A Study on the Evolution Characteristics of the Spatial Layout of The Mountain Fortress System of Sichuan and Chongqing in China during the Song and Yuan Wars

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Abstract
The Song-Yuan Mountain Fortress System in the Sichuan-Chongqing region of China emerged from the 13th-century conflict between East Asian agrarian and nomadic civilizations. Preserving military engineering relics from both the Song and Yuan dynasties, it reflects the historical evolution of diverse civilizations in the region. This study employs GIS tools and knowledge graph technologies to analyse the mountain fortress system, identifying key value elements and their interconnections. By examining the socio-economic context of Sichuan, China, during the Song-Yuan wars, the research explores the factors and internal logic shaping spatial pattern evolution, aiming to support the comprehensive preservation of the system in the Sichuan-Chongqing region.

Keywords: Song-Mongol (Yuan) Wars; Mountain Fortress Defence System; Value Elements; Spatial Patterns; Holistic Conservation

1 Introduction

1.1 Background

Military cultural heritage is a product of history, with historical value reflecting its intrinsic nature. It encompasses the remains, artifacts, and the entire historical evolution formed by successive generations through military activities, as well as the comprehensive development process of these activities[1]. With the continuous advancement of international concepts for historical and cultural heritage conservation, holistic and integrated protection has gradually become the mainstream approach, and the types of heritage preservation have increasingly diversified. Against this backdrop, military heritage has emerged as a significant topic in the global field of heritage conservation, garnering growing attention from professionals in the discipline. Military heritage not only holds profound historical value but also plays an indispensable role in shaping national cultural identity and preserving historical memory.

The Southern Song Mountain Fortress Sites in Sichuan, China, or the "Sichuan-Chongqing Song-Yuan Mountain Fortress Sites," is the collective designation for the remnants of a system of mountain fortresses—combining newly planned administrative cities and military fortifications—entirely reconstructed in the Sichuan theater during the late Southern Song period amid the Song-Yuan wars[2]. These Sichuan-Chongqing Song-Yuan Mountain Fortresses represent the most intact ancient administrative urban system preserved in China, exemplify the historic use of mountainous and riverine landscapes to establish cities and regional defenses via land and water routes, and constitute the finest material evidence of the Song-Yuan conflicts in China's Sichuan-Chongqing region.

1.2 Overview of the Study Area

Geographically, "Chuan-Yu" denotes the broad region centered on China's Sichuan Basin, extending into southern Shaanxi, western Hunan and Hubei, northern Yunnan and Guizhou, and lying east of the Hengduan Mountains along the Jinsha River. This area corresponds to the territories administered by Ba, Shu, Hanzhong, and the various Nanzhong commanderies during the Qin and Han dynasties. Surrounded by mountain ranges—the Daba and Micang Mountains to the north, the Dalou Mountains to the south, the Hengduan Mountains to the west, and the Wuling Mountains to the east—the Sichuan Basin forms a relatively enclosed geographic unit[3]. Its periphery comprises the Three Gorges of the Yangtze River to the east, the Yunnan–Guizhou Plateau to the south, the Qinghai–Tibet Plateau to the west, and the Daba Mountains to the north, while its basin floor is divided into the eastern Sichuan parallel ridge-valley system, the central Sichuan hills, and the Chengdu Plain in western Sichuan (Figure 1).

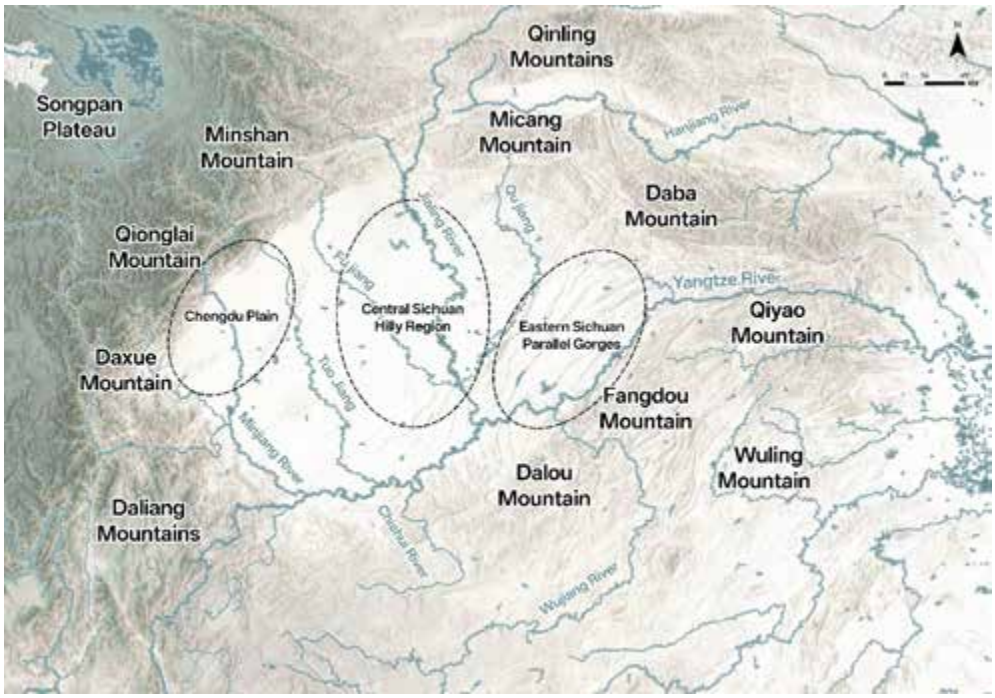

Figure 1 Geographical Division of China's Sichuan Basin (Source: the author)

In the fourth year of the Xianping era during the Northern Song Dynasty (1001 AD), the imperial court divided the former Ba-Shu region into four administrative circuits: Yizhou (present-day Chengdu, China), Zizhou (present-day Santai, China), Lizhou (present-day Guangyuan, China), and Kuizhou (present-day Fengjie, China). Collectively known as the "Four Lu (Circuit) of Chuanxia" or the "Sichuan Lu (Circuit)," these regions later gave rise to the abbreviated name "Sichuan." During this period, official positions such as the Sichuan Pacification Commissioner and Sichuan Military Commissioner were established. Historically, the water-rich Jianghuai region of China was easily defensible and difficult to attack. Northern campaigns to conquer the south, such as Emperor Wu of Jin's subjugation of Wu, Emperor Wen of Sui's destruction of Chen, and Emperor Taizu of Song's pacification of the Southern Tang—all involved first seizing Sichuan to control the Yangtze River, then advancing eastward along its flow. The strategists within the Mongol army likewise held this view[4].

1.3 Literature Review

Recent years have witnessed scholarly research on the Song-Yuan Mountain Fortress System in the Chuan-Yu region of China. For instance, Peng Feng's "Fortifying Cities to Hold Ground" and "Mutual Support between Jing and Shu": Adjustments in Late Southern Song Sichuan Defense Policies and Their Impact analyzes strategic shifts in the Southern Song's defensive policies before and after the Battle of Diaoyu Fortress, exploring their profound influence on the overall defensive framework of Chuan-Yu[5]. Wang Zhejun's Administrative and Economic Operations of the Mountain Fortress System in Sichuan During the Song-Mongol (Yuan) War investigates the economic and political characteristics of the region during the conflict[6]. Li Zhen's Characteristics of the Southern Song's Anti-Mongol Mountain Fortress Defense System in the Upper Yangtze from a Cultural Landscape Perspective examines the correlation between the fortress system layout and major transportation networks through spatial distribution and site selection[7]. Collectively, academic research has made progress in understanding the policies, economic conditions, defensive morphology, and spatial patterns of the Chuan-Yu region of China during the Song-Yuan wars. However, studies on defensive spaces largely remain confined to the "Eight Pillars of Sichuan" framework, lacking regional or holistic perspectives. Furthermore, research on the evolving spatial patterns and characteristics of fortresses across different phases remains inadequate.

Regarding GIS and knowledge graph technologies in heritage conservation, Hu Mingxing's Application of GIS Technology in Historical Neighborhood Conservation Planning establishes a GIS-based methodology for surveying, protecting, and planning historical districts[8]. Zhan Qingming's Suitability Analysis of Heritage Corridors Based on GIS and RS develops a landscape resistance evaluation system to assess corridor viability[9]. Xie Yongjian's

Knowledge Graph Construction for Shanghai's Outstanding Historical Buildings creates an associative network for 150 historic buildings, enabling single-attribute and cross-conditional searches while exploring shared traits and latent patterns[10]. Liu Yanchao's Digital Knowledge Graph for the Central Axis' Artistic Value Based on Neo4j proposes an AI-powered approach to excavate and interpret heritage values, using Beijing's Central Axis to reveal traditional Chinese philosophical essence across four dimensions[11]. Overall, domestic GIS applications in heritage conservation prioritize risk management and data mapping, with limited spatial feature analysis. Knowledge graph research in this field remains scarce, predominantly focusing on historic architecture or summarizing trends via CiteSpace, lacking urban/regional-scale studies and failing to reflect spatial distribution and evolution across historical periods.

Therefore, this study will apply emerging technological means to understand the spatial evolution characteristics of the Song and Yuan Mountain Fortress System in the Sichuan-Chongqing region of China. By using GIS tools, the coupling relationship between the mountain fortresses and ancient roads, water systems, and mountains in the Sichuan-Chongqing region during the Song and Yuan Dynasties will be explored. The distribution of mountain fortresses and the defense focus in different historical stages will be analyzed, and the spatial distribution characteristics of the mountain fortresses in the Sichuan-Chongqing region during the Song and Yuan Dynasties in each historical period will be summarized. Moreover, by combining knowledge graph technology, relevant historical materials and documents will be sorted and summarized, and the political and economic environment of the mountain fortresses in different stages in the Sichuan-Chongqing region during the Song and Yuan Dynasties, as well as the interrelationships among the mountain fortresses, will be revealed through visualized graphs.

2 Methodology

2.1 Research Objects

2.1.1 Sichuan-Chongqing Song-Yuan Mountain Fortress System

The Song-Yuan Mountain Fortress System in the Sichuan and Chongqing region of China is the most direct and intense product of the conflict between agricultural and nomadic civilizations in East Asia in the 13th century. It preserves the military engineering remains of both the Song and the Yuan (Mongol) sides, providing a complete witness to the conflict, exchange, and continuous integration between the two civilizations. The ideas of city defense system construction, military governance models, and engineering facilities reflected by it are the concentrated embodiment of outstanding military thoughts in ancient China in military engineering. At the same time, it also shows the confrontation and confrontation between the two sides of the war based on different military guiding thoughts in terms of offensive and defensive strategies, tactical methods, and engineering construction techniques. From the purity of the construction reasons, the particularity of the social environment at that time, the readability of the existing sites, as well as the war results and far-reaching influence, the Song-Yuan Mountain Fortress System in Sichuan and Chongqing is the most representative military heritage discovered so far, which can comprehensively reflect the historical evolution pattern of different civilizations in East Asia in the 13th century.

2.1.2 Sichuan-Chongqing Song-Yuan Mountain Fortresses

In the late Southern Song period, the Mongol army launched a massive invasion and occupied half of the territory, including Chengdu, the capital of Sichuan, China. The defensive system originally established by the Song dynasty along the mountainous edges of the Sichuan Basin collapsed. The Southern Song-controlled areas in Sichuan, China, found themselves in a situation devoid of natural defenses. To secure Sichuan as a strategic upper-reach shield of the dynasty's remaining territory, the Southern Song court intensified its defensive arrangements in the region. It began to construct fortifications by taking advantage of the natural barriers formed by mountains and rivers. Mountain fortresses and naval stockades were built at strategic points along the three major north-south rivers within Sichuan—namely, the Jialing River, the Tuo River, and the Min River—as well as along the east-west Yangtze River, which forms after the confluence of the three. Existing prefectural and county seats, which lacked sufficient natural defenses, were relocated to these mountain fortresses and water-based strongholds to counter the tactical superiority of Mongol cavalry. As a result, a defense system was formed that combined mountain and river fortifications as strategic nodes and used rivers as connecting lines, creating a coordinated network of mutual support between points and lines[12].

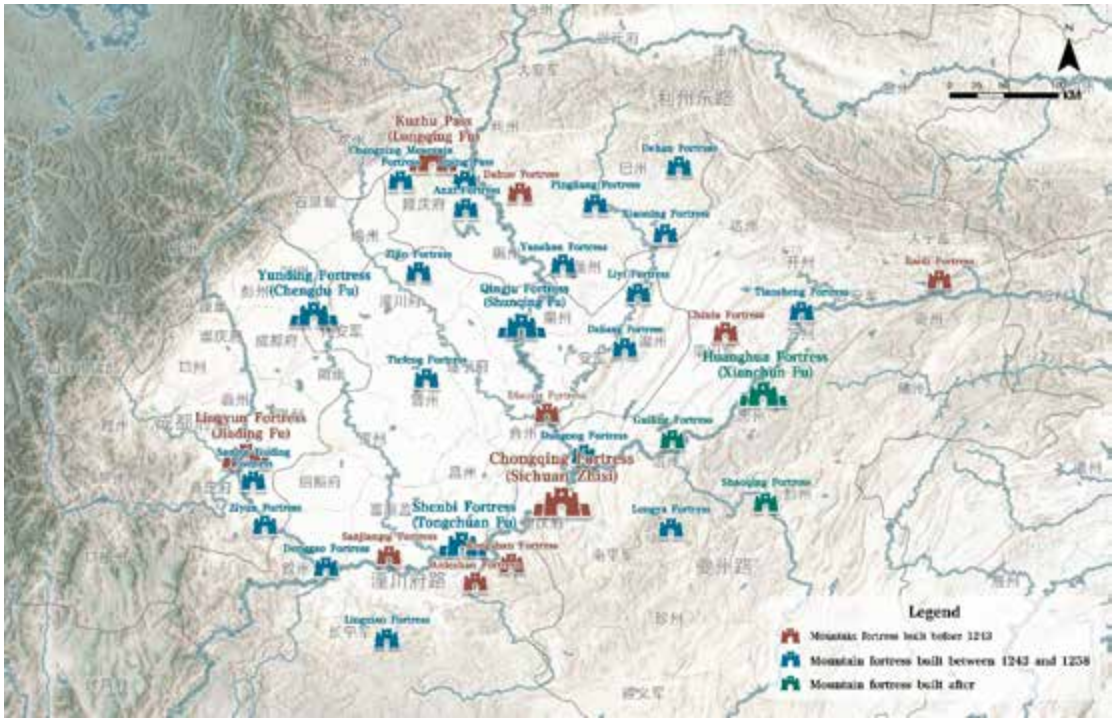

Figure 2 Distribution Map of Mountain Fortresses Built by the Song Military in Different Periods (Source: the author)

The Song Dynasty implemented a three-tier administrative system comprising Lu (Circuit), Fu/Zhou/Jun/Jian (Prefecture, Subprefecture, Military districts), and counties (Xian). Additionally, it also established overarching positions such as Xuanfushi (official positions in ancient China) or Anfu Zhizhishi (official positions in ancient China) to supervise multiple Lu. During the Southern Song period, the strategic demands of resisting northern invasions led to the progressive expansion of the Anfu Zhizhishi's authority in Sichuan, China. This elevated the role into a chief administrator overseeing military affairs, civil governance, and fiscal administration across all Lu. Consequently, Sichuan's mountain fortresses during the Song-Yuan War were organized into four administrative tiers aligned with this structure: Zhishi (overseeing the military affairs of a theater of war), Lu, Fu/Zhou/Jun/Jian, and county (Figure 3).

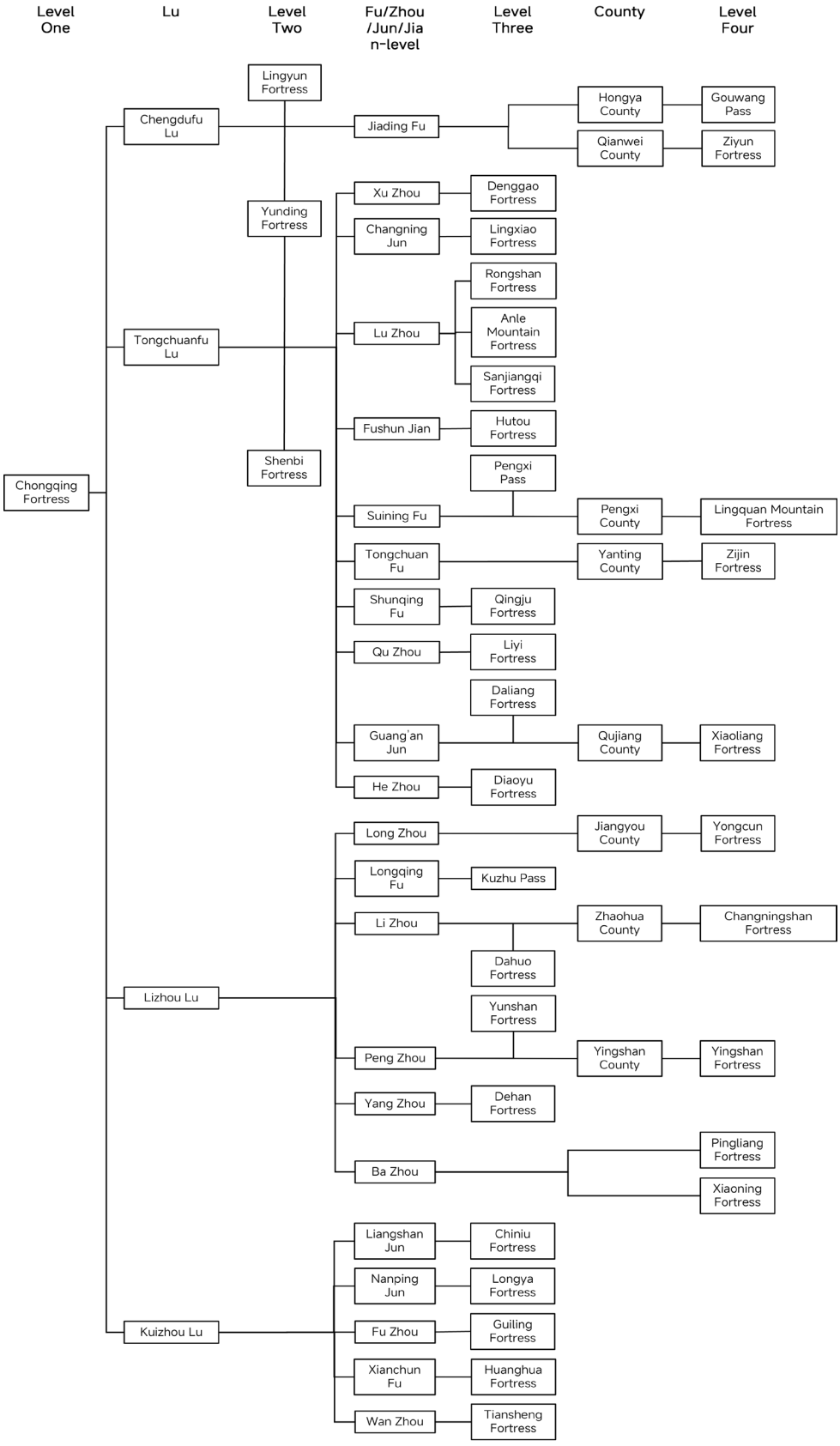

Figure 3 Administrative Hierarchy and Jurisdictions of Mountain Fortresses (Adapted from Zhou Siyan, 2017)

According to archaeological field investigations, no fewer than twenty identifiable Southern Song Mountain Fortress Sites remain within the Sichuan region of China[14]. Almost without exception, these mountain fortresses were constructed atop steep and rugged mountain peaks. After the conclusion of the Song-Yuan wars, administrative centers were relocated back to plains or gently sloping areas, resulting in minimal subsequent urban development that might have caused damage to these sites. As a result, the architectural structures of these mountain fortresses have been largely preserved, with many Song-era city walls still clearly visible today. Notably, nine city gates from the Song dynasty have survived, providing invaluable physical evidence for contemporary research into the history of the Song-Yuan wars, urban development, mountain fortress architecture, and the regional history of the areas where these fortresses are located[2].

2.2 Materials and Methods

2.2.1 Research Materials

This study draws upon archaeological literature, contemporary scholarship, and field investigations, utilizing materials including the History of Song, History of Yuan, and local gazetteers. Research materials were sourced through multiple channels such as library collections, CNKI (China National Knowledge Infrastructure), and Web of Science. An extensive review of domestic and international literature concerning military site research, the formation and development of the Song-Yuan Mountain Fortress System, and spatial morphology analyses of individual fortresses was conducted to comprehend current research trends and findings. Primary sources comprise the History of Song, History of Yuan, and Comprehensive Historical Events of Song, supplemented by local chronicles, publications on Chinese military history, and relevant academic papers. Through documentary analysis, the historical trajectory of the Song-Yuan conflicts in the Chuan-Yu region and the developmental stages of the Song Mountain Fortress System were systematically examined, laying the groundwork for subsequent GIS analysis and knowledge graph construction.

Figure 4 Related Reference Texts (Source: the author)

2.2.2 Geographic Information System

A Geographic Information System (GIS) represents an integrated information technology encompassing disciplines including geography, surveying, and computer science[15]. It constitutes a technical framework operating under computer hardware and software support for capturing, storing, managing, processing, analyzing, displaying, and describing geographically distributed data across the Earth's surface and near-surface atmosphere.

Within China's cultural heritage sector, GIS applications primarily focus on three domains: heritage conservation management platforms, visualization research for archaeological information, and disaster risk assessment of cultural assets[15]. Simultaneously, GIS facilitates spatial data management through capabilities for storing, editing, querying, and symbolizing historical heritage data, thereby providing geospatial support for knowledge graph construction. Leveraging GIS spatial analysis functions enables the identification of proximity and connectivity among geographical entities, revealing spatial distribution patterns of historical heritage.

2.2.3 Knowledge Graph

The concept of the knowledge graph was originally proposed by Google as a semantic network that describes relationships between entities. Knowledge graphs can be categorized into general knowledge graphs and domain-specific knowledge graphs based on their usage and scope. General knowledge graphs have broad coverage but limited depth of research. In contrast, domain-specific knowledge graphs focus on particular fields, requiring more rigorous data schemes and enabling deeper exploration. A domain-specific knowledge graph consists of a schema layer and a data layer and utilizes domain ontology technologies to transform unstructured data into structured data[16]. Within this framework, nodes are composed of entities, such as concepts, people, or objects, and form a network through interconnections defined by relationships and attributes.

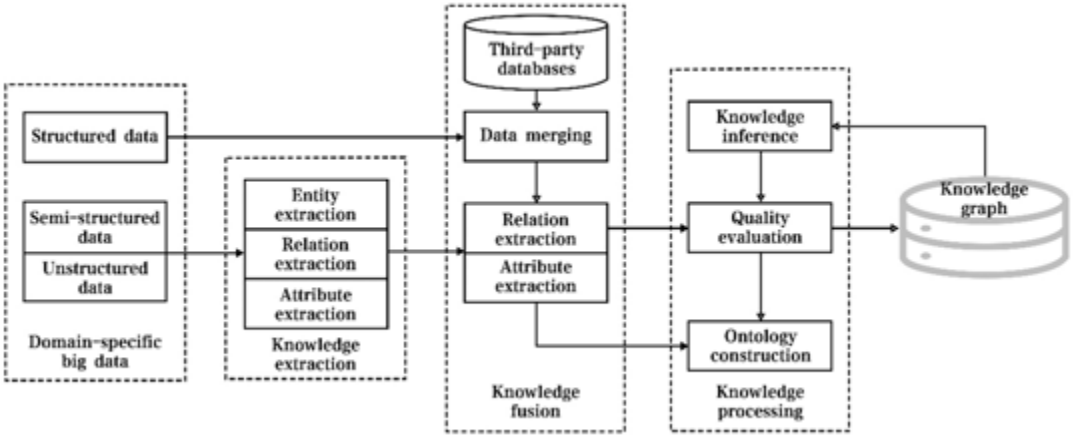

Figure 5 Architectural Framework of Domain-Specific Knowledge Graphs (Adapted from Liu, Y.C., 2020)

In a domain-specific knowledge graph, an ontology refers to a formalized framework that provides explicit definitions of entities and the relationships between them, serving as an abstract model for representing the objective world. The methods for constructing ontologies vary according to the needs of different domains and are mainly divided into bottom-up and top-down approaches. The bottom-up approach extracts entities, relationships, and attributes directly from underlying data before integrating them, and is more suitable for general knowledge graphs. The top-down approach involves constructing a domain ontology first, which then constrains and guides the structuring of data. Typically, domain-specific knowledge graphs adopt a combination of top-down and bottom-up approaches to meet the requirements for depth and accuracy within a specific field.

3 Spatial Evolution Characteristics Analysis of the Sichuan-Chongqing Song Army Mountain Fortress System Based on GIS

3.1 Kernel Density Analysis of Mountain Fortresses

The Kernel Density tool in ArcGIS calculates the density of point features around each output raster cell, aiming to identify areas of concentrated density and variations in distribution. In this study, 46 mountain fortresses with relatively well-defined geographic coordinates were selected based on historical documents and relevant local gazetteers. Combined with analytical results and the geographical division of the Sichuan Basin of China, it can be observed that Song Military Mountain Fortresses in the Sichuan-Chongqing region of China were primarily concentrated at the junction of the Jialing River and the Qinling-Daba Mountains, along the Jialing River, at the confluence of the Jialing River and the Yangtze River, along the Min River, and at the junction of the Yangtze River and the Wushan Mountains.

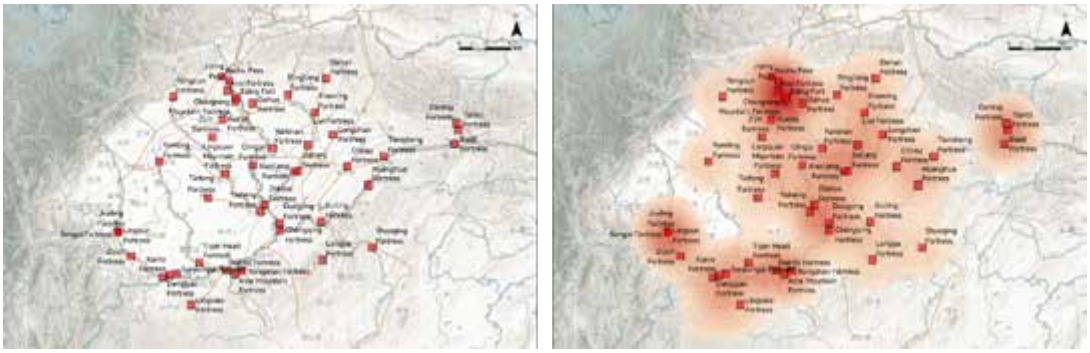

Figure 6 Kernel Density Analysis of the Song-Yuan Mountain Fortress System (Source: the author)

The ancient Qin-Sichuan route connected the Guanzhong Plain with the Sichuan Basin, organically linking most of the historical towns in the Shaanxi region of China. The distribution of historical and cultural relics along the Shu Roads, as well as the spatial patterns of historical towns, can be categorized into five major historical and cultural regions based on administrative divisions: the Guanzhong region, the Hanzhong region, the Guangyuan region, the Chengdu region, and the Chongqing region. As a historical cross-section, the system of Song-Yuan Mountain Fortress sites serves as a significant entry point for studying the military defense system along the ancient Shu Roads, the dynamic relationship between transportation and regional control, the integration of diverse cultures, and contemporary heritage conservation[17].

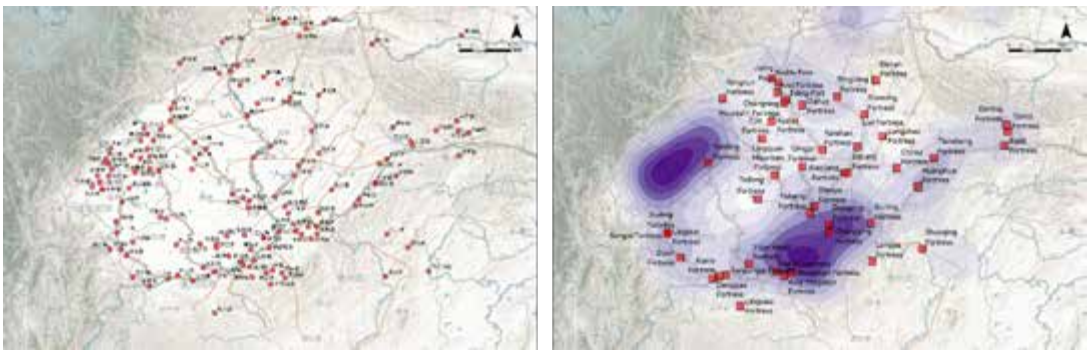

Figure 7 Kernel Density Analysis of Historical Settlements in the Sichuan-Chongqing Region of China (Source: the author)

By conducting a kernel density analysis of 155 historically significant settlements along the Qin-Sichuan route and overlaying it with the kernel density analysis map of the Song-Yuan Mountain Fortress system, it is evident that the overall distribution of mountain fortresses generally aligns with that of ancient settlements. The only notable exception is the Chengdu Plain of China, where numerous settlements are present, yet few mountain fortresses were constructed to guard Chengdu. This may be attributed, first, to the relatively flat terrain of the Chengdu Plain, which lacks natural defensive barriers, prompting the Song military to focus on controlling the upper reaches of the Jialing River to block the Mongol army's advance toward Chengdu, or to station troops in the Jiading area to slow the enemy's progress and provide timely reinforcement to Chengdu when necessary. Second, during the Song-Yuan wars, the Song military's deployment appeared more inclined toward the defense of the Chongqing region, resulting in a spatial distribution of mountain fortresses that was notably denser in the east than in the west, and more concentrated in the south than in the north.

Using the Sichuan Basin of China as the study area, five evaluation factors—elevation, slope, aspect, water availability, and soil texture—were selected for analysis. Single-factor evaluations were conducted using ArcGIS, and the weights of each factor were calculated using the Analytic Hierarchy Process (AHP)[18]. These single-factor evaluation maps were then subjected to spatial overlay analysis based on the evaluation model, resulting in a thematic map of arable land suitability levels and ultimately generating a spatial distribution map of arable land suitability across the Sichuan Basin.

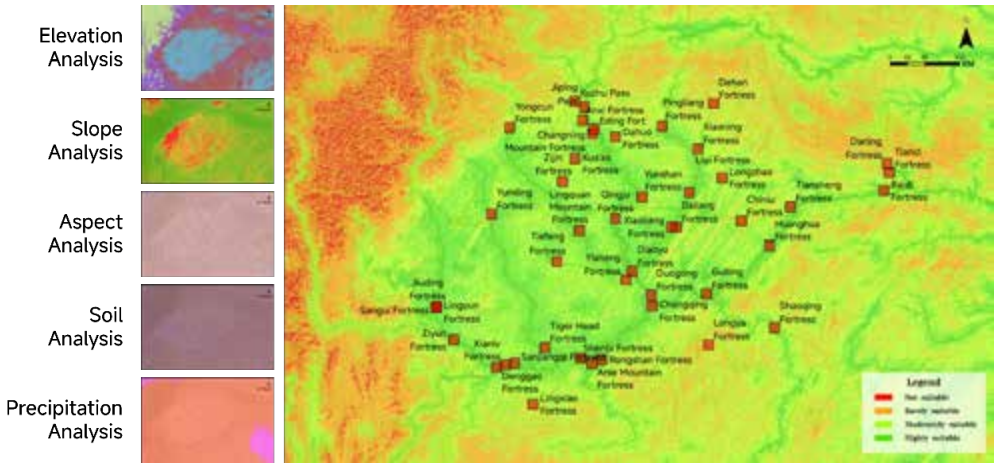

Figure 8 Map of Mountain Fortress Distribution and Agricultural Land Suitabil ity Assessment in the Sichuan Basin of China (Source: the author)

According to the results of the agricultural land suitability evaluation, the Sichuan Basin of China is generally highly suitable for cultivation, with the Chengdu Plain of China in particular standing out as an extensive area of high-quality arable land. By overlaying the distribution map of Song military mountain fortresses during the Song-Yuan wars, it can be observed that these fortresses were generally located in areas with fertile soil and adequate precipitation, which were highly suitable for farming. This pattern aligns with the overall operational model employed by the Song during the Mongol invasion, wherein local populations relocated a masse into mountain fortresses during periods of military threat and resumed agricultural activities in the surrounding areas once the Mongol forces had withdrawn. However, this also reveals that following the Mongol occupation of Chengdu, much of the high-quality farmland in the Sichuan Basin of China fell under threat from Mongol forces. Consequently, the continued functioning of the entire Sichuan-Chongqing Mountain Fortress system became heavily reliant on support from the Jinghu region.

3.2 Contour Analysis of Construction and Fall Times

The construction of the Song-Yuan Mountain Fortress System can be roughly divided into three phases, each corresponding to the growing military threat posed by the Mongol forces. Mountain fortresses built prior to 1243 mainly consisted of pre-existing fortresses as well as those constructed spontaneously by local military and civilian groups in the Sichuan-Chongqing region of China in response to evolving circumstances. Although limited in number, these fortresses occupied key transportation routes and played significant roles in subsequent military engagements. The mountain fortresses constructed between 1243 and 1259 were largely completed during the administration of Yu Jie. Following the large-scale invasion of the Sichuan-Chongqing region by Ögedei Khan, the Song military adopted the advice of strategic advisors and initiated the construction of a substantial number of mountain fortresses. This period witnessed the greatest number of fortress constructions, with a spatial distribution characterized by a higher concentration in the east than in the west. After 1259, the fierce offensives led by Möngke Khan resulted in the near-total collapse of the Song defensive system north of the Yangtze River within the Sichuan-Chongqing region. During this final phase, the number of newly constructed mountain fortresses was minimal, and their primary purpose was to reinforce the Yangtze River defense line and protect Chongqing.

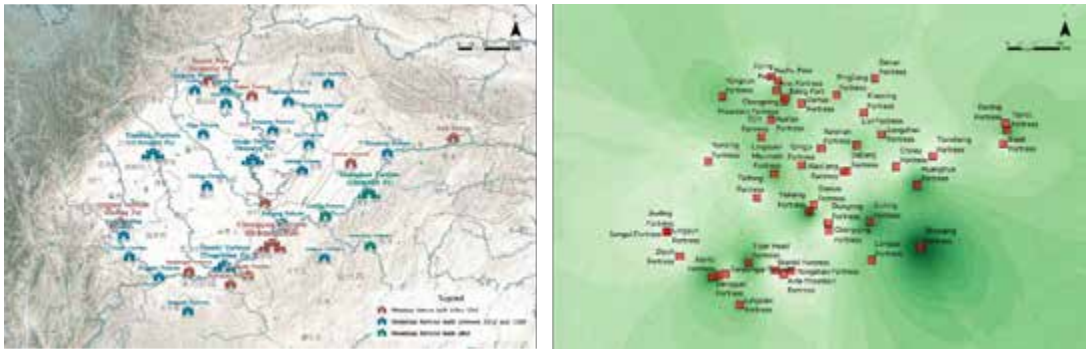

Figure 9 Analysis of Construction Timelines for Mountain Fortresses in the Song-Yuan Fortress System (Source: the author)

The Inverse Distance Weighted (IDW) interpolation method calculates weighted values based on the distance between interpolation points and sample points, considering only the distances between the interpolation point and its neighboring points during the interpolation process. It is commonly used in the construction of Digital Elevation Models (DEM)[19]. By applying the IDW method to analyze the construction dates of the Song-Yuan Mountain Fortresses (Figure 9), it is observed that the earliest-built mountain fortresses during the Song-Yuan wars were scattered throughout the Sichuan-Chongqing region of China. Subsequently, defensive efforts gradually intensified in three directions: northwest, southwest, and southeast. This pattern may be related to the late-stage Mongol occupation of Dali and the loss of Song fortresses in the upper reaches of the Jialing River, which forced the Song military to contract their defensive line to the Yangtze River area and strengthen defenses in the southwest.

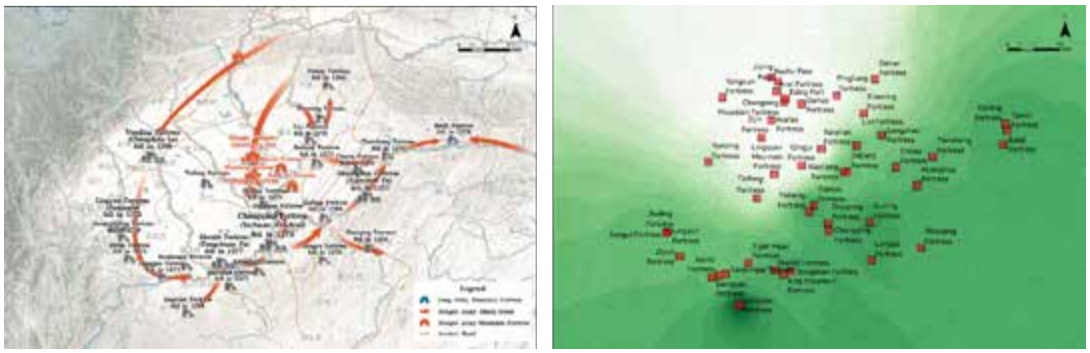

Figure 10 Analysis of Fall Timelines for Mountain Fortresses in the Song-Yuan Fortress System (Source: the author)

By analyzing the fall times of the Song-Yuan Mountain Fortresses using the Inverse Distance Weighted interpolation method (Figure 10), two distinct phases of fortress collapse become apparent. This pattern reflects the spatial contraction of the Song military defense in the Sichuan-Chongqing region of China from the upper reaches of the Jialing River to the main course of the Yangtze River. In 1258, the Mongol Great Khan Möngke personally led a three-pronged campaign against the Song, successfully breaking through the Song Mountain Fortresses around the Jialing and Min Rivers and advancing to the foot of Diaoyu Fortress. Although Möngke died at Diaoyu Fortress in 1259, during this period the Mongols also began constructing mountain fortresses themselves, utilizing the captured Qingju Fortress to establish several forward outposts north of Diaoyu Fortress. This development deprived the Song forces of any ability to reclaim lost territory and is likely the primary reason for the pronounced phased pattern in the fall times of the Song Mountain Fortresses.

3.3 Analysis of Mountain Fortress Defense Priorities Based on GIS

Since the Qin and Han dynasties, with the increasing strategic importance of Sichuan, China, the development during the Three Kingdoms, Wei-Jin, Southern and Northern Dynasties, and especially the Sui and Tang periods laid the foundation for the transportation routes in Sichuan during the Song dynasty[20]. The Shu Roads are divided into northern and southern sections, with the southern section comprising three main routes: Jinniu Road, Micang Road, and Litchi Road, among which the Litchi Road served as the key connection between the Sichuan Basin of

China and the Central Plains of China. Waterway transportation was the primary mode of travel in Sichuan at the time, with the Min River–Yangtze River system being an important channel for cargo and passenger traffic. The sites of the Song-Yuan Mountain Fortresses were all located near major water and land transportation routes in Sichuan. The mountain fortresses adjacent to land routes played a crucial supplementary role in resisting the Mongol invasion, jointly supporting the effectiveness of the anti-Mongol defense system.

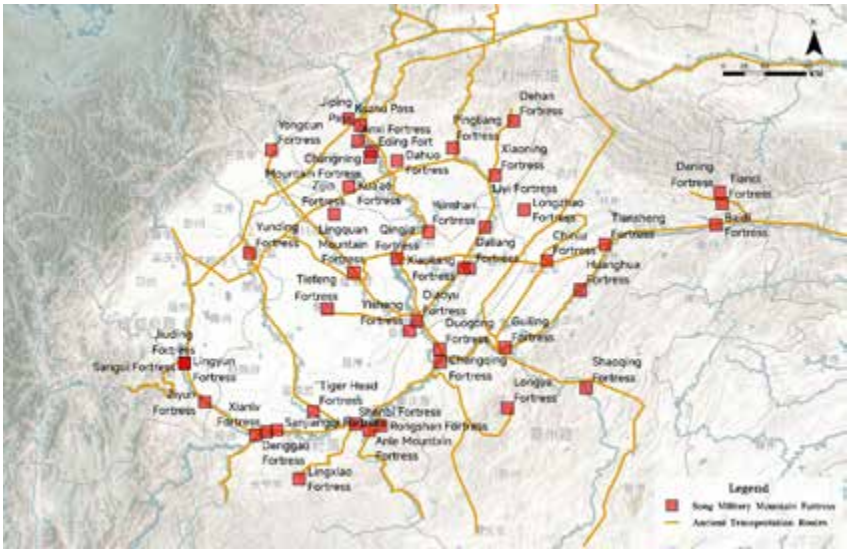

Figure 11 Map of Transportation Routes in the Sichuan-Chongqing Region during the Song-Yuan Wars (Source: the author)

Meanwhile, the defensive characteristics of the mountain fortress, formed jointly by fortification facilities and the terrain and landforms, together with the administrative functions transferred to the mountain fortress during wartime and its convenient access to both water and land transportation, collectively determined the regional defensive capability possessed by an individual mountain fortress within the entire Song-Yuan Mountain Fortress System.

The Analytic Hierarchy Process (AHP) is an objective analytical method that organizes and synthesizes subjective judgments. It is a systematic and hierarchical approach that effectively combines subjective and objective, qualitative and quantitative analyses[21]. Scores were assigned based on the mountain fortress's accessibility, defensive capability, administrative level, and terrain conditions, and AHP was employed to assess the relative importance of each evaluation factor. By comparing the significance of these factors, the weights (w) of the evaluation factors—accessibility (B1), defensive capability (B2), administrative level (B3), and terrain conditions (B4)—were determined, resulting in the construction of the evaluation matrix as shown in Table 1.

Table 1 Mountain Fortresses Defense Priority Judgment Matrix Table (Source: the author)

A	B1	B2	B3	B4	
B1	1	5	3	5	0.5579
B2	1/5	1	1/3	1	0.0963
B3	1/3	3	1	3	0.2495
B4	1/5	1	1/3	1	0.0963

To verify matrix consistency, the consistency index was calculated (n=4, CI=0.0145). Referencing Saaty's random consistency index (RI) table derived from 1,000 simulations, RI=0.90 for a 4th-order matrix yielded a consistency ratio , confirming matrix validity.

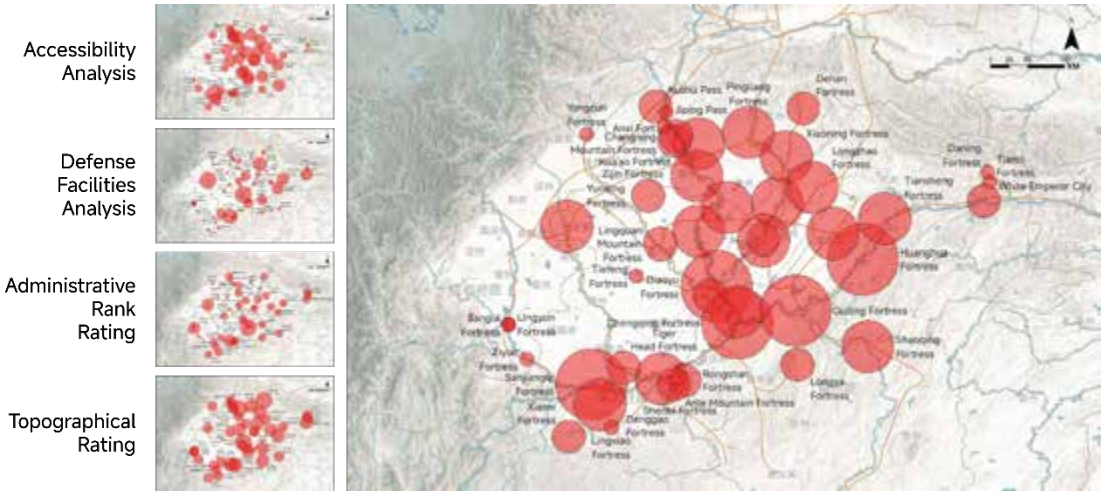

Figure 12 Evaluation of Regional Defense Levels for Song and Yuan Mountain Fortresses in the Sichuan-Chongqing Region of China (Source: the author)

Based on OD cost matrix analysis in GIS, the traffic accessibility of the mountain fortresses was evaluated using an ancient marching speed of 30 li (ancient Chinese unit of length equivalent to approximately 360 meters) per day as a reference, generating the accessibility analysis map shown above (Figure 12). Combining the evaluation results of the defensive capability, administrative level, and terrain conditions of the Song military mountain fortresses in the Sichuan-Chongqing region of China, and using the evaluation factor weights derived from the Analytic Hierarchy Process, a regional defense level evaluation map of the Song-Yuan mountain fortress system was produced. Among these, Chongqing Fortress, Diaoyu Fortress, Guiling Fortress, and Huanghua Fortress were classified as the first tier, possessing prominent regional defensive capabilities. While ensuring their own defensive strength, they were also able to effectively coordinate with surrounding mountain fortresses. Yunding Fortress, Qingju Fortress, Shenbi Fortress, and Yunshan Fortress were classified as the second tier, serving as important regional defensive strongholds capable of effectively resisting Mongol attacks. The third and fourth tiers of mountain fortresses generally functioned as supplementary defenses, reinforcing connections between mountain fortresses or filling gaps within the fortress system. Overall, a defense hierarchy was established with Chongqing City and its surrounding mountain fortresses as the first tier, mountain fortresses along the main road and waterway networks of the Sichuan-Chongqing region as the second tier, and third- tier and fourth-tier mountain fortresses providing supporting layers.

3.4 Summary of GIS Section

GIS-based spatial evolution analysis of the Southern Song Mountain Fortress System in the Chuan-Yu region reveals a high degree of coupling between its distribution patterns and geographical environments, military strategies, and transportation networks. The system exhibits an east-dense, west-sparse distribution pattern along strategic waterways, predominantly concentrated at tactical junctions including the Jialing River corridor, Yangtze mainstream-tributary confluences, with particular density clusters in the upper Jialing River defensive group and the Chongqing peripheral fortress complex. Kernel density analysis confirms spatial correlation between fortress locations and historical settlements, while the Chengdu Plain of China manifests a distinct "dense settlements but sparse fortresses" phenomenon—reflecting the Song military's strategic withdrawal from plains to mountainous terrain, prioritizing defense lines along the Jialing and Yangtze rivers.

Temporally, fortress construction demonstrates marked phasic characteristics. Early strongholds guarded the Shu Roads; mid-phase development under Yu Jie's governance established large-scale defensive networks; late-phase construction contracted to the Yangtze corridor. This spatiotemporal trajectory mirrors Mongol offensive pathways. Spatial differentiation in capture timelines reveals strategic shifts in defensive focus: after losing upper Jialing fortresses, the Song rebuilt defenses along the Yangtze anchored by core strongholds like Chongqing and Diaoyu Fortress. Analytic Hierarchy Process indicates hierarchical regional defense capabilities, with primary-tier fortresses (e.g., Chongqing Fortress, Diaoyu Fortress) forming command nuclei that integrated administrative control and military functions through multi-level, water-land coordinated networks.

Collectively, the fortress system established a tri-tiered defensive hierarchy (core-node-supplement) through its "mountaintop fortifications and waterside defenses" spatial configuration. This design leveraged synergistic terrain-fortification effects while maintaining strategic resilience through control of agricultural hinterlands and transportation arteries. Such a spatial defense paradigm represents both an evolution of traditional Shu Roads defensive frameworks and a concentrated manifestation of geo-military ingenuity under specific historical conditions, providing critical empirical insights into the spatial logic of ancient mountain warfare systems.

4 Spatial Evolution Characteristics Analysis of the Sichuan-Chongqing Song Army Mountain Fortress System Based on Knowledge Graph

4.1 Analysis of Defense Policy Association Graph Characteristics

The Southern Song Dynasty placed great emphasis on the defense and management of Sichuan and Chong regions of China. After Emperor Gaozong of Song fled south, pacified various bandits, and stabilized the regime, he devoted himself to constructing the defense system in Sichuan and Chongqing. Subsequent Southern Song monarchs also attached great importance to the defense of this region[5]. Overall, the defense policies of the Southern Song in the Sichuan-Chongqing area during the Song-Yuan wars can be roughly divided into three stages: the period of Mongke Khan Ögedei (1236–1243), the period of Yu Jie and Mongke Khan (1244–1259), and the period of Kublai Khan (1260–1288).

By extracting data from selected literature corpora, the obtained information units were categorized into periods, policies, key figures, mountain fortresses, and strategic positioning. The reclassified information was input into Gephi software to generate a knowledge graph, and modularity analysis was applied to produce the modular association diagram shown below (Figure 13). This association graph can be roughly divided into five categories: the collection of mountain fortresses initially constructed during Ögedei Khan's period, the collection of mountain fortresses forming the defensive system built during Yu Jie and Mongke Khan's period, the collection of mountain fortresses built during Yu Jie's offensive against Xingyuan Fu (Prefecture), the collection of mountain fortresses defending the southern border during Kublai Khan's period, and the collection of mountain fortresses maintaining the defensive system during the late stage of the Song-Yuan wars.

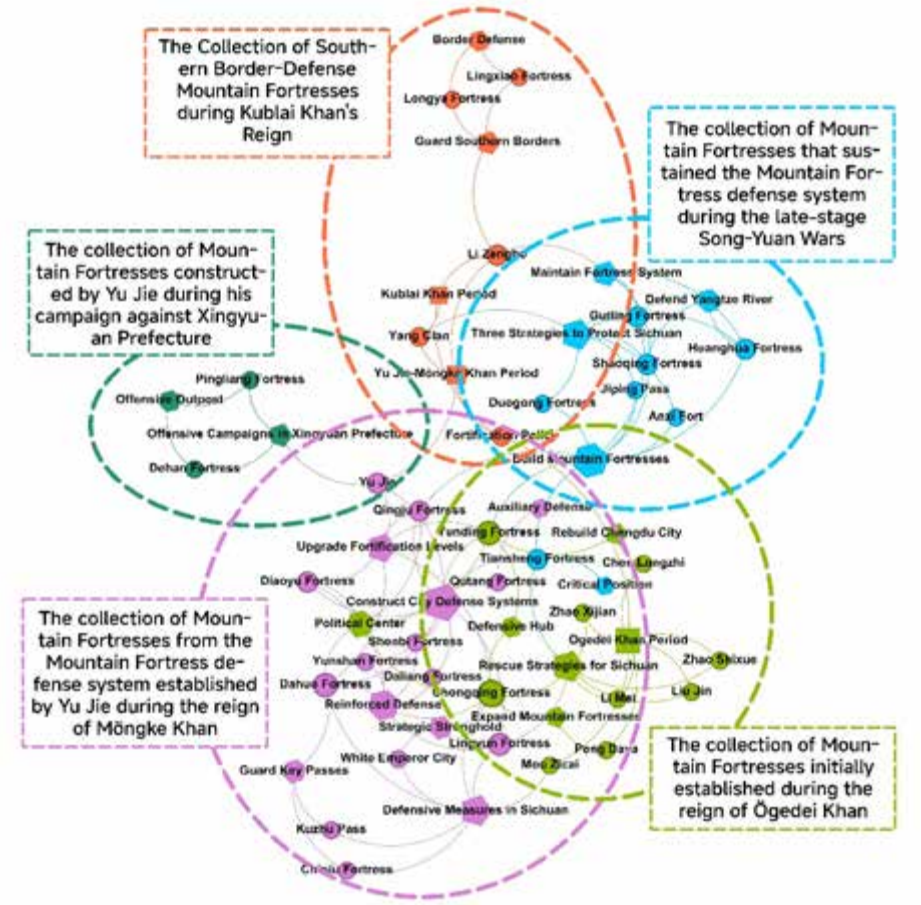

Figure 13 Modular Clustering Analysis of Policies and Mountain Fortress Construction in the Sichuan-Chongqing Region of China During the Song-Yuan Wars (Source: the author)

Based on the analysis of the modular knowledge graph, it can be observed that the construction policies of Song military mountain fortresses exhibited distinct characteristics during different historical periods. During the period of Ögedei Khan, the Song army built mountain fortresses primarily to support the court's strategy to rescue Shu, serving as emergency defensive measures following the Mongol army's first large-scale invasion in 1239. The majority of mountain fortresses were constructed during the period of Yu Jie and Mongke Khan, mainly to establish a defensive system of mountain fortresses for the Song army in the Sichuan-Chongqing region of China. It was also during this historical period that the Song forces still had the capacity to establish several forward offensive bases and launched large-scale attacks on Xingyuan Fu (Prefecture). During the Kublai Khan period, the Mongol forces expanded their territorial control to the southern borders of the Sichuan-Chongqing region of China, and the Song-Yuan Mountain Fortress System suffered severe damage following the battle with Mongke. Consequently, mountain fortress construction during this period was primarily aimed at maintaining the defensive system and guarding the border.

4.2 Analysis of Mountain Fortress Site Association Graph Characteristics

Analysis of existing archaeological evidence indicates that Southern Song Mountain Fortresses in the Chuan-Yu region during the Song-Yuan conflicts preserved not only military remnants but also numerous civilian and religious sites serving military and civilian populations. Through extraction and modular analysis of relevant documentary information, the modular association diagram presented below was constructed (Figure 14). Its nodes primarily form three clusters: living facilities sites, military facilities sites, cultural facilities sites and administrative facilities sites.

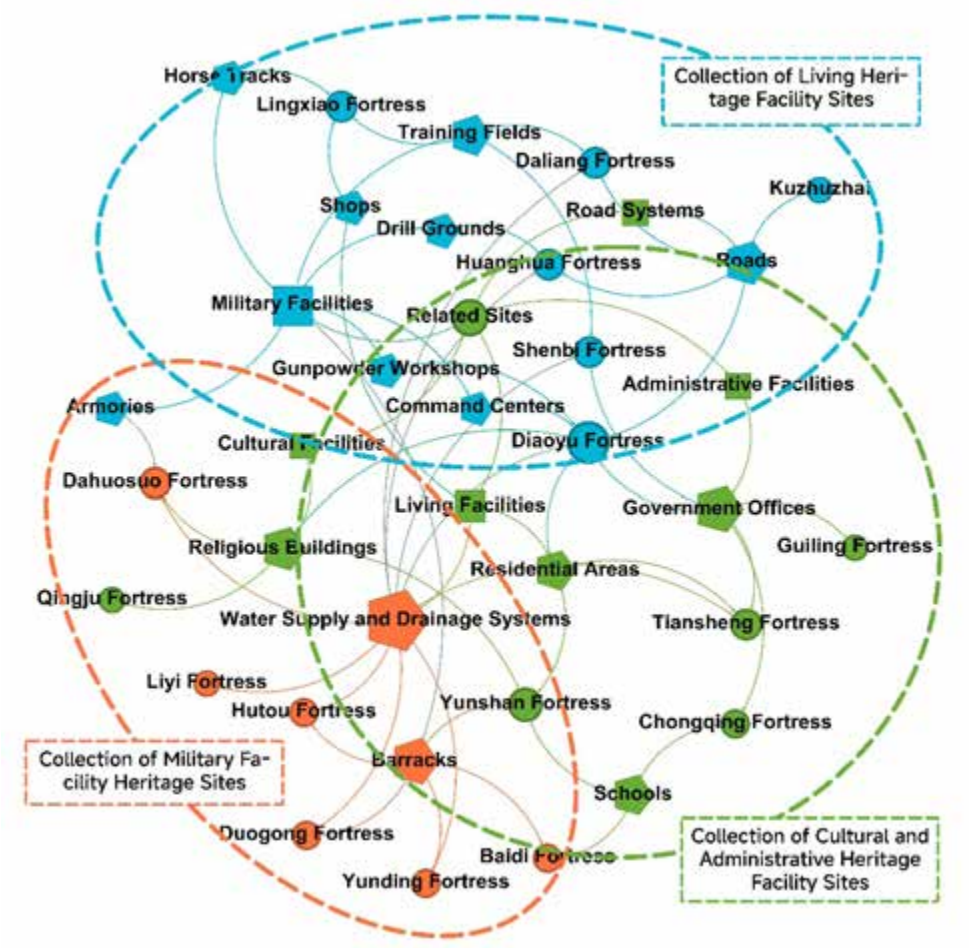

Figure 14 Modular Clustering Analysis of Mountain Fortress Archaeological Facility Sites in the Sichuan-Chongqing Region of China During the Song-Yuan Wars (Source: the author)

Based on the above modular analysis results, numerous sites related to military facilities, cultural facilities, living facilities, and administrative facilities of the Song army's mountain fortresses remain in the Sichuan-Chongqing region. This largely corresponds to the era's characteristic practice of relocating governing institutions and surrounding civilians into well-defended mountain fortresses. It also indirectly reflects that the daily life and agricultural activities of the Song military and civilians in the Sichuan-Chongqing region of China were severely hindered by the threat posed by the Mongol forces, restricting the entire region's productive and living spaces to the strategically prominent mountain fortresses.

4.3 Analysis of Historical Event Association Graph Characteristics

Recognizing repeated Mongol incursions into Sichuan, China, the Song court deemed the "upper Yangtze critically vulnerable," prioritizing Sichuan's defense as urgent since the river's strategic dominance relied entirely on Sichuan's security. Consequently, a strategic defense doctrine was established: securing the lower reaches required holding the upper reaches; defending the Yangtze necessitated controlling the Huai and Han River basins. Implementing this policy, the court empowered three theater commanders (Lianghuai, Jinghu, and Sichuan) with unified military authority over their jurisdictions. Repeated directives mandated fortifying strategic strongholds across theaters, while imperial decrees emphasized coordinated mutual support: "Sichuan's emergencies require Jinghu's aid; Hexian and Chaoxian's crises demand assistance from the Yangtze Command; Zhenjiang and Taizhou's perils necessitate relief from the Huaixi Command"[4].

Based on extant historical sources, events related to the Song-Yuan conflicts between 1223 and 1274 were systematically cataloged, with information specific to Chuan-Yu extracted to examine the region's economic, political, and military conditions during the reigns of Ögedei Khan, Yu Jie-Möngke Khan, and Kublai Khan. Modular analysis of this compiled data generated the knowledge graph presented below.

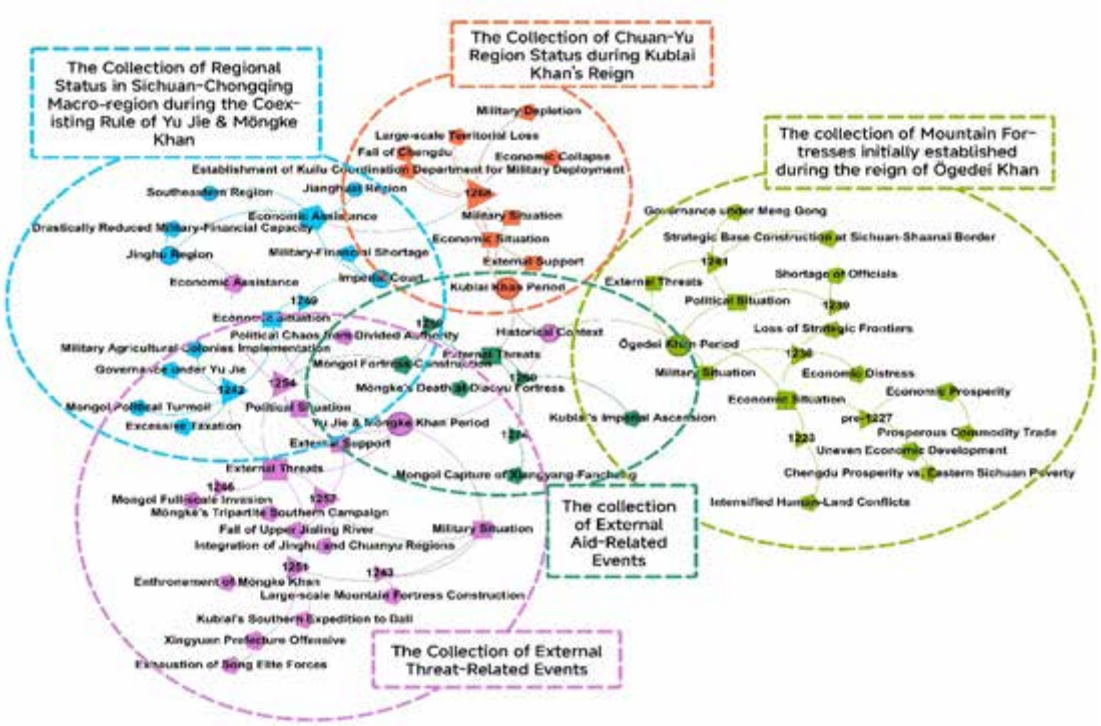

Figure 15 Modular Clustering Analysis of Historical Events in the Sichuan-Chongqing Region of China During the Song-Yuan Wars (Source: the author)

Based on the above modular analysis results, the historical event nodes related to the Song-Yuan war in the Sichuan-Chongqing region of China can be roughly divided into five sets: the status quo of the Sichuan-Chongqing region during the Kublai Khan period, the status quo during the Ögedei Khan period, the status quo during the Yu Jie–Möngke Khan period, events related to external assistance, and events related to external threats. Throughout the entire historical period of the Song-Yuan war, prior to the loss of Xingyuan Fu (Prefecture) by the Song army in 1227, the Sichuan-Chongqing region of China enjoyed relatively developed economic conditions, albeit exhibiting an unbalanced pattern characterized by the wealth of Chengdu and the poverty of the Qutang Gorge. The primary advanced economic system at the time was centered on commodity trade. As the Mongol forces gradually intensified their offensive against the Song army in Sichuan-Chongqing, the fertile Chengdu Plain became a focal point for Mongol plundering, and the region's commodity trade steadily declined amid prolonged warfare. Consequently, the economic situation in Sichuan-Chongqing deteriorated from prosperity to distress and even collapse. On the other hand, as the Sichuan-Chongqing economy became unable to sustain itself, it increasingly relied on the Jinghu region economically, and the Southern Song court made efforts to integrate Jinghu with Sichuan-Chongqing. However, continuous warfare severely depleted the military and financial resources of the Jinghu region of China, and the division of authority led to political chaos, laying hidden dangers for the later period in Jinghu.

4.4 Connections Between Mountain Fortresses

During the Song-Yuan conflicts in the 13th century, the Southern Song Mountain Fortresses in the Chuan-Yu region of China constituted an extensive and systematic "mountain fortress strategic defense system." These strongholds formed mutually responsive relationships through geographical positioning, military coordination, and resource complementarity. Leveraging the rugged terrain surrounding the Sichuan Basin, Song forces constructed fortresses on commanding heights along the Yangtze, Jialing, Tuo, Min, and Qu rivers, establishing a defense network that controlled strategic corridors through nodal points. Each mountain fortress provided

mutual support through waterways and land routes, forming a regionally interconnected network that functioned as complementary flanks, coordinating defenses and constructing a three-dimensional defensive system that operated with seamless precision.

This study selected representative Song fortresses with relatively precise geographical coordinates in the Chuan-Yu region to analyze their interrelationships in administrative division, collaborative defense, military assistance, and transit routes. Utilizing the Geo Layout plugin in Gephi software for geospatial positioning, modular clustering analysis of the constructed nodal network generated the knowledge graph association network illustrated (Figure 16). The resulting nodal network comprises four primary clusters: the Jialing-Qu River Defense Group, Eastern Sichuan Defense Group, Tongchuanfu Lu (Circuit) Defense Group, and Chengdufu Lu (Circuit) Defense Group.

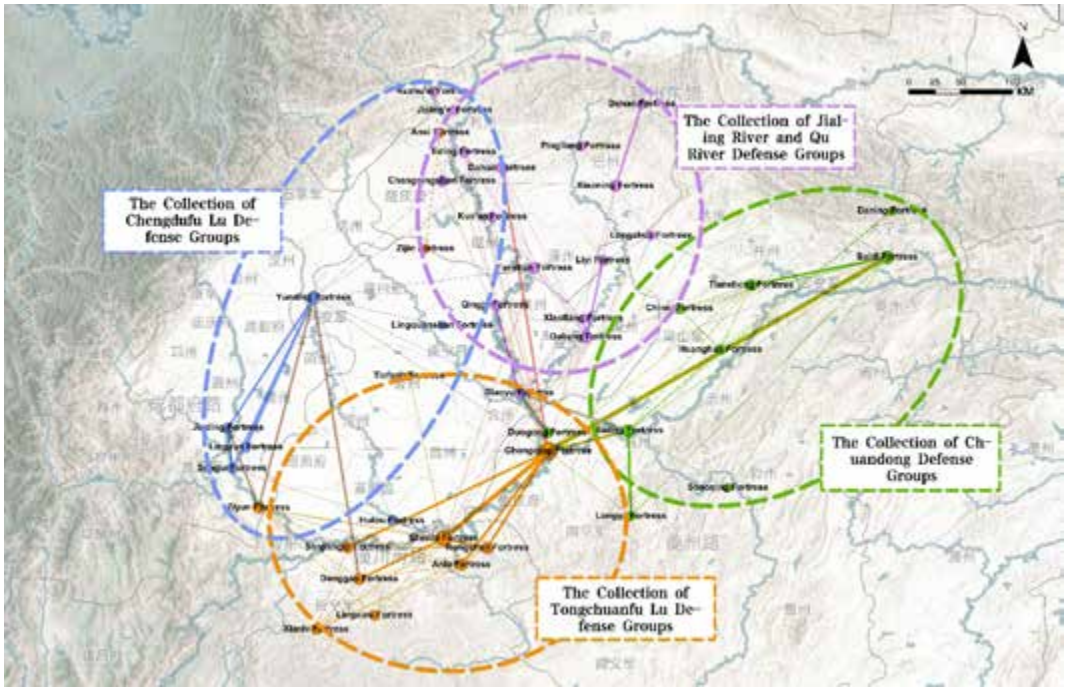

Figure 16 Modular Clustering Analysis of the Song Army's Mountain Fortresses in the Sichuan-Chongqing Region of China (Source: the author)

The size of each node in the relational network is determined by its eigenvector centrality. Eigenvector centrality is a metric used to measure the importance of nodes within a network. It considers not only the number of direct connections of a node (i.e., degree centrality) but also the importance of the nodes to which it is connected. Chongqing Fortress exhibits the highest centrality, reflecting its role as the strategic nexus of the system, functioning as both the military command hub and primary contested stronghold. Yunding, Shenbi, and Baidi fortresses demonstrate secondary centrality, serving as circuit-level administrative centers responsible for coordinating regional defenses. Fortresses such as Dahuo, Xiaoning, Yunshan, and Guiling represent the next tier, occupying critical tactical positions as pivotal nodes within the regional defense framework.

The clustering results derived from the modularized relational network reflect the regional defensive coordination among Song military mountain fortresses in the Sichuan-Chongqing region of China. According to the network analysis, during the Song-Yuan War, the Song mountain fortresses in this region can be categorized into four primary defensive clusters: one constructed around the Jialing and Qu rivers; one centered on the Chengdu Plain; another formed along the Tuo River and the upper reaches of the Yangtze River, known as the Tongchuanfu Lu (Circuit) cluster; and a final one established in eastern Sichuan, east of Chongqing. Within each cluster, the mountain fortresses maintained relatively complete systems of mutual support, collectively forming a coherent and interlocking defensive network that constituted the overall mountain fortress defense system of the Song military in the Sichuan-Chongqing region of China.

4.5 Summary of Knowledge Graph Analysis

Analysis of the knowledge graph association network reveals that the spatial evolution of the Southern Song's Mountain Fortress System in the Sichuan-Chongqing region of China during the Song-Yuan wars exhibited phased progression, hierarchical organization, and regional coordination. As Mongol offensives escalated, Southern Song defense policies transitioned through three distinct phases: emergency deployments under Ögedei Khan's incursions, systematic construction during Yu Jie's governance, and strategic contraction in the Kublai Khan era. Yu Jie's "mountain fortress defense system," centered on the "Eight Pillars of Sichuan," formed four defensive clusters along the Jialing and Yangtze waterways: the Jialing-Qu River cluster controlled eastern Sichuan's land-water junctions with Chongqing Fortress as the strategic nucleus; the Chengdufu Lu (Circuit) cluster maintained remnant plains defenses via strongholds like Yunding Fortress; the Tongchuanfu Lu (Circuit) cluster anchored by Shenbi Fortress dominated the upper Yangtze; and the Eastern Sichuan cluster shielded the Three Gorges gateway through Baidi Fortress. Within each cluster, fortresses established integrated "point-line-area" networks through waterway coordination and resource complementarity, while cross-regional command was facilitated by administrative hierarchies.

The spatial layout of this system was profoundly constrained by the wartime situation and economic changes. As the Mongol forces continued to devastate the prosperous areas, the defensive focus in the Sichuan-Chongqing region of China gradually shifted southward, ultimately forming a mountain fortress defense system centered on Chongqing and reliant on external support from the Jinghu region of China. The coexistence of military, residential, and cultural facilities found in archaeological sites confirms that the mountain fortress served both as a wartime stronghold and a place of survival. Although the coexistence of military and civilian populations enhanced the capacity for prolonged warfare, it also led to economic decline and social spatial tension within the region. Ultimately, the Mongol army compressed the living space of the Song forces by employing a strategy of "mountain fortress against mountain fortress." Coupled with the overall strategic retreat of the Southern Song, this defensive system—steadfast for nearly half a century—collapsed amid spatial fragmentation and resource depletion. Nevertheless, its regional defense concepts and mountain fortress defense system remain an important paradigm in ancient Chinese military engineering.

5 Conclusion and Outlook

5.1 Conclusion

This analysis, employing GIS and knowledge graph technologies, systematically reveals the spatial interconnections and structural features of the Song-Yuan Mountain Fortress System in China's Sichuan-Chongqing region. The fortress network exhibits a "dense in the east, sparse in the west, and strategic along the rivers" spatial pattern, relying on the Jialing and Yangtze River systems to form a three-tiered "core–pivot–supplement" defense framework. Core strongholds such as Chongqing City and Diaoyu Fortress coordinated via waterways and land routes to construct a multilevel, three-dimensional defense network, enabling regional cooperative operations. In both time and space, mountain fortress construction unfolded in three phases: an early stage of dispersed deployments along the ancient Shu Roads; a mid-stage of large-scale, systematic construction under Yu Jie's administration; and a late stage of contraction to the Yangtze corridor—reflecting the profound influence of wartime dynamics and economic transformations on the system's spatial layout. The Sichuan-Chongqing Song-Yuan Mountain Fortress System not onSly capitalized on the Sichuan Basin's interleaved mountains-and-rivers terrain but also reinforced strategic resilience by controlling key transport arteries and economic hinterlands, exemplifying the systematic and dynamic nature of ancient military geographic wisdom.

The collaborative analysis employing GIS and knowledge graph technologies provides a multidimensional theoretical foundation for the study of the distinctive values of Sichuan's Mountain Fortresses in China. Through kernel density analysis and the Analytic Hierarchy Process, GIS establishes a three-tiered "core–pivot–supplement" defensive framework, thereby quantifying the strategic significance of each mountain fortress. Meanwhile, knowledge graph technology captures the evolving wartime dynamics and economic transformations, illustrating the roles that individual mountain fortresses played within the Song military defense system amid the tides of history. These findings offer a scientific basis for uncovering the differentiated values of each mountain fortress and elucidating their historical significance and functions.

The integration of GIS and knowledge graph technologies can also provide critical support for the construction of heritage corridors for China's Sichuan-Chongqing Mountain Fortresses and their nomination for World Heritage status. By coupling kernel density maps with transportation network analysis, the structural framework of heritage corridors along the Jialing River and the main course of the Yangtze River has been precisely delineated, establishing protection priorities for core nodes such as Chongqing City and Diaoyu Fortress. The relational network derived from the knowledge graph further elucidates the systemic coherence of the mountain fortress network across administrative hierarchies, military coordination, and cultural transmission, thereby laying the foundation for the development of cross-regional collaborative preservation strategies.

5.2 Limitations and Prospects

This study acknowledges certain limitations. First, severe deterioration from age and natural erosion at some Song fortress sites in Chuan-Yu region of China, compounded by uncertain original locations, creates analytical gaps in reconstructing comprehensive defensive layouts. Second, interpretations of defensive patterns and structures at certain fortresses rely heavily on indirect archaeological inferences, where historical layering (e.g., later reconstructions or damages) may introduce biases in understanding Song-era military characteristics. Additionally, precise reconstruction of ancient Shu Road routes and historical waterways remains challenging due to geographical transformations.

Future research could advance in three directions: First, integrating Mongol offensive routes with Song-Yuan military technologies (e.g., siege engines, defensive structure iterations) to examine the system's adaptability to warfare modalities and reveal its strategic logic. Second, conducting granular studies of well-preserved exemplars like Diaoyu Fortress and Chongqing Fortress through archaeological excavations and 3D modeling technologies to validate defensive hierarchies and spatial configurations from military-geographical perspectives. Third, assessing natural disaster risks (e.g., landslides, floods) to develop GIS-based risk zoning and conservation strategies, thereby advancing preventive heritage protection. Furthermore, synthesizing multi-source historical materials with emerging technologies (e.g., remote sensing, artificial intelligence) to construct dynamic, high-precision historical-geographical databases holds potential for enhancing research rigor and optimizing heritage management efficacy.

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