Non-stone), and early Sriwijaya chronological horizon (1 = 7th–10th c. CE, 0 = 11th–14th c. or undated non-core). Output included Likelihood-Ratio χ^2, McFadden pseudo-R^2, Nagelkerke R^2, Wald z-statistics, and 95% profile/Wald odds-ratio confidence intervals. In Stream 4, we ran 18 cross-corpus Fisher exact tests comparing Old Malay and Old Javanese charter prevalence. Their p-values were adjusted for multiplicity with the Benjamini–Hochberg false discovery rate (BH-FDR q) procedure.[50]

To ensure complete mathematical transparency and independent replicability across Streams 1 through 4, all spatial, probabilistic, information-theoretic, and graph-theoretic estimators were specified algebraically as follows. First, for any binomial count k observed out of N inscriptions or editions ($\hat{p} = k/N$), 95% Wilson score confidence bounds ($z = 1.95996$) were evaluated as $[\hat{p} + z^2/(2N) \pm z\sqrt{(\hat{p}(1-\hat{p})/N + z^2/(4N^2))}] / [1 + z^2/N]$, preventing boundary collapse when cell counts approached zero or unity (such as 0/120 unprovenanced Sumatran stones or 1/1,104 Javanese G1 curses). Second, in Stream 2, geodesic distance $d_H(p, q)$ (in km, using mean Earth radius R = 6,371.0088 km) between inscription coordinate $p = (\varphi_1, \lambda_1)$ and river or chokepoint vertex $q = (\varphi_2, \lambda_2)$ in radians was computed via the exact spherical Haversine operator $d_H(p, q) = 2R \arcsin(\sqrt{[\sin^2((\varphi_2 - \varphi_1)/2) + \cos(\varphi_1)\cos(\varphi_2)\sin^2((\lambda_2 - \lambda_1)/2)]})$, taking point-to-set minima $d(\text{River})_i = \min_{q \in V(\text{riv})} d_H(p_i, q)$ across $|V_{riv}| = 102{,}011$ vertices and $d(\text{Choke})_i = \min_{c \in C(14)} d_H(p_i, c)$ across $|C_{14}| = 14$ chokepoints. Finite-sample Monte Carlo p-values across M = 10,000 random land draws were calculated as $p_{MC} = (1 + \sum_{m=1}^{M} I(T_m \le T_{obs})) / (M + 1)$, yielding a rigorous non-zero lower bound of 1 / 10,001 = 0.0001, while pairwise ordinal dominance between Core (n_1) and Other (n_2) site distances was quantified via Cliff's delta $\delta = [\sum_{i,j} I(x_i > y_j) - \sum_{i,j} I(x_i < y_j)] / (n_1 n_2)$.

Third, in Stream 2 multivariate logistic regressions, the conditional probability $\pi_i = P(Y_i = 1 \mid X_i)$ of Core *Sapatha/Siddhayātrā* status followed $\ln[\pi_i / (1 - \pi_i)] = \beta_0 + \beta_1[-\ln(1 + d(\text{River})_i)] + \beta_2[-\ln(1 + d(\text{Choke})_i)] + \beta_3 \text{Stone}_i + \beta_4 \text{Early}_i$, with model fit evaluated from null (ℓ_0) and maximized (ℓ_1) log-likelihoods via LR $\chi^2 = 2(\ell_1 - \ell_0)$, McFadden's $R^2_{McF} = 1 - (\ell_1/\ell_0)$, and Nagelkerke's $R^2_N = [1 - \exp(2(\ell_0 - \ell_1)/n)] / [1 - \exp(2\ell_0/n)]$.[46] Fourth, in Stream 3, lexical register diversity within each edition d across the four etymological proportions ($p_{d,1}$, ..., $p_{d,4}$) was measured via Shannon entropy $H'(d) = -\sum_{s=1}^{4} p_{d,s} \log_2(p_{d,s})$ (defining $0 \log_2 0 = 0$, bounded in [0, 2.00] bits).[45] Fifth, in Stream 4, for co-occurrence weight w(u, v) counting shared syntactic windows between concepts u and v, weighted node strength equaled $S(v) = \sum_u w(v, u)$, inverse-weight geodesic edge length was defined as $\ell(u, v) = 1 / w(u, v)$ so stronger semantic coupling corresponded to shorter conceptual path length in Brandes normalized betweenness $C_B(v) = [2 / ((|V| - 1)(|V| - 2))] \sum_{s \ne v \ne t} (\sigma_{st}(v) / \sigma_{st})$, eigenvector centrality solved $Ax = \lambda_{max} x$ normalized to $\max_v x_v = 1$, and ordered cross-corpus Fisher p-values $p_{(1)} \le ... \le p_{(18)}$ were adjusted via Benjamini–Hochberg step-up $q_{(r)} = \min_{s \ge r} [\min(1, (18/s)p_{(s)})]$.

3. Results

3.1 Macro-Archipelagic Genre Stratification, Dredging Provenance Attrition, and the Sumatran Hydro-Epigraphic Landscape

Across the complete N = 1,526 ERC DHARMA Nusantara epigraphic inventory in Stream 1, functional genres and material supports differed markedly between macro-regions. The three regions were the Sumatra–Bangka riverine-maritime corridor (n = 336), the Malay Straits and insular corridor (n = 39), and agrarian Java (n = 1,104; global genre $\chi^2 = 474.38$, df = 8, $p = 2.20 \times 10^{-97}$, Cramér's V = 0.4005; global material $\chi^2 = 624.05$, df = 8, $p = 1.58 \times 10^{-129}$, V = 0.4593; Table 1 and Figure 1). Sovereign *sapatha* curse and *siddhayātrā* expeditionary monuments (G1) were almost entirely confined to Sumatra–Bangka. They made up 6.55% of all Sumatran–Bangka inscriptions (22/336; 95% CI: 4.36%–9.71%), against 0.00% (0/39) in the outer Malay Straits and only 0.09% (1/1,104; 95% CI: 0.02%–0.51%) in Java. The lone cataloged parallel in Java is a late fifteenth- to sixteenth-century Old Sundanese

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abstention edict (Kawali 1b). The result is a 77.28-fold odds concentration in Sumatra–Bangka (95% CI: 10.38–575.58, Fisher p = 1.31 × 10^{-13}). Esoteric Buddhist mantra, *dhāraṇī* [protective incantation], and *praṇidhāna* ritual texts (G2) follow the same split. They comprised 28.27% (95/336) of Sumatra–Bangka records and 43.59% (17/39) of Malay Straits records, compared with only 0.45% (5/1,104) in Java (OR = 86.64, 95% CI: 34.87–215.26, p = 2.41 × 10^{-58}). The reverse holds for Java, where agrarian *sīma* tax-freehold charters and legal land grants (G3) constituted 14.67% (162/1,104; 95% CI: 12.71%–16.88%) of the Javanese corpus (plus 179 durable copper/bronze charter plates; 16.21%) versus only 0.89% (3/336) in Sumatra–Bangka (OR = 19.09, 95% CI: 6.05–60.22, p = 2.74 × 10^{-16}).

Table 1. Macro-Archipelagic Epigraphic Genre Stratification, Material Support Asymmetry, and Riverbed Provenance Vulnerability Across the ERC DHARMA Inventory (N = 1,526 Nusantara Inscriptions).

Epigraphic Stratum / Indicator	Sumatra–Bangka Corridor (n = 336)	Malay Straits & Insular (n = 39)	Agrarian Java Corridor (n = 1,104)	Archipelago Total (N = 1,526) & Inference
Panel A: Functional Genre Taxonomy (G1–G5)	**Count (% [95% Wilson CI])**	**Count (% [95% Wilson CI])**	**Count (% [95% Wilson CI])**	**Total (incl. 47 Unassigned) / Effect**
G1: Sovereign *Sapatha* Curse & *Siddhayātrā*	22 (6.55% [4.4–9.7])	0 (0.00% [0.0–9.0])	1 (0.09% [0.0–0.5])	23 (1.51%); OR (Sum vs. Jav) = 77.28 (p = 1.31× 10^{-13})
G2: Esoteric Mantra, *Dhāraṇī* & *Praṇidhāna*	95 (28.27% [23.7–33.3])	17 (43.59% [29.3–59.0])	5 (0.45% [0.2–1.1])	119 (7.80%); OR (Sum vs. Jav) = 86.64 (p = 2.41× 10^{-58})
G3: Agrarian *Sīma* Grant & Legal Charter	3 (0.89% [0.3–2.6])	1 (2.56% [0.5–13.2])	162 (14.67% [12.7–16.9])	171 (11.21%); OR (Jav vs. Sum) = 19.09 (p = 2.74× 10^{-16})
G4: Temple Dedication, Foundation & Epitaph	34 (10.12% [7.3–13.8])	8 (20.51% [10.8–35.5])	323 (29.26% [26.6–32.0])	371 (24.31%); Global Genre χ^2 = 474.38 (df = 8, V = 0.400)
G5: Short Label, Seal, Ring or Fragmentary	182 (54.17% [48.8–59.4])	13 (33.33% [20.6–49.0])	613 (55.53% [52.6–58.4])	842 (55.18%); Known-corridor N = 1,479 (p = 2.20× 10^{-97})
Panel B: Material Support & Provenance Loss	**Sumatra–Bangka Support**	**Malay Straits Support**	**Agrarian Java Support**	**Archipelago Total / Dredging Vulnerability**
Monumental Stone (Stela, Pillar, River Boulder)	120 (35.71% [30.8–41.0])	20 (51.28% [36.2–66.1])	872 (78.99% [76.5–81.3])	1,015 (66.51%); Sumatran Stone Unprovenanced = 0/120 (0.00%)
Portable Precious / Tin / Lead Foil & Jewellery	153 (45.54% [40.3–50.9])	5 (12.82% [5.6–26.7])	32 (2.90% [2.1–4.1])	193 (12.65%); Sumatran Foils Unprovenanced = 93/153 (60.78%)
Copper / Bronze Charter Plate & Statuary	8 (2.38% [1.2–4.6])	3 (7.69% [2.7–20.3])	179 (16.21% [14.2–18.5])	203 (13.30%); Global Material χ^2 = 624.05 (df = 8, V = 0.459)
Fired Clay Tablet, Votive Stūpika & Brick	53 (15.77% [12.3–20.1])	10 (25.64% [14.6–41.1])	11 (1.00% [0.6–1.8])	74 (4.85%; plus 41 other/undetermined supports; p = 1.58× 10^{-129})
Sumatran Site-Coordinate Loss (Market / Dredged)	93/336 (27.68% [23.2–32.7])	0/39 (0.00% [0.0–8.9])	N/A (Alluvial Comparison)	Foils vs. Stone OR = 372.45 (95% CI: 22.73–6,102.35; p = 6.13× 10^{-32})

Notes: Source: ERC DHARMA Nusantara Epigraphic Inventory (IDENK metadata all batches bidirectional join, N = 1,526; 47 unassigned/museum-provenance records included in Archipelago Totals). 95% Wilson score confidence intervals shown in brackets. Two-sided Fisher's exact tests with Haldane–Anscombe continuity correction when zero cells occur.

Cross-tabulating Sumatran material supports against geographic coordinate retention showed a high rate of provenance loss among alluvial finds (Table 1, Panel B). Monumental stone inscriptions constituted 78.99% (872/1,104) of Javanese records. In Sumatra–Bangka, by contrast, portable precious-metal (gold/silver) and base-metal (tin/lead) foils and rings formed the single largest material class at 45.54% (153/336), outnumbering stone monuments (120/336; 35.71%). Loss of location data was severe. Exactly 60.78% (93/153; 95% CI: 52.88%–68.16%) of Sumatran portable metal foils lacked site coordinates or village provenance. These objects are reported to have surfaced through riverbed suction dredging and antiquities-market networks, such as the Bukittinggi market tin curse/mantra foils (IDENK-00001 to IDENK-00003) and unprovenanced Musi/Batanghari foil lots. Provenance loss among Sumatran monumental stones was 0.00% (0/120; 95% CI: 0.00%–3.10%), a sharp contrast (OR = 372.45, 95% CI: 22.73–6,102.35, Fisher p = 6.13 × 10^{-32}; the odds ratio uses the Haldane–Anscombe correction for the zero cell, so the difference in proportions, 60.78% versus 0.00%, is the more direct measure).

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Figure 1. Multi-stream computational-epigraphic architecture and macro-archipelagic genre and material stratification across the ERC DHARMA Nusantara Inventory (N = 1,526): (A) four-stream research design linking macro-archipelagic inventory stratification (Stream 1: N = 1,526), zero-circularity OpenStreetMap geodesic hydro-network and 10,000-point Monte Carlo spatial modeling (Stream 2: 102,011 river vertices, n = 185 provenanced Sumatran sites), clause-level diglossic and multi-register token tagging across all 21 Old Malay EpiDoc XML critical editions (Stream 3: 1,655 word tokens), and semantic co-occurrence network comparison against 85 Old Javanese charter editions (Stream 4: 21 explicit curse charters); (B) functional genre stratification across Sumatra–Bangka (n = 336), Malay Straits/Insular (n = 39), and Java (n = 1,104) with 95% Wilson confidence intervals, highlighting 77.28-fold concentration of sovereign curse/*siddhayātrā* stones in Sumatra–Bangka ($p = 1.31 \times 10^{-13}$) versus 19.09-fold concentration of *sīma* freehold grants in Java ($p = 2.74 \times 10^{-16}$); and (C) material support distribution and the 60.78% (93/153) provenance-loss crisis among dredged Sumatran metal foils versus 0.00% (0/120) among monumental stones (OR = 372.45, $p = 6.13 \times 10^{-32}$).

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Mapping all n = 185 provenanced Sumatran–Bangka inscriptions, together with the 21 Core *Sapatha*, *Siddhayātrā*, and *Śrīkṣetra* stone monuments, against 102,011 OpenStreetMap river vertices revealed a dendritic spatial pattern (Table 2 and Figure 2). Palembang's sacred hydro-urban core holds 15 core monuments (Table 2 and Figure 2A). These trace an intentional *ulu–ilir* ritual gradient. On the elevated northwestern *ulu* terrace (8.44 km from the main Musi channel; 9.75 km from the Musi–Ogan confluence), the 684 CE Talang Tuwo slab (IDENK-00066) consecrates engineered *tavad* dams and *talāga* reservoirs for public sustenance. Around Bukit Siguntang and Bukit Lama (3.14 km from the Musi–Ogan confluence), five Kambang Purun and Kambang Unglen stones (IDENK-00024, 00143, 00144, 00145, 00153) mark *siddhayātrā* shrines. At the tidal Musi–Tatang landing (0.24 km from river; 1.82 km from the Musi–Ogan junction), Kedukan Bukit (IDENK-00159, 682 CE) records Dapunta Hiyaṁ's riverine arrival. Along the eastern *ilir* gateway, where incoming ships from the Bangka Strait approached the capital, Boom Baru (IDENK-00155, 0.95 km from the Musi bank) and the Sebokingking/Telaga Batu complex bear texts that describe oath-drinking. The complex comprises the IDENK-00158 seven-hooded *nāga* spouted curse stela plus six *siddhayātrā* stones, 0.76 km from channel and 4.83 km from the Musi–Komering/Ogan confluences. Beyond Palembang, tributary and strait *sapatha* stelae lie farther out. Kota Kapur (IDENK-00050 and 00161) lies 2.16 km off the Bangka Strait coast, Palas Pasemah (IDENK-00124) stands 14.64 km from the Sunda Strait northern throat, and Bungkuk (IDENK-00038) is 1.71 km from Way Sekampung tributary. Karang Brahi (IDENK-00120) lies 0.52 km from Batang Merangin, upstream of the Merangin–Tembesi junction in Jambi, and Baturaja (IDENK-00363) lies 2.55 km from the upper Ogan River. Their distances to the nearest chokepoint are 33.59 km (Kota Kapur), 14.64 km (Palas Pasemah), 22.38 km (Bungkuk), 35.84 km (Karang Brahi), and 122.27 km (Baturaja) (Table 2). Table 2 also shows that the 21 core stones occupy 11 distinct coordinates.

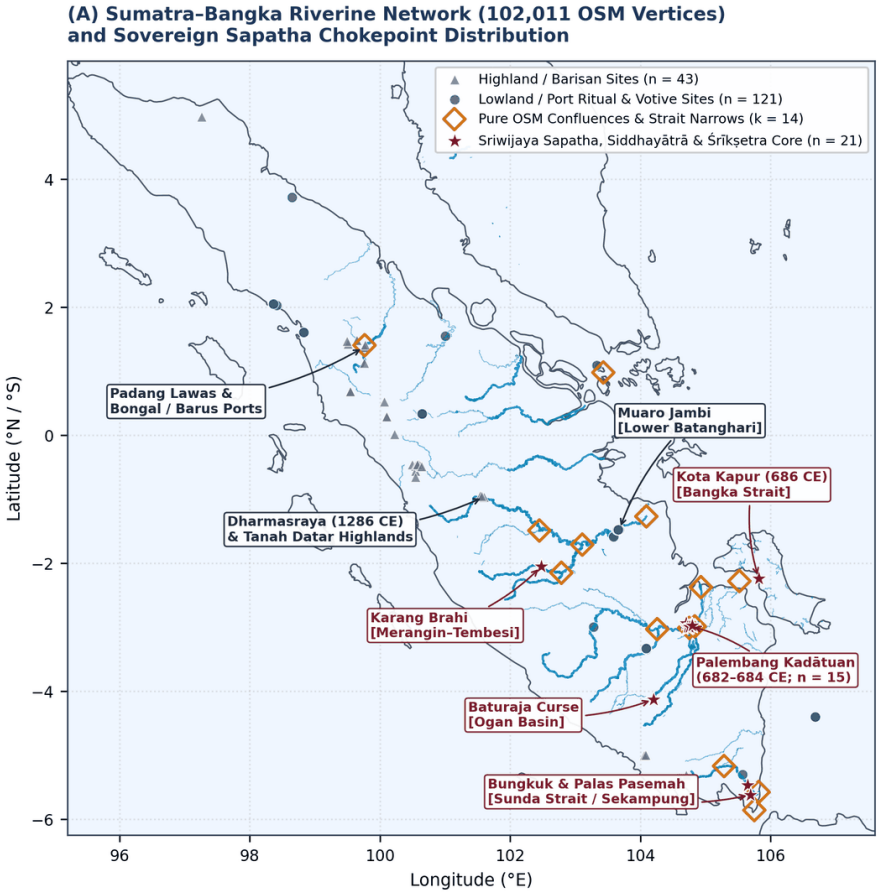
Table 2. Complete Inventory, Chronology, Epigraphic Register, and Geodesic Hydro-Chokepoint Coordinates of Sriwijaya Sovereign *Sapatha*, *Siddhayātrā*, and *Śrīkṣetra* Core Stone Monuments Across Sumatra and Bangka (n = 21).

DHARMA ID & Monument Designation	Watershed Province, Regency & Date	Ritual Function & Language Stratum	Geodesic Coordinates & Provenance Tier	d(River) / d(Chokepoint) & Coast
IDENK-00145: Kambang Unglen I	Sumatra Selatan (Kota Palembang) [600 CE]	*Siddhayātrā* (Sanskrit)	−3.0088°, 104.7335° (Strict IDENK)	1.66 km / 1.78 km (34.6 km coast)
IDENK-00159: Kedukan Bukit river stone	Sumatra Selatan (Kota Palembang) [682 CE]	Foundation (Old Malay)	−2.9964°, 104.7541° (Admin Centroid)	0.24 km / 1.82 km (35.0 km coast)
IDENK-00024: Kambang Purun River stone	Sumatra Selatan (Kota Palembang) [700 CE]	*Siddhayātrā* (Sanskrit)	−2.9971°, 104.7252° (Admin Centroid)	2.36 km / 3.14 km (33.0 km coast)
IDENK-00143: Kambang Purun Stone Fragment	Sumatra Selatan (Kota Palembang) [600 CE]	*Siddhayātrā* (Sanskrit)	−2.9971°, 104.7252° (Admin Centroid)	2.36 km / 3.14 km (33.0 km coast)
IDENK-00144: Kambang Purun Stone Fragment	Sumatra Selatan (Kota Palembang) [600 CE]	*Siddhayātrā* (Sanskrit)	−2.9971°, 104.7252° (Admin Centroid)	2.36 km / 3.14 km (33.0 km coast)
IDENK-00153: Kambang Purun River stone	Sumatra Selatan (Kota Palembang) [600 CE]	*Siddhayātrā* (Sanskrit)	−2.9971°, 104.7252° (Admin Centroid)	2.36 km / 3.14 km (33.0 km coast)
IDENK-00105: Sebokingking River Stone	Sumatra Selatan (Kota Palembang) [600 CE]	*Siddhayātrā* (Sanskrit)	−2.9773°, 104.7921° (Strict IDENK)	0.76 km / 4.83 km (36.4 km coast)
IDENK-00106: Sebokingking River stone	Sumatra Selatan (Kota Palembang) [600 CE]	*Siddhayātrā* (Sanskrit)	−2.9773°, 104.7921° (Strict IDENK)	0.76 km / 4.83 km (36.4 km coast)
IDENK-00139: Sebokingking Stone fragment	Sumatra Selatan (Kota Palembang) [600 CE]	Undetermined (Old Malay)	−2.9773°, 104.7921° (Strict IDENK)	0.76 km / 4.83 km (36.4 km coast)
IDENK-00158: Sebokingking Stela	Sumatra Selatan (Kota Palembang) [7th c. CE]	Curse (Old Malay + Language B)	−2.9773°, 104.7921° (Strict IDENK)	0.76 km / 4.83 km (36.4 km coast)
IDENK-00163: Sebokingking River stone	Sumatra Selatan (Kota Palembang) [600 CE]	*Siddhayātrā* (Sanskrit)	−2.9773°, 104.7921° (Strict IDENK)	0.76 km / 4.83 km (36.4 km coast)
IDENK-00164: Sebokingking River stone	Sumatra Selatan (Kota Palembang) [600 CE]	*Siddhayātrā* (Sanskrit)	−2.9773°, 104.7921° (Strict IDENK)	0.76 km / 4.83 km (36.4 km coast)
IDENK-00165: Sebokingking River stone	Sumatra Selatan (Kota Palembang) [600 CE]	*Siddhayātrā* (Sanskrit)	−2.9773°, 104.7921° (Strict IDENK)	0.76 km / 4.83 km (36.4 km coast)
IDENK-00155: Boom Baru River stone	Sumatra Selatan (Kota Palembang) [675 CE]	Curse (Old Malay)	−2.9738°, 104.7792° (Admin Centroid)	0.95 km / 5.40 km (35.1 km coast)
IDENK-00066: *Śrīkṣetra* Dedication	Sumatra Selatan (Kota Palembang) [684 CE]	Dedication / *Praṇidhāna* (Old Malay)	−2.9394°, 104.7000° (Admin Centroid)	8.44 km / 9.75 km (26.2 km coast)
IDENK-00124: Palas Pasemah Stele	Lampung (Kab. Lampung Selatan) [675 CE]	Curse (Old Malay + Language B)	−5.6225°, 105.6922° (Strict IDENK)	4.77 km / 14.64 km (15.1 km coast)
IDENK-00038: Bungkuk Stone	Lampung (Kab. Lampung Timur) [675 CE]	Curse (Old Malay)	−5.4694°, 105.6446° (Admin Centroid)	1.71 km / 22.38 km (21.0 km coast)

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DHARMA ID & Monument Designation	Watershed Province, Regency & Date	Ritual Function & Language Stratum	Geodesic Coordinates & Provenance Tier	d(River) / d(Chokepoint) & Coast
IDENK-00050: Kota Kapur Pillar	Kepulauan Bangka Belitung (Kab. Bangka) [686 CE]	Curse (Old Malay + Language B)	−2.2426°, 105.8200° (Strict IDENK)	20.37 km / 33.59 km (2.2 km coast)
IDENK-00161: Kota Kapur river stone	Kepulauan Bangka Belitung (Kab. Bangka) [650 CE]	*Siddhayātrā* (Undetermined)	−2.2426°, 105.8200° (Strict IDENK)	20.37 km / 33.59 km (2.2 km coast)
IDENK-00120: Karang Brahi Stela	Jambi (Kab. Merangin) [600 CE]	Curse (Old Malay + Language B)	−2.0514°, 102.4783° (Strict IDENK)	0.52 km / 35.84 km (149.0 km coast)
IDENK-00363: Stone fragmen from Baturaja	Sumatra Selatan () [600 CE]	Curse (Old Malay)	−4.1297°, 104.1979° (Admin Centroid)	2.55 km / 122.27 km (106.8 km coast)

Notes: Ordered by ascending geodesic distance to the nearest zero-circularity hydrographic chokepoint d(Chokepoint). Strict IDENK (n = 12) denotes raw decimal coordinates in the IDENK archive; Admin Centroid (n = 9) denotes verified administrative subdistrict/*kelurahan* centroids from IDENK provenance fields (Bukit Lama, Talang Kelapa, Lawang Kidul, 2 Ilir/Ilir Barat, Jabung Lampung Timur, and Baturaja Ogan). Unprovenanced Bukittinggi market tin foil IDENK-00001 (Curse) is excluded from geodesic mapping due to illicit antiquities dispersal.



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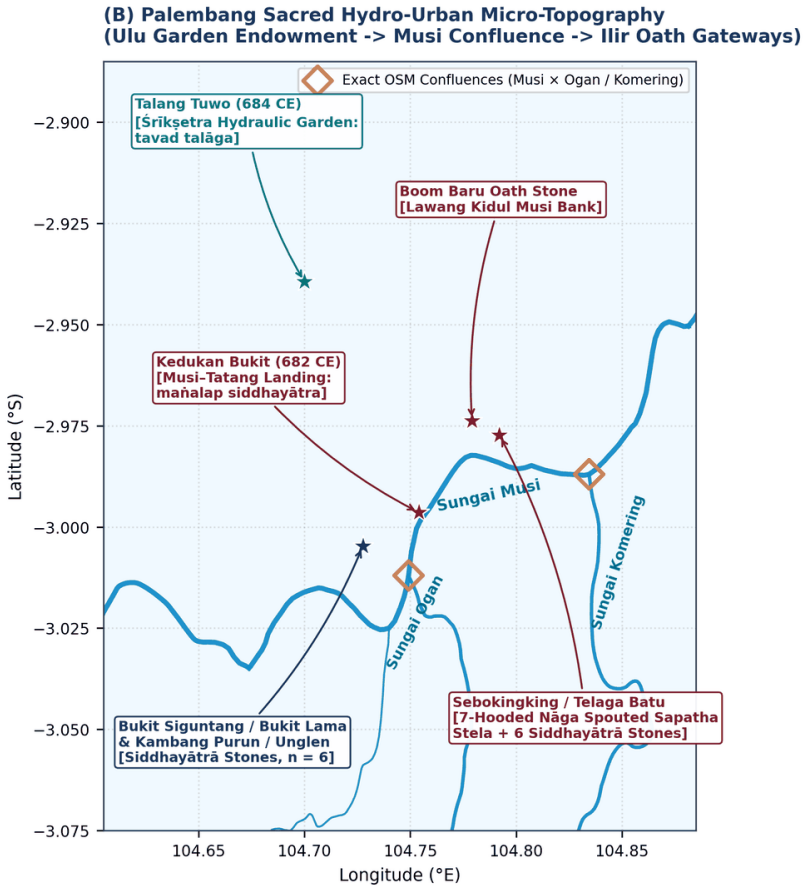


Figure 2. Geodesic riverine hydrography, zero-circularity confluence/strait chokepoints, and Palembang sacred hydro-urban micro-topography: (A) mainland Sumatra and Bangka–Belitung hydrographic network (1,123 OpenStreetMap river ways; 102,011 vertices) showing all k = 14 independently derived river-confluence, estuary, and maritime-strait chokepoints alongside n = 21 Core Sriwijaya *Sapatha*, *Siddhayātrā*, and *Śrīkṣetra* monuments and n = 164 other provenanced Sumatran inscriptions; and (B) high-resolution Palembang *ulu–ilir* inset illustrating the ritual-hydraulic gradient from the northwestern Talang Tuwo *Śrīkṣetra* dam/reservoir endowment (684 CE) and Bukit Siguntang / Kambang Purun–Unglen shrines through the Kedukan Bukit Musi–Tatang landing (682 CE) to the eastern Boom Baru and Sebokingking (Telaga Batu) 7-hooded *nāga* oath gateways.

3.2 Geodesic Riverine and Chokepoint Proximity Versus Monte Carlo Null and Multivariate Logistic Determinants

Non-parametric geodesic distance testing against N = 10,000 uniform random Sumatra–Bangka land points separated general riverine settlement orientation from specific hydrographic chokepoint selection (Table 3 and Figure 3). Random terrestrial locations across Sumatra and Bangka lay a median of 21.77 km (IQR: 9.18–46.26 km, mean 63.69 km; only 6.35% within ≤ 2 km) from the nearest mapped navigable river channel. By comparison, both Core *Sapatha*/*Siddhayātrā* monuments and non-core Sumatran epigraphic sites clustered tightly along river arteries (Monte Carlo p = 0.0001 with 10,000 draws). The Core figures were Strict IDENK n = 12: median 0.76 km, IQR: 0.76–2.44 km, 75.0% within ≤ 2 km; Extended n = 21: median 1.66 km, IQR: 0.76–2.36 km, 57.14% within ≤ 2 km. Non-core sites (n = 164) came out similar: a median of 1.11 km, IQR: 0.82–9.91 km, 67.68% within ≤ 2 km. River proximity alone, then, was not enough. Raw distance to any river segment did not statistically differentiate Core *Sapatha* monuments from later temple complexes such as Muaro Jambi, Muara Takus, or Dharmasraya (Strict Mann–Whitney U = 651.0, p = 0.0882, Cliff's delta = −0.2955; Extended U = 1,559.0, p = 0.4807, delta = −0.0947). The fourteenth-century Adityawarman highland inscriptions in Tanah Datar (n = 43 highland records) did shift farther into upland volcanic valleys (median d(River) = 9.85 km).

Table 3. Geodesic River-Channel and Chokepoint Proximity Versus a 10,000-Point Monte Carlo Land Null and Multivariate Logistic Regression Determinants of Sovereign *Sapatha* Placement.

Hydro-Spatial Metric / Logistic Predictor	Strict IDENK Tier (n = 166; 12 Core vs. 154 Other)	Extended Village-Resolved Tier (n = 185; 21 Core vs. 164 Other)	Monte Carlo Land Null (N = 10,000) / Effect Size
Panel A: Non-Parametric Geodesic Proximity	**Median [IQR] / Threshold Share**	**Median [IQR] / Threshold Share**	**Null Median [IQR] / Mann–Whitney & Cliff's δ**

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Hydro-Spatial Metric / Logistic Predictor	Strict IDENK Tier (n = 166; 12 Core vs. 154 Other)	Extended Village-Resolved Tier (n = 185; 21 Core vs. 164 Other)	Monte Carlo Land Null (N = 10,000) / Effect Size
Core *Sapatha* Distance to Navigable River d(River)	0.76 km [0.76–2.44]; ≤2 km: 9/12 (75.0%)	1.66 km [0.76–2.36]; ≤2 km: 12/21 (57.1%)	Null: 21.77 km [9.18–46.26]; ≤2 km: 6.35% (MC p = 0.0001)
Other Sumatran Sites Distance to River d(River)	1.11 km [0.82–9.53]; ≤2 km: 106/154 (68.8%)	1.11 km [0.82–9.91]; ≤2 km: 111/164 (67.7%)	Core vs. Other: Strict U = 651 (p = 0.088, δ = −0.295); Ext U = 1,559 (p = 0.481, δ = −0.095)
Core *Sapatha* Distance to Chokepoint d(Choke)	4.83 km [4.83–19.38]; ≤15 km: 9/12 (75.0%)	4.83 km [3.14–14.64]; ≤15 km: 16/21 (76.2%)	Null: 120.80 km [71.19–184.19]; ≤15 km: 1.66% (MC p = 0.0001)
Other Sumatran Sites Distance to Chokepoint d(Choke)	52.52 km [52.37–136.69]; ≤15 km: 14/154 (9.1%)	52.52 km [52.45–130.86]; ≤15 km: 14/164 (8.5%)	Core vs. Other: Strict U = 172 (p = 2.57×10^{-6}, δ = −0.814); Ext U = 358 (p = 3.29×10^{-9}, δ = −0.792)
Panel B: Multivariate Logistic Regression (Outcome = Core)	**Strict Model (LR χ^2 = 50.01, df = 4, p = 3.60×10^{-10})**	**Extended Model (LR χ^2 = 84.37, df = 4, p < 10^{-16})**	**Fit: McFadden R^2 = 0.580 / 0.645; Nagelkerke R^2 = 0.642 / 0.722**
Riverine Channel Proximity [−ln(1 + d(River) km)]	β = 0.00 (SE 0.41); OR = 1.00 [0.45–2.23], p = 0.9975	β = +0.04 (SE 0.35); OR = 1.04 [0.52–2.06], p = 0.9154	Non-significant net effect: river channels host all Sumatran genres equally
Chokepoint Proximity [−ln(1 + d(Choke) km)]	β = +0.67 (SE 0.35); OR = 1.95 [0.99–3.86], p = 0.0549	β = +0.67 (SE 0.29); OR = 1.96 [1.11–3.46], p = 0.0210	Doubles Core *Sapatha* odds per log-unit approach to confluences/straits
Monumental Stone Support (vs. Foil / Brick / Bronze)	β = +3.66 (SE 1.30); OR = 38.83 [3.04–496.78], p = 0.0049	β = +4.14 (SE 1.22); OR = 63.04 [5.73–693.61], p = 0.0007	Public lithic permanence vs. concealed ritual deposits
Early Sriwijaya Era (7th–10th c. CE vs. 11th–14th c.)	β = +3.40 (SE 1.29); OR = 30.10 [2.41–376.38], p = 0.0082	β = +3.86 (SE 1.22); OR = 47.24 [4.29–519.69], p = 0.0016	Concentrated in formative *Kadātuan* expansion phase

Notes: Hydrographic network comprises 1,123 OpenStreetMap river ways (102,011 vertices) across Sumatra and Bangka. All k = 14 chokepoints were derived independently from exact 0.000-km OSM river-confluence intersections, OSM coastal river mouths, and Natural Earth 10m strait narrows without referencing archaeological site coordinates.

What sharply distinguished Sriwijaya's Core *Sapatha*, *Siddhayātrā*, and *Śrīkṣetra* monuments from the rest of Sumatran epigraphy was geodesic proximity to the 14 zero-circularity river-confluence, estuary, and maritime-strait chokepoints (d(Choke); Table 3, Panel A and Figure 3B). The Core monuments lay a median of 4.83 km from the nearest hydrographic chokepoint in both the Strict IDENK tier (IQR: 4.83–19.38 km; 75.00% [9/12] within ≤ 15 km) and the Extended Village-Resolved tier (IQR: 3.14–14.64 km; 76.19% [16/21] within ≤ 15 km). The gap is wide. Other Sumatran inscriptions lay more than tenfold farther away, at a median of 52.52 km (Strict IQR: 52.37–136.69 km, 9.09% [14/154] within ≤ 15 km, Mann–Whitney U = 172.0, p = 2.57×10^{-6}, large negative Cliff's delta = −0.8139; Extended IQR: 52.45–130.86 km, 8.54% [14/164] within ≤ 15 km, U = 358.0, p = 3.29×10^{-9}, Cliff's delta = −0.7921). The within-15-km share of the core group (16/21) is carried by the 15 Palembang stones and Palas Pasemah; the other five stones (Kota Kapur ×2, Bungkuk, Karang Brahi, and Baturaja) lie 22.38–122.27 km from the nearest chokepoint (Table 2). Random land points were far more remote. They lay at a median of 120.80 km (IQR: 71.19–184.19 km; 1.66% within ≤ 15 km, Monte Carlo p = 0.0001).

Multivariate binary logistic regression showed that chokepoint proximity has an independent spatial association, even after controlling for baseline river-channel proximity, monumental stone materiality, and early chronological horizon (Table 3, Panel B and Figure 3C). In the Extended model (n = 185, 21 events; Likelihood-Ratio χ^2 = 84.37, df = 4, p < 10^{-16}, McFadden R^2 = 0.645, Nagelkerke R^2 = 0.722), river-channel proximity [−ln(1 + d(River))] had no net partial effect (beta = +0.04, SE = 0.35, OR = 1.04 [95% CI: 0.52–2.06], p = 0.9154). River proximity therefore did not separate the Core group from other Sumatran inscriptions. Each unit increase in log chokepoint proximity [−ln(1 + d(Choke))] nearly doubled the odds of Core *Sapatha*/*Siddhayātrā* placement (beta = +0.67, SE = 0.29, OR = 1.96 [95% CI: 1.11–3.46], p = 0.0210). Monumental stone support (OR = 63.04 [95% CI: 5.73–693.61], p = 0.0007) and seventh- to tenth-century CE chronology (OR = 47.24 [95% CI: 4.29–519.69], p = 0.0016) were also associated with Core placement. The Strict IDENK sensitivity regression (n = 166, 12 events; LR χ^2 = 50.01, p = 3.60×10^{-10}, Nagelkerke R^2 = 0.642) yielded similar point estimates (Chokepoint OR = 1.95 [0.99–3.86], p = 0.0549; Stone OR = 38.83, p = 0.0049; Early Era OR = 30.10, p = 0.0082; River OR = 1.00, p = 0.9975). The point estimates were similar across coordinate provenance tiers, although the Strict-tier chokepoint estimate is not significant at α = 0.05 (p = 0.0549).

Inspecting the exact log-likelihood decomposition and the diachronic upland trajectory in Stream 2 describes model fit and the later shift away from the estuaries (Table 3). In the Extended dataset (n = 185), adding the four predictors improved log-likelihood from $\ell0$ = −65.45 to $\ell1$ = −23.27 (LR χ^2 = 84.37, p < 10^{-16}). In the Strict IDENK dataset (n = 166), it improved from $\ell0$ = −43.08 to $\ell1$ = −18.08 (LR χ^2 = 50.01, p = 3.60×10^{-10}). The wide Wald 95% confidence intervals around monumental stone support (Extended OR = 63.04 [5.73–693.61]) and seventh- to tenth-century chronology (OR = 47.24 [4.29–519.69]) reflect a real archaeological pattern. It is a quasi-complete structural concentration: 100% (21/21) of mapped Core *Sapatha*/*Siddhayātrā*/*Śrīkṣetra* monuments were carved on durable stone during the formative Sriwijayan centuries. The chokepoint effect behaved differently. Continuous log chokepoint proximity kept a tightly bounded, stable slope across both datasets (Extended β = +0.67, SE = 0.29, OR = 1.96 [1.11–3.46]; Strict β = +0.67, SE = 0.35, OR = 1.95 [0.99–3.86]). Disaggregating later eleventh- to fourteenth-

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century Sumatran epigraphy reveals a clear inland political-ecological shift. Muaro Jambi's brick temple complex clustered along the middle Batang Hari levee (d(River) = 0.77–1.90 km, d(Choke) = 52.05–53.31 km). Fourteenth-century Malay–Sanskrit courtly inscriptions under King Adityawarman in the Tanah Datar / Minangkabau highlands (n = 43 highland records, including Bukit Gombak 1356 CE) moved into fertile intermontane volcanic basins (median d(River) = 9.85 km, d(Choke) > 110 km). These inscriptions lie far from the estuarine chokepoints, which is consistent with a shift toward highland agrarian kingship.

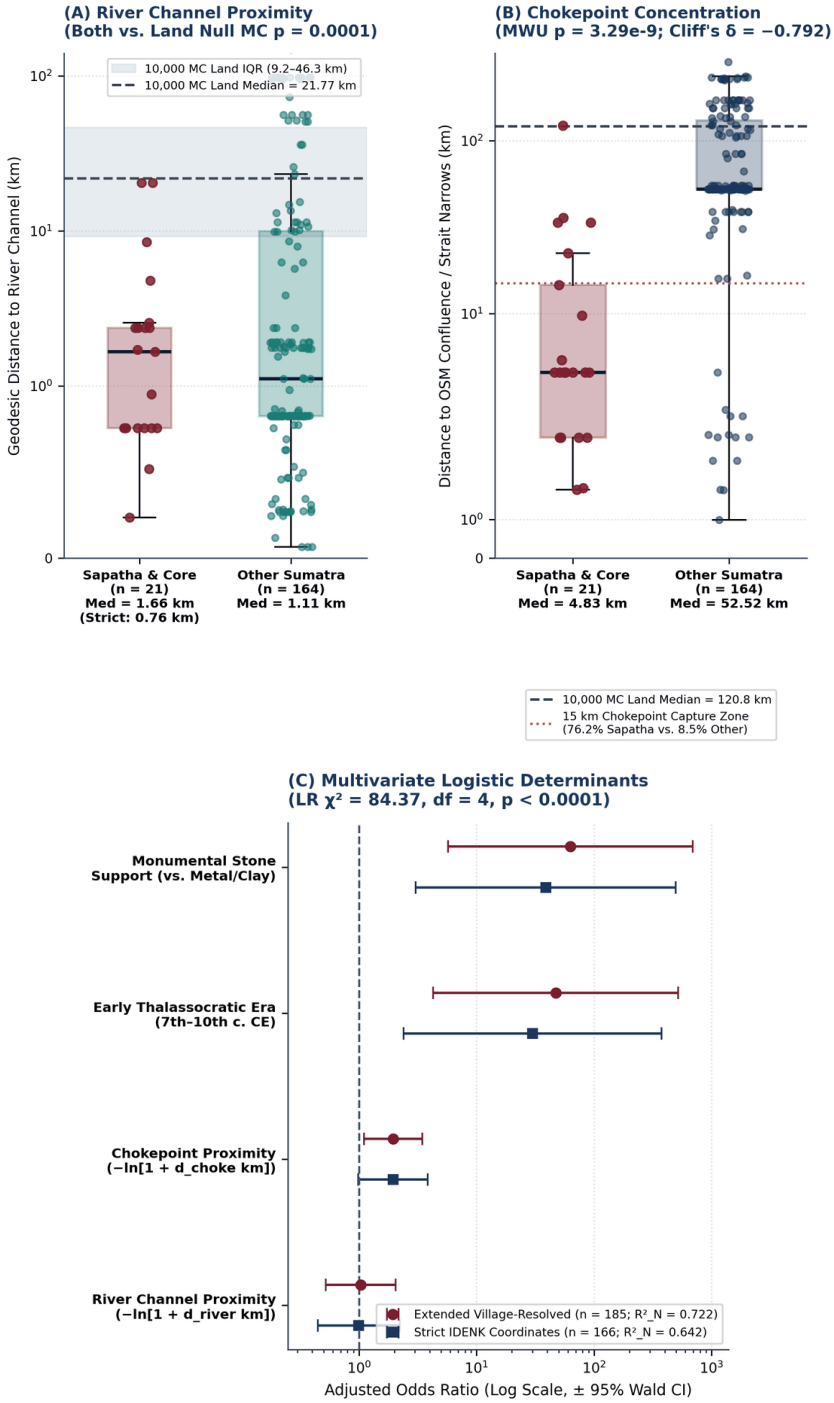


Figure 3. Non-parametric geodesic riverine and chokepoint proximity distributions versus a 10,000-point Monte Carlo Sumatra–Bangka land null and multivariate logistic regression determinants: (A) geodesic distance to nearest navigable river channel d(River), showing tight clustering of both Core *Sapatha* (median 1.66 km) and other Sumatran sites (median 1.11 km) relative to random land points (median 21.77 km; Monte Carlo p = 0.0001); (B) geodesic distance to nearest zero-circularity hydrographic chokepoint d(Choke), demonstrating selective chokepoint positioning of Core *Sapatha* stones (median 4.83 km; 76.2% within ≤ 15 km) versus other Sumatran sites (median 52.52 km; 8.5% within ≤ 15 km; Mann–Whitney p = 3.29 × 10^{-9}, Cliff's delta = –0.792) and random land points (median 120.80 km); and (C) multivariate logistic regression odds ratios (± 95% CI) across Strict IDENK (n = 166; Nagelkerke R^2 = 0.642) and Extended Village-Resolved (n = 185; Nagelkerke R^2 = 0.722) models.

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3.3 Clause-Level Triglossic Code-Switching, Semantic Network Centrality, and Divergence from Javanese *Sīma* Charters

Etymological token tagging across all 21 Old Malay EpiDoc XML critical editions in Stream 3 (N = 1,655 lexical word tokens) showed that Old Malay epigraphy was neither monolingually vernacular nor passively Sanskritized. It operated as a functionally stratified diglossic discourse system, with four co-present strata at Kota Kapur (χ^2 = 166.16, df = 12, p = 2.90 × 10^{-29}, Cramér's V = 0.1829; Table 4 and Figure 4). Across the entire 1,655-token corpus, Indigenous Austronesian Old Malay supplied 54.68% (905 tokens), Sanskrit loanwords and verse supplied 35.65% (590 tokens), Hybrid Malay-affixed Sanskrit supplied 7.85% (130 tokens), and archaic Language B supplied 1.81% (30 tokens). The register nonetheless shifted sharply with communicative function (Figure 4A). Z1 Śaka Calendrical and Astronomical Protocols (n = 280) balanced Austronesian syntax (49.29%) with technical Sanskrit chronograms (46.07%). Z2 Cosmological Hydro-Deity and Oath Invocations (n = 360) combined 56.39% Austronesian and 12.22% Hybrid forms with 8.33% (30 tokens) of Language B spirit-water formulas (*vari*, *ulu*, *tandrun luAḥ*, *paihumpaAn*). Z3 Sovereign Polity and Expedition Administration (n = 702) blended 54.13% Austronesian operational grammar with 39.60% Sanskrit administrative titles. Z4 Imprecatory Treason, Sorcery, and Toxin Sanctions (n = 238) rose to 63.45% Indigenous Austronesian (151/238, vs. 26.89% Sanskrit), which kept lethal curse predicates clearly intelligible in the vernacular (*nivunuḥ* ya *sumpaḥ* [oath-curse], *tāpik*, *ūpuḥ*, *tūva*, *kasīhan*). Z5 Mahāyāna *Praṇidhāna* and Hydraulic Benevolence (n = 75) inverted the ratio to 48.00% Sanskrit (36/75, vs. 44.00% Austronesian), raising public dam-and-reservoir engineering (*tavad talāga*) into universal Buddhist soteriology.

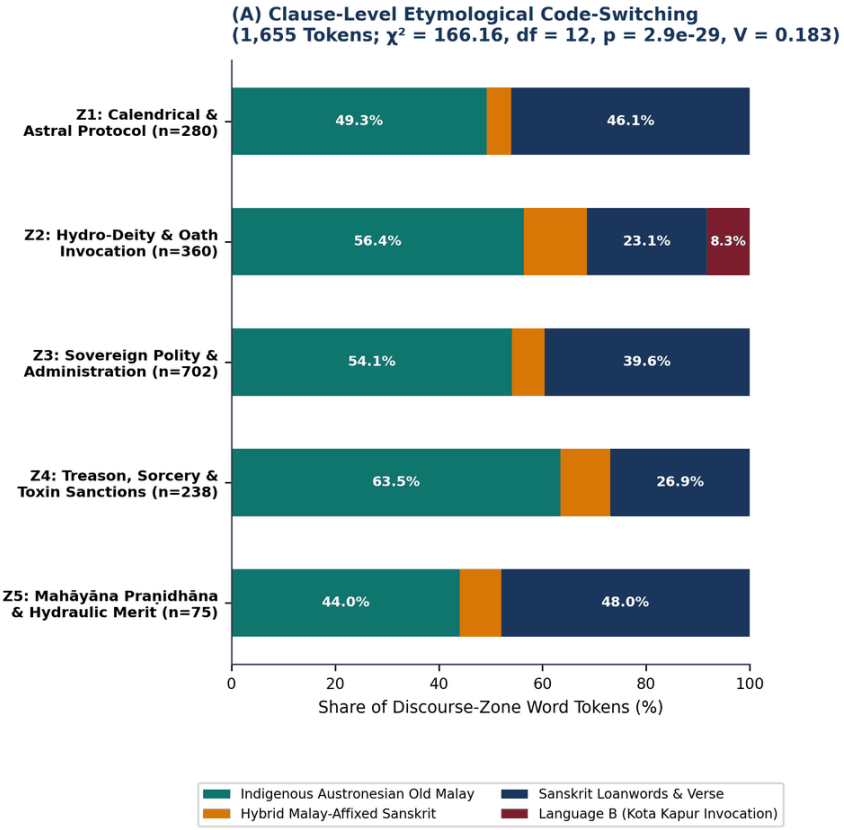
Table 4. Clause-Level Etymological Code-Switching Across Discourse Zones (Z1–Z5) and Individual Inscription Profiles Across All 21 ERC DHARMA Old Malay EpiDoc XML Critical Editions (1,655 Word Tokens)

Discourse Zone / Critical Edition	Tokens (Corpus Share)	Austronesian Old Malay	Sanskrit Loanwords & Verse	Hybrid Malay–Sanskrit, Language B & Entropy
Panel A: Functional Discourse Zones (Z1–Z5; 21 XMLs)	**Word Tokens (Share %)**	**Indigenous Austronesian**	**Sanskrit Loan / Verse**	**Hybrid Malay–Skt / Language B**
Z1: Śaka Calendrical & Astral Protocol	n = 280 (16.9%)	138 (49.29%)	129 (46.07%)	Hyb: 13 (4.64%) | LgB: 0 (0.00%)
Z2: Hydro-Deity & Oath Invocation	n = 360 (21.8%)	203 (56.39%)	83 (23.06%)	Hyb: 44 (12.22%) | LgB: 30 (8.33%)
Z3: Sovereign Polity & Expedition Admin	n = 702 (42.4%)	380 (54.13%)	278 (39.60%)	Hyb: 44 (6.27%) | LgB: 0 (0.00%)
Z4: Imprecatory Treason, Sorcery & Toxins	n = 238 (14.4%)	151 (63.45%)	64 (26.89%)	Hyb: 23 (9.66%) | LgB: 0 (0.00%)
Z5: Mahāyāna *Praṇidhāna* & Hydraulic Merit	n = 75 (4.5%)	33 (44.00%)	36 (48.00%)	Hyb: 6 (8.00%) | LgB: 0 (0.00%)
Corpus Total Across All 21 Old Malay Editions	N = 1,655 (100.0%)	905 (54.68%)	590 (35.65%)	Hyb: 130 (7.85%) | LgB: 30 (1.81%)
Panel B: Individual Substantive Editions (Top 12 + 9 Short)	**Token Count**	**Austronesian Share**	**Sanskrit Share**	**Hybrid / LgB & Entropy H' (bits)**
Gandasuli Śaiva Charter, Central Java (c. 803 CE)	n = 284	191 (67.25%)	50 (17.61%)	Hyb: 15.1% | LgB: 0.0% | H′ = 1.24 bits
Kota Kapur *Sapatha* Pillar, Bangka (686 CE)	n = 230	135 (58.70%)	60 (26.09%)	Hyb: 2.2% | LgB: 13.0% | H′ = 1.46 bits
Bukit Gombak Stela, Tanah Datar (1356 CE)	n = 224	77 (34.38%)	128 (57.14%)	Hyb: 8.5% | LgB: 0.0% | H′ = 1.29 bits
Talang Tuwo *Śrīkṣetra* Slab, Palembang (684 CE)	n = 222	122 (54.95%)	96 (43.24%)	Hyb: 1.8% | LgB: 0.0% | H′ = 1.10 bits
Laguna Copperplate Debt Acquittal, Luzon (900 CE)	n = 133	93 (69.92%)	30 (22.56%)	Hyb: 7.5% | LgB: 0.0% | H′ = 1.13 bits
Mañjuśrīgṛha Temple Foundation, Sewu (792 CE)	n = 131	55 (41.98%)	50 (38.17%)	Hyb: 19.9% | LgB: 0.0% | H′ = 1.52 bits
Dharmasraya Amoghapāśa Base, Upper Batanghari (1286 CE)	n = 109	37 (33.94%)	63 (57.80%)	Hyb: 8.3% | LgB: 0.0% | H′ = 1.28 bits
Kedukan Bukit *Siddhayātrā* Stone, Palembang (682 CE)	n = 71	43 (60.56%)	28 (39.44%)	Hyb: 0.0% | LgB: 0.0% | H′ = 0.97 bits
Dieng Śaiva Temple Inventory, Central Java (9th c. CE)	n = 68	60 (88.24%)	6 (8.82%)	Hyb: 2.9% | LgB: 0.0% | H′ = 0.62 bits

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Discourse Zone / Critical Edition	Tokens (Corpus Share)	Austronesian Old Malay	Sanskrit Loanwords & Verse	Hybrid Malay–Sanskrit, Language B & Entropy
Puhawang Glis Benefice, Lampung (827 CE)	n = 67	45 (67.16%)	19 (28.36%)	Hyb: 4.5% | LgB: 0.0% | H′ = 1.10 bits
Sojomerto Śailendra Lineage Stone, Java (7th–8th c. CE)	n = 28	9 (32.14%)	13 (46.43%)	Hyb: 21.4% | LgB: 0.0% | H′ = 1.52 bits
Gunung Tua Lokanātha Statue, Padang Lawas (1039 CE)	n = 26	3 (11.54%)	22 (84.62%)	Hyb: 3.9% | LgB: 0.0% | H′ = 0.74 bits
Remaining 9 Short / *Siddhayātrā* Formula Editions Combined	n = 62	35 (56.45%)	25 (40.32%)	Hyb: 2 (3.2%) | LgB: 0.0% | Sebokingking N.139 n = 25, Kebonkopi n = 14

Notes: Zone-by-stratum contingency across N = 1,655 lexical word tokens yields Pearson $\chi^2 = 166.16$ (df = 12, $p = 2.90\times10^{-29}$, Cramér's V = 0.1829). Shannon lexical stratum entropy $H' = -\sum p(s) \log_2 p(s)$ reaches a theoretical maximum of 2.00 bits across four strata (Kota Kapur H' = 1.46 bits is the sole monument combining all four linguistic registers; Mañjuśrīgṛha and Sojomerto reach H' = 1.52 bits across three strata). Hyb, hybrid Malay–Sanskrit; LgB, Language B; H′, Shannon entropy.



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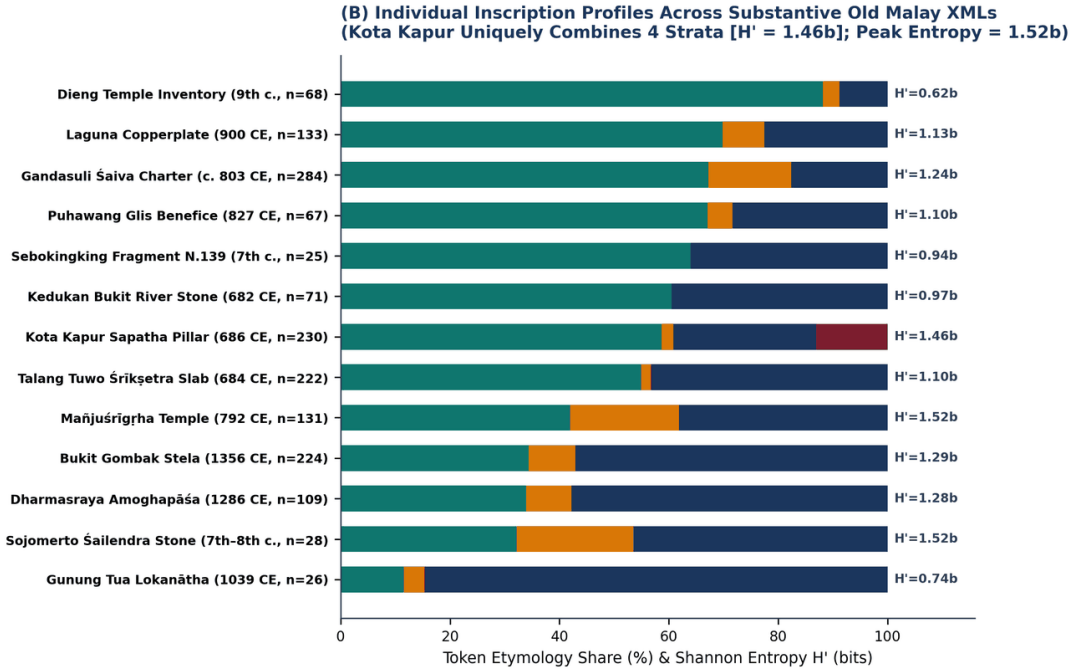


Figure 4. Clause-level diglossic and multi-register code-switching across all 21 ERC DHARMA Old Malay EpiDoc XML critical editions (N = 1,655 lexical word tokens): (A) etymological stratification across functional discourse zones Z1–Z5 (Pearson chi-square = 166.16, df = 12, p = 2.90 × 10^{-29}, Cramér's V = 0.183), contrasting archaic Language B invocation in Z2 (8.3%) and Austronesian vernacular dominance in Z4 treason/sorcery/toxin sanctions (63.5%) against Sanskrit soteriological framing in Z5 Mahāyāna *praṇidhāna* hydraulic endowments (48.0%); and (B) individual inscription etymological profiles and Shannon lexical entropy H' (bits), highlighting Kota Kapur (686 CE, n = 230, H' = 1.46 bits) as the sole monument uniting all four linguistic registers.

Across individual editions (Table 4, Panel B and Figure 4B), the 686 CE Kota Kapur *sapatha* pillar (n = 230 tokens: 58.70% Austronesian, 26.09% Sanskrit, 2.17% Hybrid, 13.04% Language B; Shannon entropy H' = 1.46 bits) was the only monument that united all four linguistic strata in a single public proclamation. Three-stratum entropy peaked in the Central Javanese Old Malay Śailendra-era inscriptions: Mañjuśrīgṛha (792 CE, n = 131, H' = 1.52 bits; 19.85% Hybrid Malay–Sanskrit) and Sojomerto (n = 28, H' = 1.52 bits). Late Sumatran royal Malay–Sanskrit inscriptions moved back toward Sanskritic courtly panegyric. These were Dharmasraya (1286 CE, 57.80% Sanskrit, H' = 1.28 bits), Gunung Tua (1039 CE, 84.62% Sanskrit), and Adityawarman's Bukit Gombak (1356 CE, 57.14% Sanskrit, H' = 1.29 bits). The Dieng temple inventory (88.24% Austronesian, H' = 0.62 bits) and Laguna Copperplate (69.92% Austronesian, H' = 1.13 bits) contrast with them. Both show vernacular dominance.

Projecting the 18-node cosmological ontology across 71 Old Malay syntactic discourse windows in Stream 4 generated a tightly integrated 16-node, 80-edge co-occurrence graph centered on the triad of ruler/elite hierarchy, riverine deity guardianship, and lethal treason sanctions (Table 5 and Figure 5A). P2 Ruler/Chieftain Elite (*dātu* / punta / huluntuhan) formed the primary structural broker (degree = 15, weighted strength = 53, weighted Brandes betweenness = 0.2917, eigenvector = 1.0000). It directly bridged P1 *Kadātuan* [royal palace-compound]/Vanua polity space (strength = 44, betweenness = 0.0870, eigenvector = 0.9176; edge P1–P2 weight = 8) and B1 Guardian Deities and Water Spirits (*tandrun luAḥ* / devata; strength = 32, betweenness = 0.0625, eigenvector = 0.6026; edge P2–B1 weight = 7), S1 *Sumpaḥ* [oath-curse] Oath Imprecation (strength = 35, eigenvector = 0.7358), and P4 Drohaka Treason (strength = 32, eigenvector = 0.7121; edge P3–P4 weight = 6), S2 Execution and Lineage Ruin (strength = 31, betweenness = 0.0686; edge S1–S2 weight = 6), and P3 *Bhakti* [devotional loyalty] / *Tatvārjjava* [inner uprightness] Political Devotion (strength = 30, eigenvector = 0.6700). Hydro-ecological nodes split cleanly into two functional sub-circuits. H2 River/Confluence/Upstream (*luAḥ* / *ulu* / *mināṅa* [river]) coupled most strongly with B1 Guardian Deities (weight = 3), P1 *Kadātuan* (weight = 2), and S1 *Sumpaḥ* (weight = 2). H3 Hydraulic Dam/Reservoir (*tavad* / *talāga*) coupled most strongly with B2 *Praṇidhāna* Bodhisattva Merit (weight = 3) and H1 Potable Water (weight = 2).

Table 5. Co-Occurrence Network Centrality Across 71 Old Malay Syntactic Discourse Windows and Document-Level Cosmological Divergence Against Old Javanese *Sīma* Curse Charters (n = 14 Substantive Old Malay vs. n = 21 Explicit Old Javanese Curse Editions).

Cosmological / Political Concept Node	OMY Window Hits, Degree & Strength	Weighted Brandes Betw. & Eigenvector	Substantive Document Prevalence	Fisher Odds Ratio (p-value; BH-FDR q)
H1: Potable & Oath Water (*vari* / *āir* / *tīrtha*)	Hits = 4 | Deg = 10 | Str = 13	Betw = 0.0000 | Eig = 0.2183	OMY: 3/14 (21.4%) vs. OJ: 13/21 (61.9%)	OR = 0.17 (p = 0.03639; q = 0.0936)
H2: River, Upstream & Confluence (*luAḥ* / *ulu* / *mināṅa*)	Hits = 3 | Deg = 10 | Str = 14	Betw = 0.0000 | Eig = 0.2831	OMY: 2/14 (14.3%) vs. OJ: 4/21 (19.0%)	OR = 0.71 (p = 1.00000; q = 1.0000)

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Cosmological / Political Concept Node	OMY Window Hits, Degree & Strength	Weighted Brandes Betw. & Eigenvector	Substantive Document Prevalence	Fisher Odds Ratio (p-value; BH-FDR q)
H3: Hydraulic Dam & Reservoir (*tavad* / *talāga* / *tebat*)	Hits = 3 | Deg = 7 | Str = 12	Betw = 0.0000 | Eig = 0.2084	OMY: 2/14 (14.3%) vs. OJ: 1/21 (4.8%)	OR = 3.33 (p = 0.55080; q = 0.7626)
H4: Maritime Craft & Sacred Voyage (*sāmvau* / *siddhayātra*)	Hits = 7 | Deg = 7 | Str = 9	Betw = 0.0000 | Eig = 0.1750	OMY: 2/14 (14.3%) vs. OJ: 7/21 (33.3%)	OR = 0.33 (p = 0.26207; q = 0.4288)
P1: Sovereign Mandala & Settlement (*kadātuan* / *vanua* / *bhūmi*)	Hits = 13 | Deg = 12 | Str = 44	Betw = 0.0870 | Eig = 0.9176	OMY: 5/14 (35.7%) vs. OJ: 13/21 (61.9%)	OR = 0.34 (p = 0.17558; q = 0.3432)
P2: Ruler, Chieftains & Retinue (*dātu* / punta / huluntuhan)	Hits = 15 | Deg = 15 | Str = 53	Betw = 0.2917 | Eig = 1.0000	OMY: 9/14 (64.3%) vs. OJ: 15/21 (71.4%)	OR = 0.72 (p = 0.72102; q = 0.8652)
P3: Political Devotion & Uprightness (*bhakti* / *tatvārjjava*)	Hits = 10 | Deg = 11 | Str = 30	Betw = 0.0000 | Eig = 0.6700	OMY: 4/14 (28.6%) vs. OJ: 0/21 (0.0%)	OR = 18.43 (p = 0.01912; q = 0.0574)
P4: Sovereign Treason & Defection (*drohaka* / *kāli* / muah)	Hits = 7 | Deg = 12 | Str = 32	Betw = 0.0000 | Eig = 0.7121	OMY: 2/14 (14.3%) vs. OJ: 0/21 (0.0%)	OR = 8.60 (p = 0.15294; q = 0.3432)
P5: Punitive Expeditionary Force (*vala* / *tāpik* / *daṇḍa*)	Hits = 6 | Deg = 11 | Str = 23	Betw = 0.0000 | Eig = 0.5150	OMY: 4/14 (28.6%) vs. OJ: 0/21 (0.0%)	OR = 18.43 (p = 0.01912; q = 0.0574)
S1: Sovereign Oath & Imprecation (*sumpaḥ* / *sapatha* / *paihumpaAn*)	Hits = 8 | Deg = 11 | Str = 35	Betw = 0.0110 | Eig = 0.7358	OMY: 1/14 (7.1%) vs. OJ: 15/21 (71.4%)	OR = 0.03 (p = 0.00033; q = 0.0015)
S2: Execution & Clan Annihilation (*nivunuḥ* / gotra / *santāna*)	Hits = 8 | Deg = 11 | Str = 31	Betw = 0.0686 | Eig = 0.6650	OMY: 1/14 (7.1%) vs. OJ: 3/21 (14.3%)	OR = 0.46 (p = 0.63503; q = 0.8165)
S3: River/Dart Toxins & Love Sorcery (*ūpuḥ* / *tūva* / *kasīhan*)	Hits = 5 | Deg = 5 | Str = 8	Betw = 0.0000 | Eig = 0.1864	OMY: 1/14 (7.1%) vs. OJ: 0/21 (0.0%)	OR = 4.78 (p = 0.40000; q = 0.6000)
S4: Agrarian Freehold & Wet-Rice Land (*sīma* / *sawah* / kabikuan)	Hits = 1 | Deg = 3 | Str = 3	Betw = 0.0000 | Eig = 0.0562	OMY: 1/14 (7.1%) vs. OJ: 15/21 (71.4%)	OR = 0.03 (p = 0.00033; q = 0.0015)
S5: Ritual Egg-Smashing & Sacrifice (*saṅ makudur* / hantiga / hayam)	Hits = 0 | Deg = 0 | Str = 0	Betw = 0.0000 | Eig = 0.0000	OMY: 0/14 (0.0%) vs. OJ: 14/21 (66.7%)	OR = 0.02 (p = 5.85×10^{-5}; q = 0.0005)
S6: Predator Jaws & Hell Retribution (*ulā* / *bājul* / *mahāpātaka*)	Hits = 0 | Deg = 0 | Str = 0	Betw = 0.0000 | Eig = 0.0000	OMY: 0/14 (0.0%) vs. OJ: 15/21 (71.4%)	OR = 0.01 (p = 1.76×10^{-5}; q = 3.17×10^{-4})
B1: Guardian Deities & Water Spirits (*tandrun luAḥ* / devata / *nāga*)	Hits = 14 | Deg = 14 | Str = 32	Betw = 0.0625 | Eig = 0.6026	OMY: 10/14 (71.4%) vs. OJ: 19/21 (90.5%)	OR = 0.26 (p = 0.19069; q = 0.3432)
B2: Bodhisattva Vow & Merit (*praṇidhāna* / bodhicitta / *puṇya*)	Hits = 10 | Deg = 8 | Str = 19	Betw = 0.0184 | Eig = 0.3514	OMY: 5/14 (35.7%) vs. OJ: 7/21 (33.3%)	OR = 1.11 (p = 1.00000; q = 1.0000)
B3: Harvest Abundance & Civic Peace (*subhikṣa* / *nirvyādhi* / *śānti*)	Hits = 9 | Deg = 13 | Str = 28	Betw = 0.0417 | Eig = 0.5601	OMY: 5/14 (35.7%) vs. OJ: 7/21 (33.3%)	OR = 1.11 (p = 1.00000; q = 1.0000)

Notes: Co-occurrence network comprises 16 active Old Malay nodes and 80 weighted undirected edges across 71 syntactic discourse windows (S5 and S6 have zero attestations in Old Malay and represent strictly Javanese *sīma* curse mechanics). Document prevalence compares n = 14 substantive Old Malay editions (≥15 word tokens) against n = 21 explicit Old Javanese curse charters selected from 85 Old Javanese *sīma*/charter XMLs in ERC DHARMA; q denotes Benjamini–Hochberg FDR-adjusted p-value.

Document-level comparison between substantive Old Malay editions (n = 14) and explicit Old Javanese *sīma* curse charters (n = 21) showed a pronounced difference in document-level prevalence between thalassocratic network sovereignty and agrarian territoriality (Table 5 and Figure 5B). Old Malay editions more often attested P3 *Bhakti* / *Tatvārjjava* political loyalty clauses (28.6% [4/14] vs. 0.0% [0/21], OR = 18.43, Fisher p = 0.0191, BH-FDR q = 0.0574) and P5 *Vala* [punitive expedition] / *Tāpik* [military strike] punitive military expedition clauses (28.6% [4/14] vs. 0.0% [0/21], OR = 18.43, p = 0.0191, q = 0.0574); neither difference remains significant after the multiplicity adjustment. Single-corpus attestations appeared for P4 Drohaka sovereign treason (14.3% vs. 0.0%, OR = 8.60), H3 public *Tavad* [weir] / *Talāga* [reservoir] reservoirs (14.3% vs. 4.8%, OR = 3.33), and S3 *Ūpuḥ* [dart poison] / *Tūva* [fish-stupefying root toxin] dart- and river-toxin sorcery prohibitions (7.1% vs. 0.0%, OR = 4.78). These three contrasts are not statistically supported (raw p = 0.153, 0.551, and 0.400, respectively). Both corpora shared comparable Mahāyāna/Indic merit vocabulary (B2 *Praṇidhāna* / *Puṇya*: 35.7% vs. 33.3%, p = 1.0000). Old Javanese curse charters, by contrast, concentrated heavily on S4 *Sīma* / *Sawah* tax-freehold rice-land boundaries (71.4% [15/21] vs. 7.1% [1/14, Gandasuli in Central Java], OR = 0.03, p = 0.00033, BH-FDR q = 0.0015), S5 *Saṅ Makudur* ritual egg-smashing and chicken-decapitation blood oaths (66.7% [14/21] vs. 0.0% [0/14], OR = 0.02, p = 5.85×10^{-5}, q = 0.00053), and S6 Zoomorphic Predator and Karmic Hell Retribution (*ulā* [serpents], *bājul* [crocodiles], *pañcamahāpātaka* [five mortal sins]; 71.4% [15/21] vs. 0.0% [0/14], OR = 0.01, p = 1.76×10^{-5}, q = 0.00032). The Old Javanese charters also attested S1 *Sumpaḥ* Oath Imprecation (71.4% [15/21] vs. 7.1% [1/14], OR = 0.03, p = 0.00033, q = 0.0015) more often than the Old Malay editions, and the same direction holds for H1 water vocabulary (61.9% [13/21] vs. 21.4% [3/14], OR = 0.17, p = 0.0364, q = 0.0936, not significant after adjustment).

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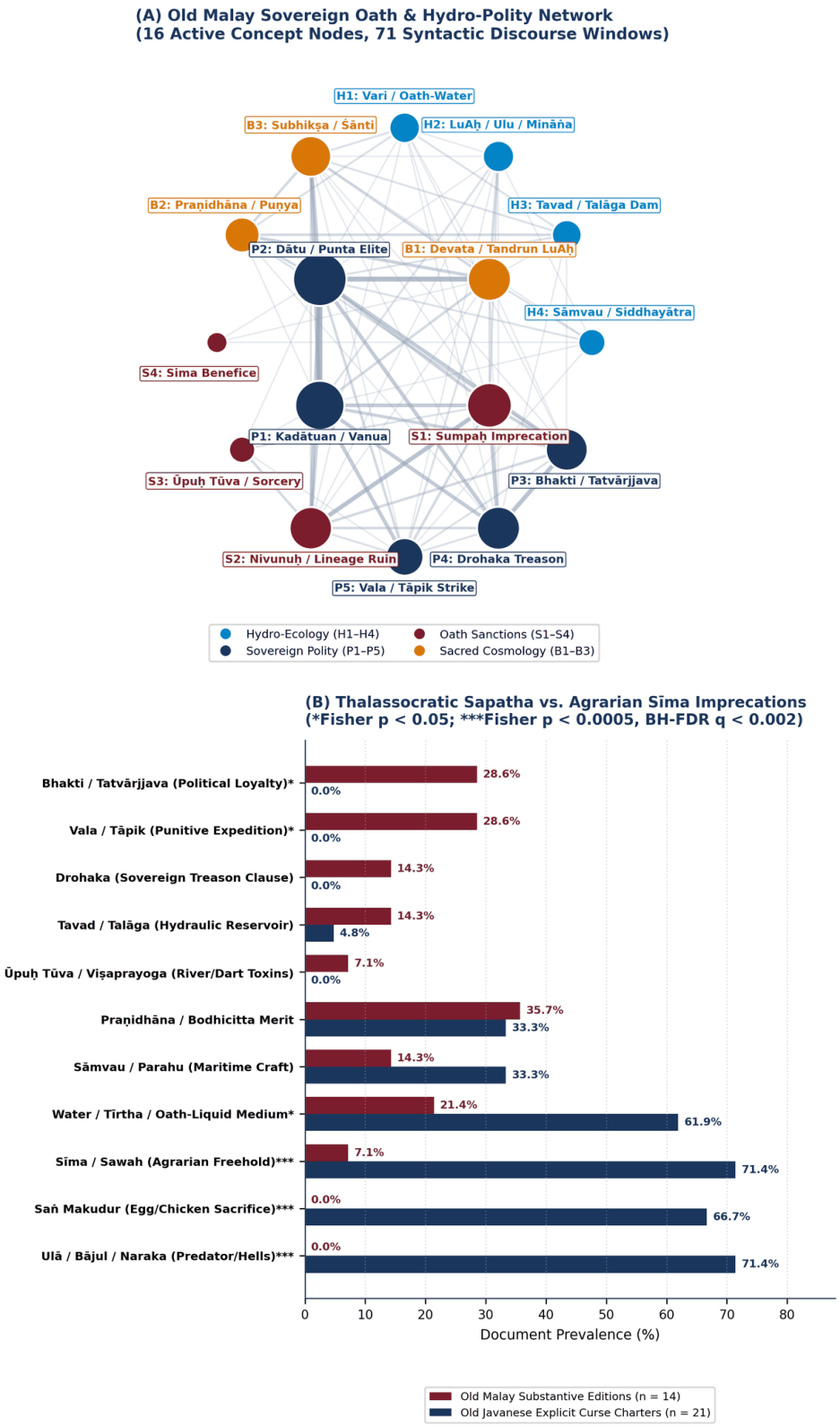


Figure 5. Syntactic co-occurrence network of Old Malay sovereign oath cosmology and document-level divergence against Old Javanese *sīma* curse charters: (A) 16-node, 80-edge weighted co-occurrence graph across 71 Old Malay syntactic discourse windows, illustrating the central brokerage of P2 *Dātu*/Elite (strength = 53, betweenness = 0.2917), P1 *Kadātuan*/Vanua (strength = 44), S1 *Sumpaḥ* Imprecation (strength = 35), P4 Drohaka Treason (strength = 32), and B1 Guardian Deities/Tandrun *LuAḥ* (strength = 32); and (B) comparative document prevalence across substantive Old Malay editions (n = 14) versus explicit Old Javanese curse charters (n = 21), contrasting thalassocratic loyalty/expedition clauses (*bhakti*/*vala* OR = 18.43, p = 0.0191) against Javanese *sīma* freehold boundaries (q = 0.0015), *saṅ makudur* egg/chicken blood sacrifices (q = 0.00053), and predator/hell retributions (q = 0.00032).

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3.4 Philological and Cosmological Concordance Across Key Epigraphic Passages

Close philological examination of six representative passages across Sumatra, Bangka, and Java illustrates how these quantitative spatial and lexical patterns may be read as embodied ritual speech acts (Table 6). In lines 1–2 of the Kota Kapur pillar (IDENK-00050, 686 CE), the inscription opens in archaic Language B: *siddha titam hamba nvari i avai kandra kāyet ni paihumpaAn namuha ulu lavan tandrun luAḥ makamataṅna parvvāṇḍa datu śrīvijaya*. It explicitly invokes *nvari* (cognate with Western Austronesian *danum/wari* [water]), *ulu* [the upstream interior], and *tandrun luAḥ* [the sacred Guardian Spirit of the River] to watch over the *kadātuan*. Only in line 3 does the text switch to intelligible Old Malay. By addressing estuarine and river-mouth guardian powers in an archaic maritime Austronesian liturgical tongue, the court symbolically co-opted the ancestral spirit ecology of Bangka Strait boatmen and *ulu–ilir* river traders.

Table 6. Philological, Etymological, and Hydro-Cosmological Concordance of Representative Passages Across Language B, Old Malay Sovereign *Sapatha* Stones, *Śrīkṣetra* Hydraulic *Praṇidhāna*, and Comparative Old Javanese *Sīma* Charters.

Edition, Date & Watershed Locus	Critical Epigraphic Transliteration (EpiDoc)	Etymological Register & Key Lexemes	Literal Philological Translation	Hydro-Political & Cosmological Function
Kota Kapur Pillar (IDENK-00050, 686 CE; Bangka Strait Narrows)	*siddha titam hamba nvari i avai kandra kāyet ni paihumpaAn namuha ulu lavan tandrun luAḥ makamataṅna parvvāṇḍa datu śrīvijaya*	Language B (Western Austronesian / Barito-Malayic affinity) + Sanskrit *śrīvijaya*	Success! Spoken oath-water formula invoking upstream (*ulu*) and the Guardian of the River (*tandrun luAḥ*) protecting the Lord Datu of Śrīvijaya.	Anchors thalassocratic authority in archaic riverine-estuarine spirit guardianship before switching to Old Malay.
Kota Kapur Pillar (IDENK-00050, 686 CE; Lines 4–6)	*kita tuvi tandrun luAḥ vanaḥ ta kadātuan ini ... nivunuḥ ya sumpaḥ nisuruh tāpik ya mulāṁ parvvāṇḍa datu śrīvijaya tālu muah ya dṅan gotrasantānāña*	Austronesian Old Malay (*nivunuḥ*, *tāpik*, *mulāṁ*) + Sanskrit (*kadātuan*, *drohaka*, *gotrasantāna*)	You also, O Guardian of the River, watch over this palace-polity ... they shall be slain by the curse and struck by punitive expeditionary troops along with their clans.	Couples supernatural oath-water lethality (*nivunuḥ* ya *sumpaḥ*) directly with naval/riverine military retaliation (*tāpik*).
Kota Kapur Pillar & Telaga Batu Parallel Clauses (686 CE / late 7th c.)	*yam marjjahāti ... mamāva yam vukan tīda bhakti ... marvvṅun ūpuḥ tūva tamval sāriḥ kasīhan vaśīkaraṇa ... nivunuḥ ya sumpaḥ niminuṁña ini*	Austronesian ethnobotanical toxins (*ūpuḥ* [Antiaris], *tūva* [Derris], *kasīhan*) + Sanskrit *vaśīkaraṇa*	Whoever harms or lacks devotion ... concocting dart-poison, Derris river-fish root toxin, love-philters, or subjugation sorcery ... shall be killed by this curse which they drink.	Materializes loyalty through potable oath-water ingestion (*niminuṁña*) while criminalizing indigenous botanical/riverine toxins.
Kedukan Bukit Boulder (IDENK-00159, 682 CE; Musi–Tatang Confluence)	*dapunta hiyaṁ nāyik di sāmvau maṅalap siddhayātra ... marlapas dari mināṅa tāmvan mamāva yaṁ vala dualakṣa kośa duaratus cāra di sāmvau*	Austronesian maritime verbs/nouns (*nāyik*, *sāmvau*, *mināṅa*) + Sanskrit (*siddhayātra*, *vala*, *lakṣa*)	Dapunta Hiyaṁ boarded a ship to obtain potent voyage-success ... departing from *Mināṅa Tāmvan* leading an army of twenty thousand and two hundred chests by boat.	Inaugurates the Palembang *kadātuan* via river-confluence mobilization and charismatic ritual potency (*siddhayātra*).
Talang Tuwo Slab (IDENK-00066, 684 CE; Palembang Ulu Terrace)	*svasti śrī śakavarṣātīta 606 ... niparvuat parlak śrīkṣetra ... tavad talāga savañakña yaṁ vuatña ... āir niminuṁña savañakña vuatña maṅhidupi*	Austronesian hydraulic engineering (*tavad* [weir/dam], *parlak*, *āir niminuṁña*) + Sanskrit Mahāyāna *praṇidhāna*	Hail! In Śaka 606 ... the garden *Śrīkṣetra* was created ... dams and reservoirs and all works made ... may the water drunk by all beings sustain life toward Awakening.	Inverts lethal oath-drinking (*niminuṁña sumpaḥ*) into Mahāyāna Bodhisattva hydraulic welfare (*āir niminuṁña*).
Comparative Old Javanese *Sīma* Charters (e.g., Mantyasih / Lintakan, 9th–10th c. CE)	*maṁmaṅmaṅ saṅ makudur mamantinakan hantiga iṅ watu sīma manumbalakan hayam ... panahaṅana niṅ ulā bājul pañcamahāpātaka*	Old Javanese ritual/ecological lexicon (*saṅ makudur*, hantiga, hayam, *watu sīma*, *ulā*, *bājul*) + Sanskrit *mahāpātaka*	The makudur priest uttered the curse, smashing the egg upon the *sīma* boundary stone and decapitating the chicken ... may violators be seized by snakes, crocodiles, and five mortal sins.	Protects demarcated wet-rice freehold boundaries (*sawah sīma*) via sacrificial violence and zoomorphic/karmic terror.

Notes: Transliterations follow the ERC DHARMA Guide to Indic Romanization (Acri & Griffiths, 2014) directly from verified EpiDoc TEI-XML critical editions.

Right after this invocation, Kota Kapur lines 4–10 (paralleling the longer bureaucratic enumeration on Palembang's Sebokingking *nāga* stela IDENK-00158) fuse supernatural hydro-lethality with state violence and ethnobotanical policing (Table 6). The offenders are subjects who commit *drohaka*, conspire with rebels, or concoct indigenous tropical poisons and sorcery. The named substances are *ūpuḥ* (Antiaris toxicaria blowpipe dart latex), *tūva* (Derris elliptica rotenone root used by Sumatran river communities to stupefy fish in stream pools), and *kasīhan* / *vaśīkaraṇa* [erotic/subjugation charms]. Such offenders are condemned first to die from the ingested oath-water itself (*nivunuḥ ya sumpaḥ niminuṁña ini* [slain by this

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curse which they drink]). They are also to be struck down, together with their entire *gotrasantāna* lineage, by a dispatched Sriwijayan naval-riverine expedition (*nisuruh tāpik ya mulāṁ parvvāṇḍa datu śrīvijaya*). Four years earlier at Palembang, the 682 CE Kedukan Bukit boulder (IDENK-00159) anchored the polity's foundation in *mināṅa tāmvan* [river confluence] mobilization (*dapunta hiyaṁ nāyik di sāmvau maṅalap siddhayātra*). The 684 CE Talang Tuwo slab (IDENK-00066) then turned the lethal *niminuṁña* [water-drinking] trope into a compassionate Mahāyāna *praṇidhāna*, consecrating *tavad* dams and *talāga* ponds so that *āir niminuṁña* [potable water drunk by all beings] sustains *subhikṣa* prosperity and spiritual awakening. The ninth- and tenth-century Old Javanese *sīma* charters offer the sharpest ritual contrast (Table 6, Row 6). There the *saṅ makudur* priest stood beside a fixed wet-rice boundary stone (*watu sīma*), smashed a chicken egg (*mamantinakan hantiga*), wrung off a fowl's head (*manumbalakan hayam*), and scattered hearth ashes while calling upon *ulā* snakes and *bājul* crocodiles to devour anyone trespassing a tax-exempt agricultural parcel.

4. Discussion

4.1 Dendritic Chokepoint Sovereignty and the Dual Polarity of Sacred Water in Sriwijaya

Our four empirical streams bear on a long-standing tension in Southeast Asian historiography. One view treats Sriwijaya as an ephemeral, institutionally weak harbor chiefdom; the other assumes centralized imperial administration.[2,3,10,12] In Stream 1, sovereign *sapatha* and *siddhayātrā* monuments were concentrated 77.28-fold more strongly in Sumatra–Bangka than in agrarian Java ($p = 1.31 \times 10^{-13}$). Stream 2 showed that Core *Sapatha*/*Siddhayātrā*/*Śrīkṣetra* stones do more than sit near rivers, which host virtually all Sumatran epigraphy (median 1.11–1.66 km vs. 21.77 km Monte Carlo null; logistic River OR = 1.04, p = 0.9154). They lie closer to river confluences, coastal estuaries, and maritime strait throats than other Sumatran sites do, mainly because 15 of the 21 stand in Palembang (median 4.83 km vs. 52.52 km for other Sumatran sites; Cliff's delta = −0.7921, $p = 3.29 \times 10^{-9}$; multivariate Chokepoint OR = 1.96, p = 0.0210). Seen through Tambiah's galactic mandala[5,6] and Manguin's and Andaya's accounts of *ulu–ilir* riverine exchange,[12,14] Sriwijaya did not need boundary stones around dispersed forest swiddens. Nor did it attempt to erect them. Instead, the distribution is consistent with a *kadātuan* that placed monumental curse pillars at the Musi–Ogan–Komering–Tatang nexus in Palembang (d(Choke) = 1.78–5.40 km), the Merangin–Tembesi upland gold corridor at Karang Brahi, the Way Sekampung / Sunda Strait pepper-and-resin approach at Palas Pasemah and Bungkuk, and the Bangka Strait maritime funnel at Kota Kapur (2.16 km from coast, facing the Musi estuary). In this reading it turned unavoidable hydrographic bottlenecks into liturgical checkpoints of watchful control.[10,14,40]

Sriwijayan ideology also sacralized water itself, as a technology of sovereignty with two opposed polarities across the Palembang *ulu–ilir* micro-topography (Figure 2B and Table 6).[8–10,27] Along the tidal *ilir* riverbanks at Sebokingking and Boom Baru, and at outer tributary/strait gates, water poured over Pallava script and cobra hoods became *sumpaḥ niminuṁña*. This was an internalized, self-activating somatic toxin. It is understood to have policed distant *dātu* governors, boat captains, and allied warbands even when royal fleets were out of sight, backed by the credible threat of *vala* [punitive expedition] / *tāpik* naval-riverine retaliation (OR = 18.43 vs. Javanese charters).[1,2,14] On the flood-safe *ulu* terrace of Talang Tuwo (684 CE), by contrast, engineered *tavad* check-dams and *talāga* reservoirs turned royal water into *āir niminuṁña* consecrated by Mahāyāna bodhicitta vows (48.00% Sanskrit tokens in Zone Z5).[1,27,28] Lansing showed that Balinese water temples coupled cosmology to irrigation scheduling.[8] Early Palembang did something similar. It paired coercive downstream oath-waters with benevolent upstream hydraulic infrastructure, which stabilized urban provisioning in an amphibious tidal environment.[9,10]

The material and semiotic details of Palembang's monumental epigraphy reinforce this synthesis of Indic cosmology and Austronesian hydro-politics.[1,9,10,27] Consider the Sebokingking (Telaga Batu) stela (IDENK-00158). It is housed at the National Museum of Indonesia and was recovered at 2 Ilir on Palembang's eastern river approach, 4.83 km from the Musi–Ogan/Komering confluences. The carver crowned 28 lines of Old Malay *sapatha* prose with seven rearing *nāga* cobra hoods and cut a raised lower rim that channels poured water into a projecting *soma-sūtra* spout.[1,2,10] In pan-Indic mythology, *nāga* serpent lords guard subterranean waters, rain, and hidden wealth. In Austronesian Sumatran river lore, estuarine serpents and river spirits (*tandrun luAḥ*) govern safe passage across whirlpools, sandbars, and tidal bores.[10,14,25] The monument routed lustral water over engraved treason clauses and out through a *nāga*-guarded spout into the mouths of *rājaputra* [royal princes], *bhūpati* [regional rulers], *senāpati* [generals], *nāyaka* [chiefs], pratyaya [confidants], *hāji* pratyaya [lesser vassal kings], *dātu*, and huluntuhan. The Sebokingking monument thus turned epigraphic literacy into an inescapable corporeal sacrament, even for subjects who could not read every Pallava ligature.[1,2,40]

Other work on the Sriwijaya inscriptions points in compatible directions. Ceramics and ancient coins from the Musi River at Palembang have been read as evidence that the river was Srivijaya's main route for distributing trade goods.[51] The Kedukan Bukit inscription was found on the Tatang riverbank in Palembang and has been treated as the oldest evidence of the polity.[52] Studies of single monuments read the seven-headed serpent of the Telaga Batu stone as protector of the datu and as the datu's manifestation,[53] and read the Telaga Batu curse as a statement about the political value of firmness and justice in the datu's rule.[54] Our counts do not test these readings. They do show that monuments carrying such curses stand close to the Musi confluences, which fits an interpretation that links curse monuments to the river routes along which loyalty had to be secured.

4.2 Vernacular Coercion Within the Sanskrit Cosmopolis and the Sumatra–Java Epigraphic Divide

Our Stream 3 and Stream 4 findings refine Sheldon Pollock's Sanskrit Cosmopolis paradigm[19,20] for Austronesian Southeast Asia. Pollock argued that early Southeast Asian courts preferred Sanskrit for royal praise (*praśasti* [royal praise]) and reserved vernaculars, at first, for mundane documentary bookkeeping. That pattern is well attested in ninth-century Java and Angkor. It is echoed within our own corpus by the 88.24% Austronesian Dieng temple inventory (DHARMA-INSIDENK01481) and the 69.92% Austronesian Laguna Copperplate debt acquittal (DHARMA-INSIDENKLaguna).[19,34] Yet Sriwijaya's 682–686 CE monuments invert that hierarchy. They deploy Old Malay at the very heart of sovereign statecraft (Z3: 54.13% Austronesian) and push Austronesian lexical

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dominance to 63.45% in Z4 Imprecatory Sanctions. At the same time they preserve archaic Language B (8.33% of Z2) for river-spirit invocation and Sanskrit (46.07% of Z1, 48.00% of Z5) for astral timekeeping and Bodhisattva soteriology ($p = 2.90 \times 10^{-29}$).[1,22,25] The code-switching among four strata in Kota Kapur (H' = 1.46 bits) therefore does not signal peripheral, incomplete Indianization. It was a sophisticated semiotic strategy. Each language had a task. Sanskrit conferred universal Buddhist cosmos-making, and Language B may have bound indigenous maritime *orang laut* and Barito-Malayic boatmen to the *tandrun luAḥ* river guardian.[25,26] Vernacular Old Malay guaranteed that every vassal drinking the oath understood the exact bodily and clan consequences of *drohaka* treason and *ūpuḥ* / *tūva* poison plots.[1]

Comparable work on other written traditions helps to place these patterns. Medieval English sermons that mix Latin and English are better explained by functional code-switching theory than by random mixing.[55] Medieval Tamil temple inscriptions divide the work between two languages, with Sanskrit-derived terms for acts of worship and Tamil for spaces.[56] Old Javanese prose commentaries on Sanskrit verses show local reinterpretation of Sanskrit messages.[57] A structural comparison of Old Malay inscriptions from Srivijaya and ancient Mataram argues that Srivijaya influenced Mataram.[58] That argument bears on our contrast between Old Malay and Old Javanese texts, because the Old Malay set includes Central Javanese editions. Curse formulae are also a wider genre. Aksumite royal inscriptions threaten the destroyers of monuments with divine punishment, and these formulae have been compared with those of other ancient societies.[59] The Language B reading needs care. Linguistic evidence links Malagasy to the Ma'anyan of southern Borneo, whereas genome-wide data give a contrasting picture.[60] A later genomic study points to the Banjar, formed through a Malay trading post that admixed with the Ma'anyan in southeast Borneo, as the probable Asian source of Malagasy ancestry.[61] These studies support a Barito–Malay connection for Malagasy. They do not show that the opening lines of the Kota Kapur pillar belong to that register.

Our semantic network and charter comparison (Stream 4) offers a quantitative description that is consistent with an influence of ecological political economy on imprecatory imagination across Nusantara.[31–33] In Old Malay inscriptions, the co-occurrence graph revolves around mobile human allegiance. Its nodes are P2 *Dātu* [titled chieftain] elites (betweenness = 0.2917), P1 *Kadātuan*/Vanua, P3 *Bhakti* / *Tatvārjjava* loyalty, P4 Drohaka defection, and P5 *Vala* / *Tāpik* expeditionary strikes (OR = 18.43; q = 0.0574, nominal only). The texts also explicitly prohibit riverine *tūva* (Derris) root-toxins. They forbid *ūpuḥ* blowpipe poisons too, both indigenous to Sumatran forest-river warfare. Old Javanese curse charters (n = 21) differ. They contain zero *drohaka* or *tāpik* expedition clauses (0.0%) and focus instead on immobile wet-rice *sawah sīma* parcels (71.4%, q = 0.0015), public village blood-and-egg rituals by the *saṅ makudur* (66.7%, q = 0.00053), and fearsome zoomorphic/hell punishments (71.4%, q = 0.00032). An agrarian rice kingdom feared cadastral encroachment by neighboring landlords or royal tax-collectors. A riverine thalassocracy feared the silent defection of mobile fleets and confluence *dātu* brokers.[14,16,31]

Placing the Kota Kapur and Sebokingking poison-and-sorcery prohibitions (*marvvṅun ūpuḥ tūva tamval sāriḥ kasīhan vaśīkaraṇa*; Node S3 in Table 5 and Table 6) beside Southeast Asian medical and legal anthropology helps explain why ethnobotanical toxins held such prominence in seventh-century statecraft.[1] In tropical Sumatran forest and riverine warfare, *ūpuḥ* was the cardiac-glycoside latex of the *ipoh* [upas] tree (Antiaris toxicaria), applied to blowpipe darts. *Tūva* was the rotenone-rich crushed root of *tuba* [derris plant] (Derris elliptica), cast into dammed stream pools to asphyxiate fish. Both were potent and decentralized. They made covert assassination and water contamination accessible to upland *ulu* foragers and disgruntled retainers alike.[1,14] Paired with tamval, *sāriḥ* [charm], *kasīhan* [Austronesian affective love-magic], and Sanskrit *vaśīkaraṇa* [tantric mental subjugation rites], these substances threatened charismatic hierarchy from within. The danger could arise inside the court or the tributary network. Rahayu et al. document a similar idiom in contemporary clinical settings, where Balinese cetik [sorcery-attributed mystical poison] expresses interpersonal suspicion and somatic vulnerability.[43] Sriwijaya's *sapatha* formula neutralized covert subaltern poison by opposing it with a supreme sovereign counter-toxin. This was the ingested royal oath-water (*niminuṁña sumpaḥ*) itself, believed to induce madness (*gīla* [madness]), internal rupture, and clan extinction (*gotrasantāna*) the instant a sworn official harbored *drohaka* or tampered with *ūpuḥ* and *tūva*.[1,2]

Studies of dart poisons support the botanical statements. An analysis of nine Malaysian dart poisons confirmed that their main active components are cardenolides from Antiaris toxicaria.[62] Clinical reports describe the latex of the *ipoh* tree (pokok *ipoh*) and Strychnos root bark as the main poison sources in dart and arrow poisons prepared across Southeast Asia.[63] Derris-like taxa of the palaeotropics are well-known sources of rotenone, which has been used as an insecticide and as a fish poison.[64,65] None of these sources concerns the seventh century. None names Derris elliptica as a fish poison specifically, so the identification of *tūva* with that species remains a philological question.

4.3 Riverine Cultural Heritage Governance: The Proposed *Ulu–Ilir* Mandala Safeguarding Protocol

Beyond historical theory, Stream 1 uncovered a grave empirical problem for Indonesian and Southeast Asian cultural heritage management. Of the Sumatran portable precious- and base-metal mantra and curse foils in the international epigraphic inventory, 60.78% (93/153) have lost all site and subdistrict provenance (OR = 372.45 vs. stone, $p = 6.13 \times 10^{-32}$). Unregulated mechanical suction dredging (*kapal isap* [suction dredgers] and artisanal ti / sand pumps) along the Musi, Komering, Batang Hari, and Bangka riverbeds, compounded by urban wetland infill across Palembang's ancient canals, is the usual explanation for such losses, although the inventory records only the absence of coordinates and not the mode of recovery. Tin or gold foils bearing seventh- to eleventh-century *dhāraṇī* or *sapatha* formulas are vacuumed from river silts and dispersed through Bukittinggi, Palembang, or international antiquities dealers. Scholars lose forever the micro-hydrological context that connected portable ritual deposits to monumental stone chokepoints. That loss is permanent.

Evidence on the scale and organization of looting should be used with care. The widely repeated claim that antiquities trafficking is the world's third-largest illicit trade has no basis in original research.[66] A review of policy fifty years after the 1970 UNESCO Convention argues that poor understanding of how the trade is organized hinders regulation.[67] In Southeast Asia a commodity market for antiquities emerged in the 1950s

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and 1960s and triggered illicit excavation. Domestic collecting, not only Western demand, has driven trafficking in Thailand and the Philippines.[68] Many Southeast Asian underwater sites and wrecks have been commercially salvaged, with the artifacts auctioned, and the 2001 UNESCO Convention is under-ratified in the region.[69] Indonesian law has been found to permit the removal and commercial salvage of underwater cultural heritage while lacking specific provisions.[70] Reviews of Indonesian heritage legislation point to enforcement challenges and to a state-centric discourse that impedes locally led activism,[71] and work at Sangiran and Liang Bua advocates negotiated custodianship.[72]

Drawing on UNESCO's Historic Urban Landscape (HUL) recommendation, which urges integrating cultural monuments with their underlying geomorphological and hydrological watersheds,[73] and on Indonesian Law No. 11/2010 on Cultural Heritage (*Undang-Undang Cagar Budaya*),[74,75] we propose a five-zone *Ulu–Ilir* Riverine Mandala Epigraphic–Hydrological Safeguarding Protocol (Table 7 and Figure 6). First, in Zone I (Palembang Ilir Confluence Core), Balai Pelestarian Kebudayaan (BPK) Wilayah VI and municipal planners should legally unify the fragmented 14-km Bukit Siguntang–Talang Tuwo–Kedukan Bukit–Sebokingking corridor into an integrated Hydrological *Kawasan Cagar Budaya Nasional* [National Cultural Heritage Area]. It would mandate piezometric water-table monitoring. It would also prohibit unmonitored canal dredging within 500 m of registered findspots.[9,73] Second, in Zone II (Alluvial Dredging Hotspots) across the Musi, Batang Hari, and Bangka tin reaches, licensing authorities should require pre-dredging archaeological screening. This would be paired with non-punitive provenance-amnesty reporting and portable X-ray fluorescence (pXRF) / Reflectance Transformation Imaging (RTI) documentation for river divers, so that newly surfaced metal foils retain GPS subdistrict coordinates prior to museum acquisition. Third, Zone III (Tributary Chokepoints) establishes 1-km riparian buffer easements and annual 3D photogrammetric erosion tracking around in-situ stelae at Karang Brahi, Palas Pasemah, Bungkuk, and Baturaja. Fourth, Zone IV (Maritime Strait & West-Coast Entrepôts) links coastal peatland conservation with waterlogged timber and epigraphic rescue excavations at Kota Kapur and Bongal (Museum Fansuri).[42] Fifth, Zone V (Open-Science Digital Epigraphy) prioritizes full EpiDoc TEI-XML encoding and trilingual (Old Malay–Indonesian–English) pedagogical interfaces for all 22 Sumatran G1 monuments. The aim is living community engagement rather than extractive digital archiving.[44]

Table 7. Proposed *Ulu–Ilir* Riverine Mandala Epigraphic–Hydrological Safeguarding Protocol Responding to Alluvial Suction Dredging, Urban Canal Encroachment, and Digital Corpus Fragmentation Across Sumatra and Bangka.

Watershed Zone & Empirical Vulnerability	Target Epigraphic Landscapes & Sites	Statutory & Hydro-Archaeological Action	Community & Museum Custodianship	Verifiable 2026–2030 Governance Indicator
Zone I — Ilir Confluence & Urban Canal Core (Palembang Musi–Ogan–Komering; d(Choke) median 3.14–4.83 km)	Sebokingking (Telaga Batu), Kedukan Bukit, Boom Baru, Kambang Purun/Unglen, Bukit Siguntang, Talang Tuwo	Integrate the 14-km Bukit Siguntang–Talang Tuwo–Sebokingking axis into a unified Hydrological *Kawasan Cagar Budaya Nasional* buffer regulating canal dredging and wetland infill under Law No. 11/2010	Co-curate bilingual Old Malay–Indonesian hydro-cosmological trails with Museum Balaputradewa, Taman Purbakala Kerajaan Sriwijaya, and kampung river stewards	Zero unmonitored mechanical dredging permits within 500 m of registered Musi–Tatang–Sekanak epigraphic findspots; quarterly piezometric water-table logging
Zone II — Alluvial Riverbed Suction-Dredging Hotspots (60.78% [93/153] Metal-Foil Provenance Loss; OR = 372.45)	Musi, Komering, Batang Hari, and Bangka tin/sand-mining reaches yielding unprovenanced gold, silver, lead, and tin mantra/curse foils	Enforce mandatory archaeological impact screening on riverine sand/tin suction licenses and establish non-punitive provenance-amnesty reporting protocols for artisanal river divers	Deploy rapid portable XRF alloy fingerprinting and high-resolution RTI imaging at regional BPK Wilayah V/VI/VIII offices before artefacts enter private trade	≥70% reduction in newly surfaced unprovenanced metal foils lacking subdistrict GPS coordinates; open-access alloy-and-palaeography reference registry
Zone III — Middle-Watershed & Tributary Chokepoints (d(Choke) 14.6–35.8 km; Tributary Oath Frontier)	Karang Brahi (Merangin–Tembesi, Jambi), Palas Pasemah & Bungkuk (Way Pisang / Sekampung, Lampung), Baturaja (Upper Ogan)	Designate 1-km riparian protective easements around in-situ tributary oath stones and micro-watershed springheads against plantation runoff and stone weathering	Support village-level *Juru Pelihara* [site custodians] and integrate local Lampung/Jambi/Ogan oral river-lore alongside critical epigraphic editions in school curricula	Annual 3D photogrammetric surface-erosion monitoring (<0.2 mm/yr glyph recession tolerance) across all tributary *sapatha* stelae
Zone IV — Maritime Strait Throats & West-Coast Camphor Entrepôts (d(Coast) 2.16–2.51 km)	Kota Kapur & Sungai Menduk (Bangka Strait), Bongal & Lobu Tua / Barus (Tapanuli Tengah), Padang Lawas (Barumun–Pane)	Couple coastal peatland/mangrove conservation with rescue excavations of waterlogged timber ship-remains, tin seals, and inscribed trade rings	Link Museum Fansuri Bongal, Kota Kapur community eco-archaeological park, and Bangka Belitung heritage boards in cross-strait maritime heritage interpretation	Joint terrestrial–intertidal GIS cadastre covering 100% of documented 7th–11th c. strait/port findspots with public open-science metadata
Zone V — Open-Science Digital Epigraphy & Nusantara Corpus	Museum Nasional Indonesia, Palembang/Jambi/Ba	Expand EpiDoc TEI-XML encoding to currently unedited Sumatran *sapatha*	Provide trilingual (Old Malay–Indonesian–English) interactive digital editions	100% EpiDoc XML coverage of all 22 Sumatran G1 Curse/*Siddhayātrā*

Watershed Zone & Empirical Vulnerability	Target Epigraphic Landscapes & Sites	Statutory & Hydro-Archaeological Action	Community & Museum Custodianship	Verifiable 2026–2030 Governance Indicator
Interoperability (1,526 IDENK Records; 310 XMLs)	ngka provincial museums, and international ERC DHARMA TEI-XML repositories	parallels (Telaga Batu IDENK-00158, Karang Brahi IDENK-00120, Palas Pasemah IDENK-00124) with standardized hydrological gazetteer URIs	and syntactic glossaries for Indonesian universities and regional teachers	monuments synchronized with *Satu Data Cagar Budaya* Nasional

Notes: Governance architecture operationalizes UNESCO's Historic Urban Landscape (HUL) watershed integration principles (Bandarin & van Oers, 2012) and Indonesian Law No. 11/2010 on Cultural Heritage (*Undang-Undang Cagar Budaya*) across Balai Pelestarian Kebudayaan (BPK) Wilayah V (Jambi & Bangka-Belitung), Wilayah VI (South Sumatra), and Wilayah II/VIII.

Turning our *Ulu–Ilir* Riverine Mandala Safeguarding Protocol from scholarly recommendation into enforceable heritage practice requires explicit statutory coordination across Indonesia's cultural, environmental, and spatial-planning frameworks (Table 7 and Figure 6).[73] Under Articles 10 and 11 of Law No. 11 of 2010 on Cultural Heritage (*Undang-Undang Nomor 11 Tahun 2010 tentang Cagar Budaya*),[74] a geographical landscape containing two or more spatially and functionally connected heritage sites can be designated as a single *Kawasan Cagar Budaya* [Cultural Heritage Area] across municipal or provincial boundaries. Our Stream 2 geodesic findings supply the exact quantitative justification needed. Balai Pelestarian Kebudayaan (BPK) Wilayah VI (South Sumatra) and Palembang's *Rencana Tata Ruang Wilayah* [Regional Spatial Plan] (RTRW) municipal zoning board can use it to link Bukit Siguntang, Kambang Unglen/Purun, Talang Tuwo (*ulu* hydraulic endowment), Kedukan Bukit (Musi–Tatang landing), Boom Baru, and Sebokingking (*ilir* oath gateway) as one hydrological heritage system rather than isolated monument parcels. Archaeological impact assessments would then be embedded directly into ongoing Sekanak–Lambidaro and Musi urban flood-canal dredging programs.[9,73] Law No. 5 of 2017 on the Advancement of Culture (*Undang-Undang Nomor 5 Tahun 2017 tentang Pemajuan Kebudayaan*) adds protection for manuscripts, rites, traditional hydraulic knowledge (*tebat* [pond] / *talāga*), and oral riverine histories across South Sumatra, Jambi (*Kawasan Cagar Budaya Nasional* Muaro Jambi and Merangin–Tembesi under BPK Wilayah V), Bangka–Belitung (Kota Kapur), Lampung (BPK Wilayah VIII), and Tapanuli Tengah (Situs Bongal under BPK Wilayah II).[76]

Reversing the 60.78% (93/153) provenance-loss rate among Sumatran gold, silver, lead, and tin foils demands more than punitive policing. It needs incentive-compatible community custodianship. Experience across the Musi, Komering, and Batang Hari basins shows what follows when artisanal river sand-divers and tin panners fear uncompensated confiscation or criminal prosecution. Newly surfaced inscribed metal foils bypass local museums entirely and enter opaque dealer networks stripped of findspot coordinates (as exemplified by the Bukittinggi market curse/mantra foils IDENK-00001 to 00003). Article 23 of Law No. 11/2010 entitles good-faith discoverers to fair statutory compensation (*imbalan* [reward]) upon reporting finds within 30 days. Operationalizing it alongside mobile *Pos Lapor Warisan Sungai* [Riverine Heritage Reporting Desks] at Palembang, Muaro Jambi, and Muntok/Kota Kapur can secure scientific provenance while compensating local riverine communities fairly. These desks would be equipped with non-destructive portable X-ray fluorescence (pXRF metallurgical fingerprinting), Reflectance Transformation Imaging (RTI), and subdistrict GPS logging.[73] Open-access EpiDoc TEI-XML integration into Indonesia's *Satu Data Cagar Budaya* registry and trilingual school modules would complete this *ulu–ilir* custodial model. It ensures that Sriwijaya's epigraphic heritage remains anchored in the living river basins that gave it birth.[44,73]

Precedents for community-based reporting come from elsewhere. Local participation sustained the conservation and the values of the USAT Liberty shipwreck site in Bali.[77] In England and Wales, the Portable Antiquities Scheme records finds made by the public following reform of the Treasure law, although archaeologists and metal detectorists remain divided on several issues.[78] In Norfolk, the goodwill of metal-detector users produced a large, geographically based dataset of provenanced finds before the Scheme joined in 1997.[79] These examples suggest that the reporting desks proposed here are workable in principle. They do not show that incentive-based reporting would reduce riverbed dredging in Sumatra, which remains to be tested.

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Figure 6. Proposed *Ulu–Ilir* Riverine Mandala Epigraphic–Hydrological Safeguarding Protocol for Sumatran and Bangka Strait Epigraphic Landscapes: integrated five-zone watershed governance architecture linking Palembang *ilir* canal-buffer protection (Zone I), alluvial riverbed suction-dredging screening, statutory discoverer compensation, and pXRF/RTI metal-foil provenance registration (Zone II), middle-watershed tributary stela easements (Zone III), coastal strait waterlogged rescue archaeology at Kota Kapur and Bongal (Zone IV), and open-science trilingual EpiDoc TEI-XML community curation (Zone V).

4.4 Methodological Strengths, Limitations, and Epistemic Humility

The key methodological strengths of this study are coverage of all N = 1,526 records in the ERC DHARMA IDENK inventory, zero-circularity derivation of hydrographic chokepoints from 102,011 empirical OpenStreetMap river vertices, and transparent reporting of both Strict IDENK (n = 166) and Extended Village-Resolved (n = 185) coordinate sensitivity models. A further strength is the deterministic, reproducible parsing of all 21 Old Malay and 85 Old Javanese TEI-XML editions. Five limitations bound our inferences. First, archaeological survival bias is asymmetric across materials and environments. Tropical acid-sulfate peat soils in eastern Sumatra decompose organic palm-leaf (*lontar* / *nipah*), bamboo, and timber administrative records that likely accompanied stone *sapatha* pillars. Surviving lithic and metallic inscriptions therefore represent only the most durable ritual apex of Sriwijayan literacy.[10,12] Second, eastern Sumatran alluvial progradation and river-meander migration over the

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past 1,300 years have shifted outer coastline margins, particularly along the Upang–Sungsang Musi delta and Jambi coast. Major bedrock/terrace confluences (Musi × Ogan, Musi × Komering, Merangin × Tembesi, and the Bangka Strait rock headland at Kota Kapur), however, have remained geomorphologically stable since the first millennium CE.[9,10]

Third, 310 ERC DHARMA inscriptions currently have full scholarly EpiDoc TEI-XML editions (21 in Old Malay). Several key Sumatran *sapatha* parallels still await finalized XML release and are cataloged only in IDENK metadata (Streams 1–2). They include the monumental Sebokingking/Telaga Batu stela (IDENK-00158), Karang Brahi (IDENK-00120), and Palas Pasemah (IDENK-00124). Those parallels are reported to share most of their curse clauses with Kota Kapur (DHARMA-INSIDENK00050), so our Stream 3–4 token estimates may understate *sapatha* lexical centrality, and future XML releases will refine the edge weights. Fourth, the relatively compact number of Core monuments (12 Strict, 21 Extended events across four predictors, at 11 distinct coordinates) in Stream 2 logistic regressions produces wide 95% confidence intervals around monumental stone and chronological odds ratios. They must therefore be read as descriptive structural associations rather than precise causal elasticities. Finally, the proposed *Ulu–Ilir* Riverine Mandala Safeguarding Protocol is a policy design informed by the findings above. Its real-world efficacy against illicit riverbed dredging awaits prospective institutional implementation and hydrological monitoring across South Sumatra, Jambi, Bangka–Belitung, and Lampung.

Three methodological cautions follow from the literature. First, testing with non-independent replicates, termed pseudoreplication, was found in 27% of 176 experimental studies reviewed in ecology,[80] and the repeated coordinates of the core stones raise the same concern for the tests reported here. Second, the rule of ten events per variable has been examined in simulations covering 2 to 25 events per variable,[81] and later work found it too conservative in many circumstances.[82] With 21 and 12 events, however, the logistic models remain small. Firth's penalized-likelihood procedure gives finite estimates under separation,[83] and it removes the first-order bias of maximum likelihood estimates.[84] Third, settlement patterns have been analyzed with point-process models and multi-model comparison of competing covariate hypotheses,[85] and archaeological applications of network analysis have been criticized for adopting methods from other disciplines without caution.[86] The chokepoint contrast and the co-occurrence network should therefore be read as exploratory.

5. Conclusion

5.1 Synthesis of Hydro-Cosmological Findings and Heritage Significance

This study unites macro-archipelagic epigraphic stratification (N = 1,526), zero-circularity geodesic hydro-network modeling (102,011 river vertices and 10,000 Monte Carlo land points), clause-level multi-register token analysis (1,655 Old Malay tokens), and comparative charter network analysis (85 Old Javanese editions). The findings are consistent with seventh- to eleventh-century Sriwijaya having organized sovereign power through a dendritic hydro-cosmology. Sovereign *sapatha* and *siddhayātrā* monuments concentrated 77.28-fold more strongly in Sumatra–Bangka than in Java. They lay closer to river confluences, tidal estuaries, and strait narrows than other Sumatran sites did (median 4.83 km vs. 52.52 km; $p = 3.29 \times 10^{-9}$), mainly because 15 of the 21 stand in Palembang. Etymological strata differed across discourse zones ($p = 2.90 \times 10^{-29}$). The texts invoke *tandrun luAḥ* river guardians in archaic Language B. They enforce *bhakti* loyalty and criminalize *drohaka* treason and *ūpuḥ* / *tūva* toxins in vernacular Old Malay. They consecrate *tavad* / *talāga* potable waterworks in Mahāyāna Sanskrit. This pattern diverges from Old Javanese *sīma* rice-land curses officiated by the *saṅ makudur*. The 60.78% provenance loss documented among Sumatran metal foils is high. It supports consideration of integrated *ulu–ilir* watershed heritage governance, so that Southeast Asia's earliest vernacular archive may survive within its living riverine landscape.

Declarations

Ethical Approval. Not applicable. This computational-epigraphic and spatial-network study analyzed only open-access secondary archaeological metadata, historical transliterations, and public hydrographic vector datasets released under permissive academic and open-data licenses (ERC DHARMA Nusantara Epigraphy, OpenStreetMap ODbL hydrography, and Natural Earth public-domain cartography). No live human participants, clinical interventions, private personal records, or unconsented ethnographic interviews were involved.

Consent to Participate. Not applicable. No human subjects were recruited or surveyed in this historical and computational investigation.

Consent for Publication. Not applicable. This manuscript contains no identifiable personal data, private correspondence, or restricted third-party imagery.

Use of Artificial Intelligence. None.

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Data Availability. All primary epigraphic metadata and XML editions analyzed in this study are publicly accessible through the European Research Council (ERC) DHARMA Task Force C Nusantara Epigraphy repository (https://github.com/erc-dharma/tfc-nusantara-epigraphy), together with public hydrographic vector geometries from OpenStreetMap (https://www.openstreetmap.org) and Natural Earth 1:10m physical vectors (https://www.naturalearthdata.com). The derived datasets and analysis scripts are available from the corresponding author on reasonable request.

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