

A Framework for Cartographic Representation of Archaeological Sites under the Digital Humanities Perspective

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Abstract

This study is based on the intersection of digital humanities and archaeological geography, and aims to construct a multidimensional classification system (value dimension, spatial form, cultural connotation) that integrates ontology and phenomenological cognition for the spatial characteristics of large archaeological sites, thereby breaking through the bottleneck of traditional mapping. Building on this foundation, the paper innovatively proposes a three-in-one framework of "attribute data-process specification-symbol system": through multi-source heterogeneous data fusion (3D point cloud, remote sensing image, historical image), combined with spatial registration and semantic association technology to achieve complementary information verification. Furthermore, a triple mapping mechanism (representation layer, experience layer, abstraction layer) is established based on Pierce's symbol triadism, constructing a dynamic symbol system that combines scientific and interpretive aspects. Consequently, the intelligent mapping tool developed provides standardized solutions for archaeological surveys, heritage monitoring, and public interpretation, promoting the cognitive upgrade of archaeological mapping from static expression to dynamic deduction, and laying the theoretical and methodological foundation for digital protection of archaeological sites.

1. Introduction

Archaeological sites, as the core spatial carriers carrying rich historical and cultural information, their accurate map representation is not only an indispensable technical foundation for archaeological research (Alef Y, 2019), but also a key way to reconstruct ancient social spatial cognition, support cultural heritage protection, and achieve the reproduction of historical scenes. Maps, as the main medium for spatial information of archaeological sites, play an increasingly important intermediary role in social cognitive activities that connect academic research with public cultural dissemination (Cristina PĂTRAȘCU, 2011). Currently, the deep application of digital technology, such as 3D modeling, remote sensing measurement, and geographic information systems (GIS)—the latter being a hot topic of continuous attention in the field of map symbol research (Tang Jianbo, 2012)—provides unprecedented technical support for holographic modeling of sites and deep integration of multidimensional information (Liu Weihong, 2013).

However, the traditional archaeological surveying model is facing a series of systemic bottlenecks. Specifically, the fragmentation of multi-source heterogeneous data, such as LiDAR point clouds, remote sensing images, and historical maps, severely hinders effective information fusion (Chen Yun, 2015); In addition, semantic defects in map symbol systems often lead to the distortion or simplification of the profound cultural connotations expressed by archaeological sites. In addition, the non-standardized mapping process leads to a lack of comparability between different project outcomes (Sun Xiao, 1997); However, in the face of large or complex sites, labor-intensive operational models are difficult to meet the practical needs of rapid response (Lu Jiansong, 2005). These contradictions profoundly reveal the urgent need for theoretical,

methodological, and technological innovation in the field of archaeological surveying and mapping (Lin Shaohua, 2006).

To address these challenges, this study focuses on reconstructing the spatial cognitive framework and value evaluation standards at the theoretical level, and establishing a symbol system that can accurately convey the cultural significance and narrative logic of the site. At the methodological level, there is an urgent need for innovation and the development of key technologies that can effectively couple multi-source heterogeneous data, especially data with spatiotemporal attributes (Zhang Xiaonan, 2015). At the technical support level, there is an urgent need to develop dynamic and adjustable symbol systems to flexibly express diverse cultural information, and to build powerful intelligent processing engines to automate complex mapping synthesis tasks.

Therefore, combining the specific needs of archaeology for the expression of spatial information in archaeological sites with the strong adaptability of digital technology, constructing a standardized archaeological site mapping system can further promote the expression of site mapping (Li Gui'e, 2024). This system should be able to effectively integrate the complete chain from multi-source data collection, intelligent processing to cultural meaning expression, drawing on the framework ideas of the new thematic mapping automation system (Wang Qiuling, 2020), and fully considering the narrative mechanism and contextual constraints of the symbol system (Yao Yao, 2018), ultimately achieving a comprehensive improvement of archaeological site spatial information from accurate recording to cultural narrative.

2. The Archaeological Site Cartography Framework

2.1 Design Approach

In the era of digital intelligence, driven by big data, intelligent technologies, new industry demands, and the innovation of map expression forms, the mapping content, expression forms, and response timeliness of thematic maps are being profoundly transformed, putting forward higher requirements for the development of archaeological site thematic maps. Against this backdrop, studying and designing a site mapping framework has become a top priority, with its core encompassing the following key research directions:

First, the construction of a model-driven mapping content system explores the intelligent discrimination mechanism of site attributes and multi-source data, and achieves the structured transformation from archaeological semantics to spatial elements through the collaborative application of basic statistical models and complex computational models. Second, the design of highly expressive and readable expression forms integrates cutting-edge visualization technologies to construct a symbol system that balances the accuracy of cultural representation and cognitive efficiency, ensuring the visual consistency of the symbol system in cross-media output. Third, the implementation of a full-process intelligent mapping framework formulates the logical specifications for site thematic mapping and constructs a standardized mapping framework.

2.2 Archaeological Site Cartography Framework

Site maps involve numerous elements, rich informational content, and diverse presentation formats. Their production process entails extensive repetitive operations, necessitating standardized and iteratively optimizable workflows. Therefore, systematically consolidating cartographic knowledge and rules to construct intelligent data processing tools for site mapping is the core pathway to achieving efficient map production and the foundation for intelligent automation in the mapping process.

Ultimately, leveraging the deep synergy between data processing tools and thematic mapping models will expand the industry-specific applications of site maps, meeting the high-level demands of the digital intelligence era for map services: fast, high-quality, innovative, and cost-efficient.

This study proposes a hierarchical framework for archaeological site mapping, using a vertical integration path of "data analysis specification output". At the top level, the "Site (Group)" module simultaneously processes dual source inputs: the data layer absorbs heterogeneous spatial datasets, including 3D point clouds, remote sensing images, and topographic maps, while the analysis layer combines archaeological semantic dimensions such as value dimension, functional typology, and social attributes. The middle representation specification layer focuses on standardizing 2D graphic representations by systematically defining site elements including the site itself, unearthed artifacts, site environment, mathematical elements including coordinate systems and projection rules, auxiliary elements including legends and scales, and graphic and textual symbol systems, thereby providing a mapping rule library for data conversion. The basic output layer has built a specialized two-dimensional drawing system, in which the core basic drawings: spatial positioning distribution map, structural layout plan, and cultural layer sequence stratigraphic profile map ensure basic representation, while specialized supplementary drawings: slope

map for terrain analysis, pathological map for material degradation, and axonometric projection for functional zoning extend the analysis depth. As shown in Figure 1.

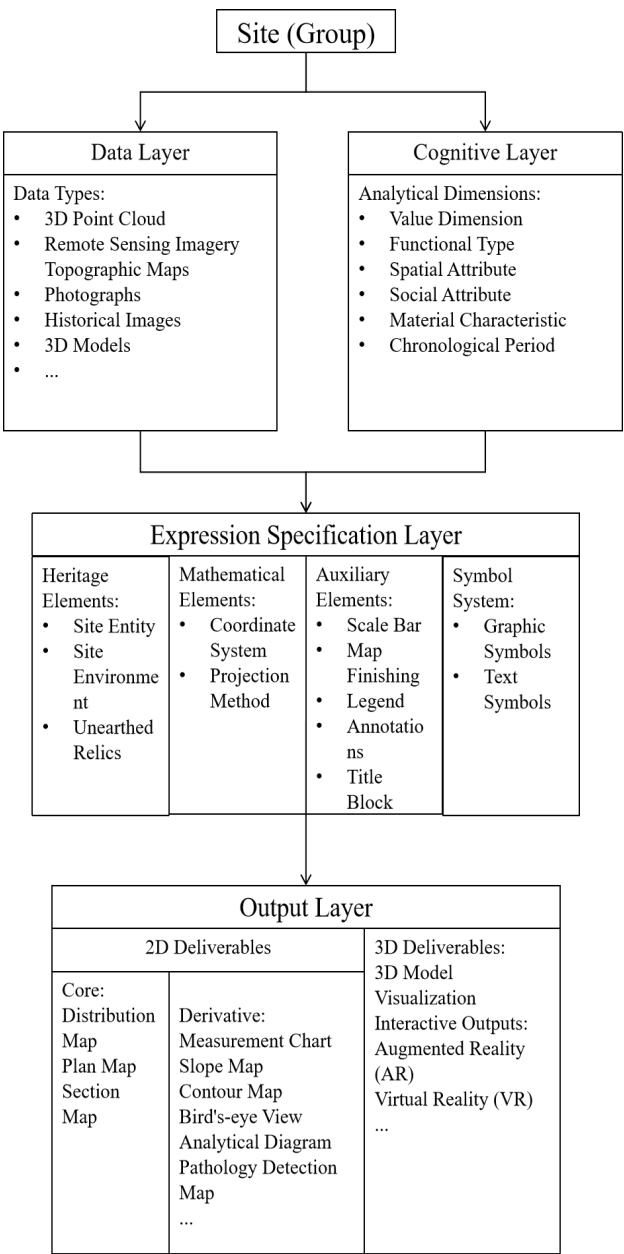


Figure 1. Archaeological Site Cartography Framework.

2.2.1 Cognitive layer. Through semantic refinement, ancient knowledge ontology constructs the typology of archaeological site attributes, systematically defining core features such as functional types represented by residence, burial, and ritual, value dimensions represented by historical/artistic/scientific significance, spatial attributes represented by regional classification, and social attributes represented by hierarchical markers and economic models. This framework interprets social organization and division of labor - for example, inferring stratification from tomb hierarchy - and directly drives protection strategies. Function driven protection will customize methods, while value based priority will guide resource allocation, such as the display oriented utilization of high artistic value cave temples. This achieves end-to-end support from attribute analysis to protection mapping. As shown in Table 1.

Cognitive Layer	
Attribute Characteristics	Definition
Functional Typology	Social functions and practical uses of the site within its historical context
Value Dimensions	Assessment of historical, cultural, scientific, and social significance
Spatial Delimitation	Definition of spatial boundaries for archaeological sites
Social Attributes	Reflection of social organizational structures and power dynamics
Material Characteristics	Analysis of construction materials and technical features
Chronology	Scientific determination of the site's temporal existence

Table 1. Cognitive Layer.

2.2.2 Data layer. Multi source data integration. The data layer integrates heterogeneous sources, including 3D point clouds captured with millimeter level accuracy through LiDAR/UAV photogrammetry for building foundations and micro terrain, remote sensing images in panchromatic/multispectral/thermal infrared bands with resolutions ranging from 10m to sub meters, static single period or dynamic time multi period stacking, 3D models with polygon counting grading details, and DEM/DTM format topographic maps with scales ranging from 1:500 to 1:50000. These datasets comprehensively record spatial forms, material compositions, and environmental backgrounds, enabling spatial deconstruction, environmental relationship inference, and serving as the mapping foundation for archaeological surveying. As shown in Table 2.

Data Layer	
Data Type	Definition
Point Cloud Dataset	Discrete point sets containing spatial coordinates (X,Y,Z) and other attributes
Remote Sensing Imagery	Image data of archaeological sites and surrounding areas acquired via aerial or satellite platforms
Historical Images	Photographic records documenting site appearances across historical periods
3D Digital Models	Computationally reconstructed 3D digital representations of archaeological sites
Photographs	Images captured through on-site photographic documentation
Topographic Map	Cartographic representation of terrain undulations and morphological characteristics within a site's region

Table 2. Data Layer.

2.2.3 The mapping elements of archaeological sites. The expression standard layer uses structured rules to transform cognitive layer input into actionable mapping standards. The site elements clearly classify natural geographical elements and human geographical elements. Mathematical elements standardize technical specifications - using national coordinate systems, projection methods, scales, and directional indicators. Auxiliary elements standardize legends and titles by defining symbols and color coding, integrating site names and scales, and providing explanatory explanations based on data sources and mapping dates to ensure readability and authority, collectively providing an accurate regulatory framework for map output.

2.2.4 The symbol system. The symbol system is the core translator of spatial information. Its design specifications and principles include three key aspects: scientific principles that require dynamic alignment with data, such as using slope color gradients obtained from DEM analysis to avoid subjective allocation; Strict normative requirements for color, font, and scaling; And readability optimization, using hierarchical expression and comprehensive legends to emphasize artifacts while conquering base map elements. The symbol system consists of graphic symbols, including point symbols, line symbols, and polygon symbols; Text symbols consist of annotation tags and descriptive text that provide attribute data and contextual annotations. In addition, static/dynamic image symbols further enrich the representation. Overall, these elements form a standardized visual language for multidimensional heritage representation. As shown in Table 3.

Symbol System	
Design Specifications and Principles	Scientific Principle
	Normative Requirements
	Readability Optimization
Composition	Point Symbols
	Cartographic Graphic Symbols
	Line Symbols
	Polygon Symbols
	Annotation Labels
Text Symbols	Descriptive Text

Table 3. Symbol System.

2.2.5 Output layer. The final stage converts the structured information processed by the expression standard layer into multidimensional visual output. Its core 2D deliverables include basic heritage entity representations, including spatial positioning distribution maps, plan maps, and section maps of the site, extending to specialized analysis maps. 3D output includes basic measurement products, terrain derivatives, and immersive scenes, while integrating bird's-eye views and specialized analysis maps to assist decision-making. By utilizing a dynamic adaptive symbol system and multi platform output, this layer ensures a lossless transition from data to actionable insights, ultimately providing scientifically accurate and visually striking spatial presentation outputs for heritage preservation.

3. Key Technologies for Archaeological Site Mapping

Site map is an integrated fusion of geographic basic framework and specific site entities, where the core information interface relies on the collaborative expression of map symbols and information charts. These visual elements are not only the medium for transforming the topographical connections and historical logical relationships between the site and its environment into visual forms, but also the key tool for transforming complex geographic information into intuitive

cognitive language. In design, the symbol system must reflect the aesthetic expression of characteristic attributes, ensure the artistic harmony of color and form, and achieve dual optimization of knowledge dissemination efficiency and human perceptual experience through the integration of standardized and artistic unified visual language.

This study is based on the Pierce symbol ternary model and the representation, experience, and abstract dimensions of symbol representation (Weng Min, 2021), systematically improving the design of archaeological map symbols (Figure 2). In response to the limitations of current site mapping, such as overly simplistic symbol layering, insufficient utilization of visual variables, and disjointed textual and graphic narratives, it adopts a layered design strategy to amplify the meaning of symbols: at the representational level, geometric shapes accurately determine the location of the site; At the experiential level, combining typical venue features to evoke associations; At the abstract level, cultural themes convey deeper narratives (Table 4). Meanwhile, utilizing the theory of intertextuality, it constructs a symbiotic relationship between graphic design, images, and text - in which verbal symbols condense core site information and reconstructed images enhance contextual immersion. Ultimately, this method constructs a multidimensional symbolic text that integrates localization, features, and cultural narrative, significantly improving the contextual adaptability and narrative effectiveness of the site map.

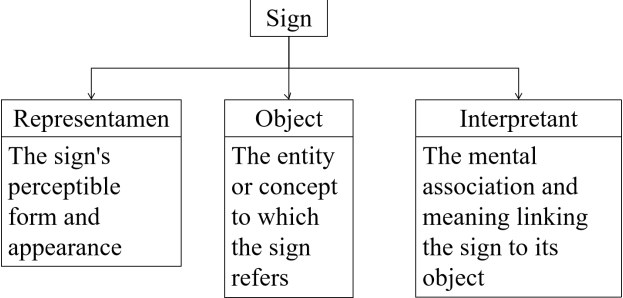


Figure 2. Peircean Semiotic Triad

Symbolic Level	Connection Degree	Function	Characteristics
Representational	Spatial Connectivity (positional markers)	Artistic signification of stylistic features	Emphasizes positional anchoring and visual form
Experiential	Perceptual Resemblance (evokes object associations)	Wayfinding utility through experiential cues	Triggers memory via salient features
Abstract	Essential Homology (conveys semantic essence)	Pragmatic signification of positionality and symbolism	Embodies cultural philosophy & thematic style

Table 4. Symbolization.

In the design of narrative maps for archaeological sites, concrete depictions are used to carefully present physical elements such as site foundations, structural foundations, and sacrificial pits,

supplemented by dashed symbols that divide the boundaries of ditches and canals, to jointly construct a narrative framework of historical background. Regarding tangible relics in cultural heritage sites with specific materiality, core relic components are transformed into representative symbols based on their archaeological significance and visual recognizability - these entities establish stable cognitive images in public consciousness. In the process of translation, formal abstraction and reconstruction are carried out based on its actual structural characteristics and spatial configuration, and combined with graphic semiotics to produce visually unique graphic forms. Based on the material properties of the site entity, these representative symbols are expressed empirically, promoting the visual transmission of core cultural narratives by accurately presenting key details such as rammed earth platforms, column hole distribution, and artificial product combinations. By comprehensively analyzing on-site survey data and archaeological reports, Su Shiliang (2025) systematically transformed material cultural elements such as stratigraphic profiles, residential patterns, and burial types into standardized graphic symbols with artificial product ID codes and functional descriptions, thereby enhancing the expressive power of the core site components in narrative mapping (Figure 3).

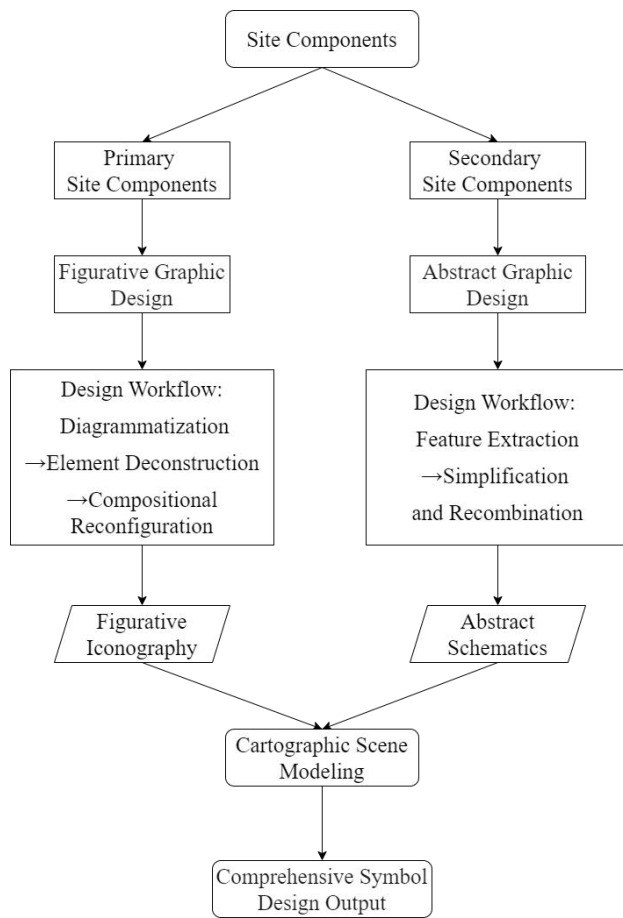
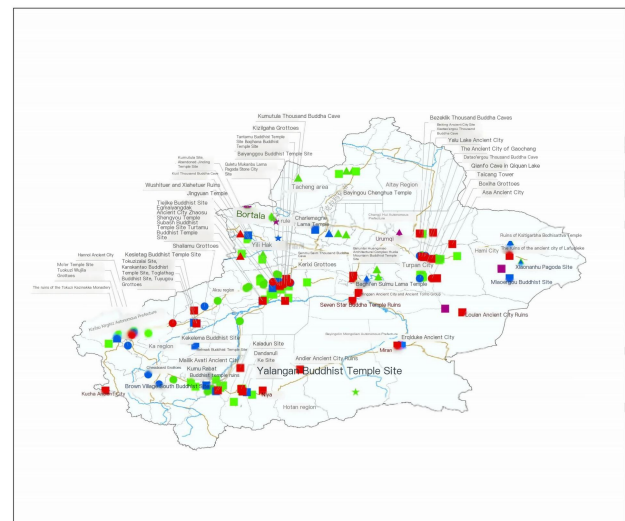


Figure 3.Site symbol design

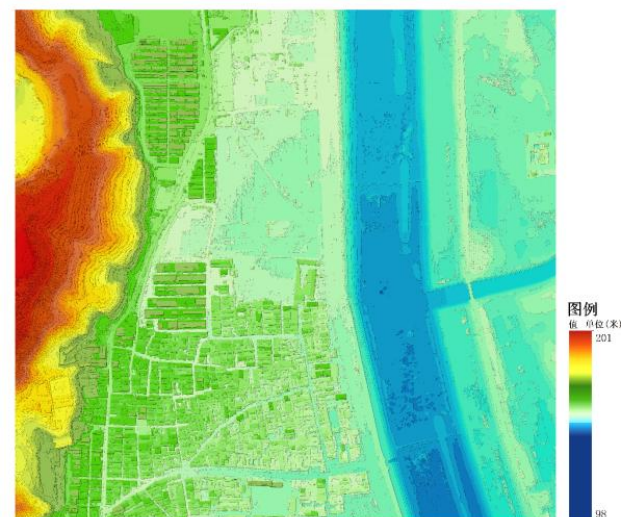
4. Application Practice

This article proposes a three in one mapping specification framework that integrates the "attribute data process specification symbol system" based on the theoretical framework of Pierce's semiotic triad. This framework achieves standardization in the cognitive logic, data source integration,

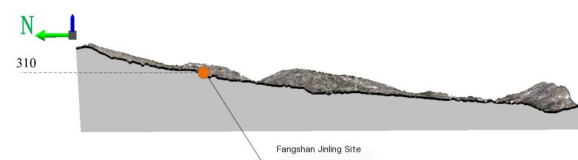
and representation layer design of archaeological site maps through unified symbol representation, object association, and explanatory meaning. Taking the study of ancient mapping as an example, the feasibility of the new standard in enhancing the collaborative effect of site spatial representation and spatial information expression was demonstrated through thematic requirement analysis, mapping data processing, rendering of basic map elements, thematic symbol design, and map refinement (Figure 4).



a. Site classification display



b. DEM display



c. Sectional view display
Figure 4.Mapping results

5. Conclusions

In the deep integration of the digital wave and diverse application scenarios, the field of thematic mapping is undergoing unprecedented paradigm changes. The growing demand for dynamic data integration, the complexity of multi

platform visualization expression, and the urgent need for in-depth interpretation of cultural heritage together constitute the core driving force for promoting the high-level evolution of thematic mapping standards. The explosive development of information technology provides the underlying support for this evolution, with the integration and application of innovative technologies such as high-precision 3D laser scanning, multispectral remote sensing, AI driven image analysis, and cross platform virtual reality, constantly reconstructing the collection, processing, and representation system of thematic information. This article is based on the background of this era, and through a forward-looking analysis of the evolution path of visualization technology and the development trend of thematic mapping, constructs a set of "fusion standardization dynamic" thematic mapping specification framework for archaeological practice needs. This will promote the strategic transformation of archaeological mapping from "static recording tools" to "dynamic cognitive infrastructure", laying the theoretical foundation and engineering paradigm for the intelligent upgrading of digital cultural heritage protection.

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