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*RESEARCH ARTICLE*

# SPATIAL PATTERNS OF CLIFF ROCK ART IN GUANGXI'S ZUOJIANG RIVER BASIN: A GIS APPROACH

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**ABSTRACT**

From the perspective of landscape archaeology, the study of rock art extends beyond the symbolic interpretation of imagery to consider the broader environmental context shaped through interactions between ancient communities and their surroundings. This research focuses on the cliff rock art of the Zuojiang River Basin in Guangxi, examining how spatial distribution patterns reflect the dynamic relationship between people and landscape. Employing ArcGIS and archaeological survey reports, a comprehensive GIS-based database of identified rock art sites is established. The analysis investigates key spatial variables—geomorphology, elevation, hydrology, viewsheds, cliff face orientation, and proximity to other archaeological sites—to understand their influence on the placement and significance of rock art. By quantitatively analyzing the spatial patterns of these sites, the study underscores the strong interrelationship between rock art and its environmental setting. The findings contribute not only to a deeper understanding of cultural landscape formation in the region but also offer valuable guidance for the conservation and sustainable management of cliff rock art in the Zuojiang River Basin.

**KEYWORDS**

Landscape Archaeology, Rock Art, Spatial Environment, Human-Land Relationship, ArcGIS

## 1. INTRODUCTION

The ongoing evolution of landscape archaeology has significantly influenced the trajectory of rock art research. Contemporary documentation of rock art necessitates not only the analysis of images and their semantic content but also a comprehensive examination of their geographical context and spatial relationships (He, 2012). This research paradigm demands consideration of both macro and micro-environmental factors, encompassing natural and cultural geographical settings (Wang, 2013). Rock art, conceptualized as a form of earth art, is inextricably linked to its environmental context. Its immobility (Fairén, 2007) renders it largely devoid of research value if dislocated from its original setting, impeding a holistic understanding of its community distribution patterns and overarching cultural implications (Chippindale, et al, 1998). Moreover, the observed consistency in site selection between rock art and other archaeological sites is postulated to reflect the environmental dependencies of early human populations (Zhang, 2019). The selection of rock art sites embodies a group's landscape epistemology and the symbolic transformation of the physical environment. The creation and practice of rock art constitute a "cultural process" and a form of social praxis. The choice of rock art locations reflects shared cultural memory and social identity (Zhang, 2019), wherein natural landscapes are structured and conceptualized through complex and iterative social practices, such as rock art creation and ritual ceremonies (Lewis, 2002). This process reinforces social identity and engenders a reciprocal construction between human populations and the landscape, ultimately crystallizing into a cultural and symbolic capital that integrates diverse social forces. This study advances existing research by moving beyond descriptive approaches to apply a systematic GIS-based quantitative analysis of 81 sites and 180 sections. By integrating landscape archaeology with spatial analysis, it identifies new patterns, including the predominance of south-facing orientations, the clustering of sites along river bends, and the combined influence of geomorphological and hydrological factors. These contributions not only extend previous qualitative studies but also establish a novel framework for interpreting the cultural landscape of the Zuojiang Basin.

## 2. STUDY SITE

This study focuses on the cliff rock art in the Zuojiang River Basin, located in Guangxi, southern China, to examine the intricate relationship between cliff rock art and its surrounding environment. The Zuojiang rock art in Guangxi is approximately situated at . The Zuojiang River Basin, as defined in this research, encompasses the area within the Guangxi Zhuang Autonomous Region through which the Zuojiang River and its tributaries flow. The administrative region roughly corresponds to present-day Chongzuo City, comprising Jiangzhou District, Fusui County, Ningming County, Pingxiang City, Longzhou County, Daxin County, and Tiandeng County—a total of five counties, one district, and one city (Figure 1).

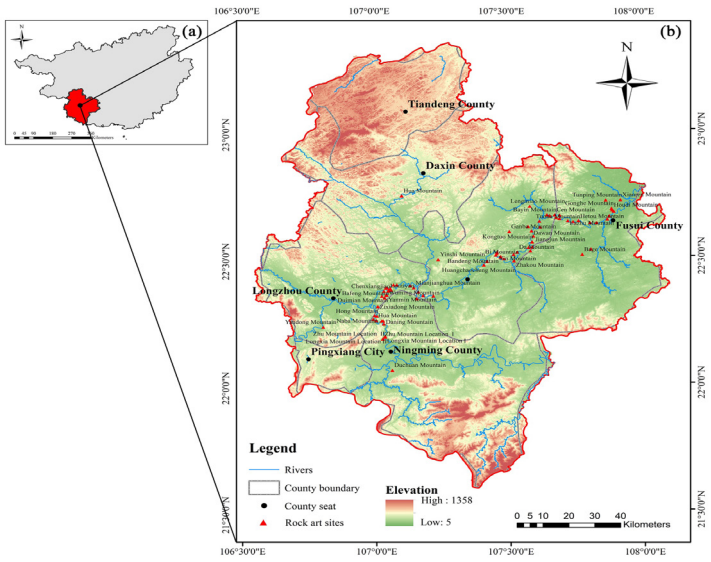



**Figure 1** Scope of Study Site: (a) Within the Scope of the Guangxi Zhuang Autonomous Region; (b) Within the Scope of Chongzuo City.

Through comprehensive field surveys and meticulous analysis of relevant archaeological survey reports and literature, a total of 81 rock art sites with 180 sections (Figure 1) were identified in the Zuojiang River Basin, spanning over 200 kilometers (Huang, 2019; Xu, 1988; Tong, 2016; Qin, 1987; Guangxi Zhuang Autonomous Region Cultural Relics Work Team, 2004). The distribution of these sites is as follows:

Longzhou County: 21 sites with 39 sections, accounting for 26% of the total.

Ningming County: 8 sites with 29 sections, representing 9.9%.

Chongzuo City: 28 sites with 67 sections, constituting 34.5%.

Fusui County: 23 sites with 44 sections, comprising 28.3%.

Daxin County: 1 site with 1 section, accounting for 1%.

These rock art sites collectively form a distinctive distribution zone along the Zuojiang River Basin. The geographical extremities of this distribution are as follows:

Westernmost site: Yangong Mountain in Longzhou County (106°48’40’’E, 22°14’16’’N)

Easternmost site: Xianren Mountain in Fusui County (107°56’4’’E, 22°43’29’’N)

Southernmost site: Zhushan first site in Ningming County (107°21’’E, 22°11’15’’N)

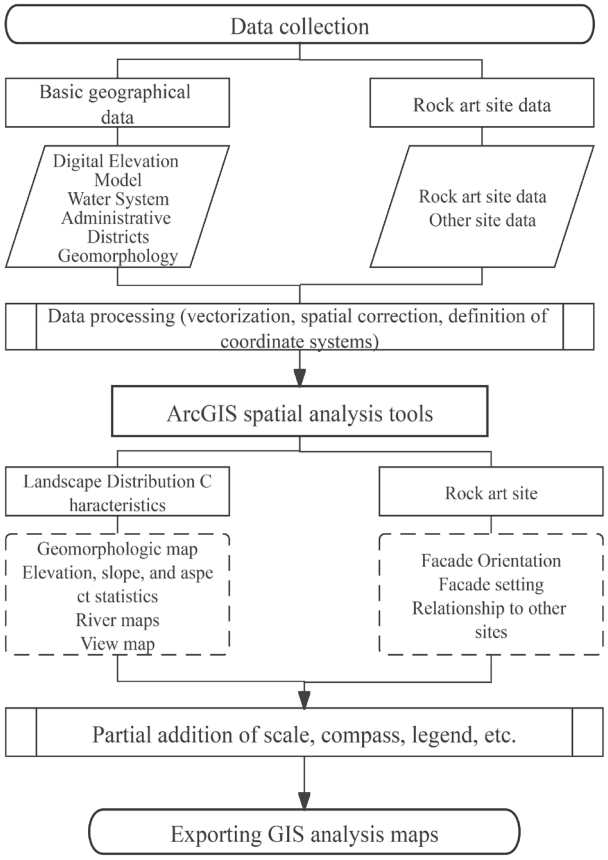



**Figure 2** Flowchart Foranalysis of Landscape Distribution and Facade Setting for Rock Art Sites

Northernmost site: Huashan in Daxin County (107°45’10E, 22°4510’’N) (Guangxi Zhuang Autonomous Region Cultural Relics Work Team, 2004).

The Table 1 distinguishes between the concepts of “site” and “section” based on the definition provided by Professor Emmanuel Anati, Director of the Prehistoric Center of Camunni, Italy, and Chairman of the International Committee on Rock Art, in his report submitted to UNESCO in 1984, “A Global Overview of Rock Art Studies”. The boundary of a “site” is defined as the area extending 500 meters beyond the most peripheral rock art image. A “section” refers to a concept smaller than a “site,” with a site comprising one or more sections. The edge images between every two “sections,” viewed from the north, south, east, west, and vertically, are spaced more than 10 meters apart.

## 3. METHOD AND DATA

### 3.1 Analytical Framework

**Table 1** Statistics of Rock Art Sites in the Zuojiang River Basin

| County Name | | Longzhou | Ningming | Chongzuo | Fusui | Daxin | Total |
|---|---|---|---|---|---|---|---|
| Cliff Rock Art Sites | Number of Sites | 21 | 8 | 28 | 23 | 1 | 81 |
| | Percentage (%) | 26 | 9.9 | 34.5 | 28.3 | 1 | 100 |
| | Number of Sections | 39 | 29 | 67 | 44 | 1 | 180 |
| | Percentage (%) | 21.7 | 16 | 37.2 | 24.4 | 0.5 | 100 |

### 3.2 Data Collection and Processing

The data used and processed in this paper include:

Data on Zuojiang Basin cliff rock art sites and other archaeological sites: Based on the latest cultural relics census, field surveys, and organization of previous literature, relevant works include "Investigation and Research of Cliff Rock Art in the Zuojiang River Basin in Guangxi (Guangxi Zhuang Autonomous Region Cultural Relics Work Team, 2004)", "Ningming County Annals (Li, 1970)", "Rock Art of Zuojiang in Guangxi (Wang et al., 1988)", etc. GPS coordinates of relevant rock art sites were extracted and organized into tabular data. Using Excel, these were converted into geographical coordinates, then into spatial point data with WGS1984 projection coordinates, and vectorized into point files using ArcGIS 10.8 software.

Topographical data: The Digital Elevation Model (DEM) was obtained from the Geospatial Data Cloud platform (http://www.gscloud.cn/), with a spatial resolution of 30 m. The ASTER GDEM V2 data, developed and provided for free by the United States and Japan in 2015, offers users free access to a high-accuracy, well-integrated global digital elevation model (Xiao, 2019). For this study, DEM data for the Zuojiang Basin rock art sites were seamlessly mosaicked and clipped, and elevation information from the DEM was assigned to the corresponding rock art sites using the Extract Values to Points tool in ArcGIS 10.8 spatial analysis.

Administrative division data: Obtained from the Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (http://www.resdc.cn/).

River and lake system data: Derived from the National Basic Geographic Database (2017 edition) (http://www.geodata.cn/main/#/), including names, lengths, and areas of polygonal lakes and linear water systems, mainly used to study the relationship between the distribution of rock art sites and water system density(Acevedo et al., 2019).

Using ArcGIS 10.8 software, the information of rock art points was entered into and extracted to the geographic information database. The selected and recorded information included the latitude and longitude of the rock art points, the elevation, slope, slope aspect, geomorphological environment, river data, the latitude and longitude coordinates of other site points, and the scope of the viewshed in the surrounding environment. Kernel density analysis was performed with a bandwidth of 2000 m to identify clustering patterns; visibility analysis was conducted based on 30 m resolution ASTER GDEM V2 data using the surface analysis tools of ArcGIS (Merino, 2020). In addition, spatial overlay analysis incorporated hydrological and geomorphological layers, all unified under the WGS 1984 projection coordinate system. By collecting and analyzing the geographical environmental information of the rock art points, a series of image data can be generated to further analyze and verify the existing rock art images at the sites. These technical details and parameter settings ensure the reproducibility and transparency of the study.

## 4. RESULTS

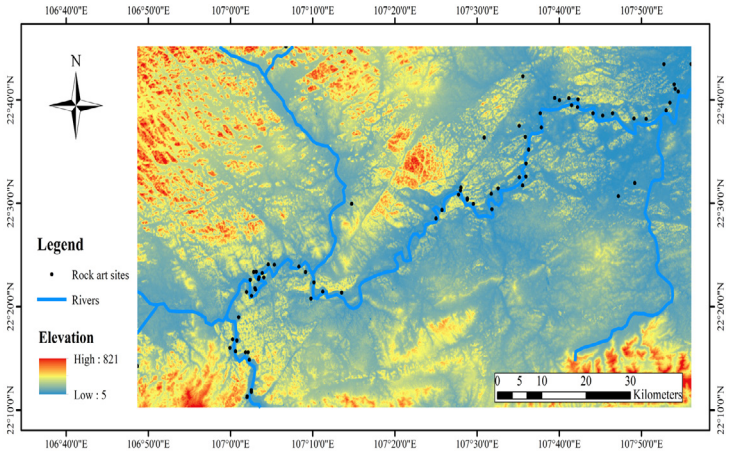
### 4.1 Geomorphological Context of Rock Art Distribution

The basin's fault structures are mainly "joints" and "faults". Most cliff art images are located on cliffs formed by rock collapse along joint planes; a few, such as the cliff rock site at Mianjiang Huashan in Longzhou County, are formed by faults. Field investigations revealed that many rock art sites in the Zuojiang River Basin are near cracks or caves (Demattè, 2012). Some scholars believe these openings were considered pathways between the underworld and the terrestrial world in ancient times, serving as a means for shamans to gain power and knowledge in some areas. This indicates a significant connection between the entrances to the underworld and the rock art sites(Yang et al., 2023).

Out of the 81 rock art sites in the Zuojiang River Basin, excluding one site in Daxin County, there are 80 remaining sites (Table 2). In Ningming County, among the 8 sites: Zhushan first site, Zhushan second site, Gaoshan first site, and Gaoshan second site, 4 sites are distributed around rock caves, accounting for 50% of Ningming County's rock art sites. In Longzhou County's 21 rock art sites, 11 sites such as Hongshan, Yandong Mountain, Chenxiangjiao, Baojian Mountain,

**Table 2** Geomorphological Characteristics of Rock Art Sites in the Zuojiang River Basin

| County Name | Longzhou | Ningming | Chongzuo | Fusui | Daxin | Total |
|---|---|---|---|---|---|---|
| Number of Cliff Rock Art Sites | 21 | 8 | 28 | 23 | 1 | 81 |
| Number of Sites with Nearby Caves | 11 | 4 | 11 | 9 | 0 | 35 |
| Number of Sites with Nearby Fractures | 0 | 0 | 2 | 0 | 0 | 2 |
| Percentage (%) | 52.4 | 50 | 32.1 | 39.1 | 0 | 45.8 |




**Figures 3** 2D Elevation Maps of the Zuojiang River Basin

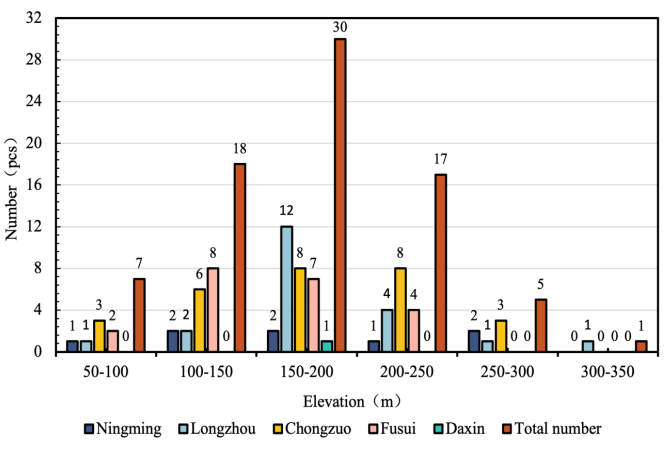



**Figure 4** Statistics of the Elevation Information of Rock Art sites in the Zuojiang River Basin

Chaochuantou Mountain, Duchuan Mountain, Sanjiaoyan, Shamao Mountain, Mianjianghua Mountain, Zixiadong Mountain, and Shuiyan Mountain are distributed around rock caves, accounting for 52.4% of Longzhou County's rock art sites. Chongzuo County has 28 rock art sites, with 11 sites such as Tuobai Mountain, Mabi Mountain, Wanren Cave, Dawan Mountain, Baiguihong Mountain, Baiyang Mountain, Denglong Mountain, Gaomatouhong Mountain, Jiangjun Mountain, Lingzhi Mountain, and Baandeng Mountain distributed around rock caves, and Baandeng Mountain and Lingzhi Mountain are distributed along fractures in broken rocks, accounting for 32.1% of Chongzuo County's rock art sites. Fusui County has 23 rock art sites, with 9 sites such as Balai Mountain, Hetou Mountain, Ganzao Mountain, Kongtuo Mountain, Yanhuai Mountain, Tuona Mountain, Tuoyun Mountain, Bage Mountain, and Lazhu Mountain distributed around rock caves, accounting for 39.1% of Fusui County's rock art sites. In the Zuojiang River Basin, rock art sites with nearby caves or fractures account for 45.8% of the total rock art sites, indicating a certain correlation between these sites and the surrounding geomorphological features, suggesting these sites were considered sacred by ancient people.

### 4.2 Elevation Patterns of Site Distribution

After seamless mosaicking and cropping of the DEM data for the Zuojiang River Basin, the study used the Extract Values to Points tool in ArcGIS spatial analysis to assign elevation information from the DEM to the corresponding rock art sites (Figure 3). The relative elevation range of the rock art sites in the Zuojiang River Basin is between 60-326 meters. The highest relative elevation is at the Yandong Mountain rock art site in Longzhou County, at 326 meters, and the lowest relative elevations are at Wuming Mountain in Longzhou County and Zhakou Mountain in Fusui County, at 60 meters. The overall distribution of rock art sites in the Zuojiang River Basin is concentrated in areas with elevations below 450 meters, which are relatively flat, indicating that the rock art sites are located in lower elevation areas surrounded by higher elevation regions.

According to the analysis of Figure 4, looking at the distribution of rock art sites across the entire Zuojiang River Basin, the widest elevation range is between 150-200 m, accounting for 38.7%; the next largest groups of rock art sites are in the 100-150 m and 200-250 m elevation ranges, accounting for 22.8% and 21.5% respectively. The number of rock art sites in other elevation ranges is fewer, with a lower proportion, and there is only one site in the 300-350 m range. By specific counties, except for the 300-350 m range where no rock art sites are found, Ningming County's rock art site elevations are relatively evenly distributed across other ranges. Approximately 57.1% of Longzhou County's rock art sites are in the 150-200 m range, showing a relatively concentrated elevation distribution. Chongzuo County has an equal number of rock art sites in the 150-200 m and 200-250 m ranges, each accounting for 28.6%; the number of rock art sites in the 50-100 m and 250-300 m ranges are also equal, each accounting for 10.7%. Fusui County's rock art sites are mainly distributed in the 100-150 m and 150-200 m ranges, accounting for 38.1% and 33.3% respectively; no rock art sites are found above an elevation of 250m. Overall, most rock art sites in different counties are distributed within 150-200 m, followed by those in the 100-150 m and 200-250 m ranges; there is a clear difference in the number of rock art sites across different elevation ranges; generally, rock art sites are mostly distributed in the middle elevation range of 100-250 m, with fewer sites in lower or higher elevations.

Among the 81 cliff rock art sites in the Zuojiang River Basin, 70 are located on the riverbanks, accounting for approximately 86.4% of the total, thus the elevation of these 70 rock paintings above the river surface needs further discussion. Based on data statistics, the distance of these 70 riverside cliff art sites above the water surface ranges from 3 to 130 meters. The highest above the water surface is the rock art site at Yanhuai Mountain in Fusui County, with the rock paintings located about 130 meters above the water level. The lowest above the water surface is at Huashan in Ningming County, where the rock paintings are situated between 3 and 80 meters above the water level, with the lowest painting being approximately 3 meters above the water surface.

### 4.3 Proximity to Rivers

The Zuojiang, an important tributary of the Yujiang (the upper reach of the West River), belongs to the Pearl River system, flowing from southwest to northeast. In this GIS analysis, the hydrological data primarily consisted of linear data. Firstly, a hydrological analysis of the region was conducted, then, building on previous analyses of the relationship between water systems and site distributions and considering changes in water systems, this study applied a kernel density method to calculate the density of rock art sites (Zhang, 2014) within the study area to analyze the relationship between rock art site distribution and water system density. A geometric spacing method was used to ensure clear differentiation between rock art site density and water system density.

Figure 5 indicates that rock art in the Zuojiang River Basin is predominantly distributed along the river, with most sites located on the

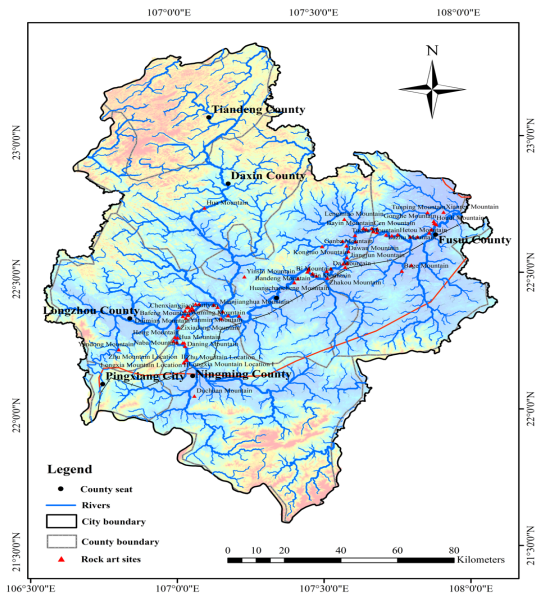



**Figure 5** Relationship Between Rock Art Sites and the Zuojiang River Basin

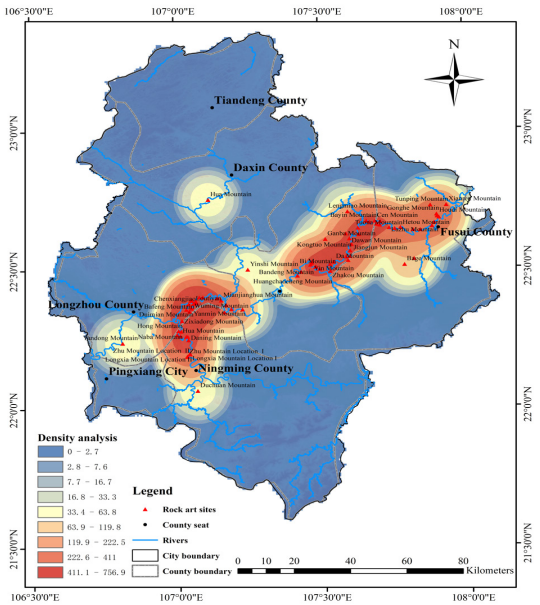



**Figure 6** Relationship Between Rock Art Sites and Water System Density in the Zuojiang River Basin

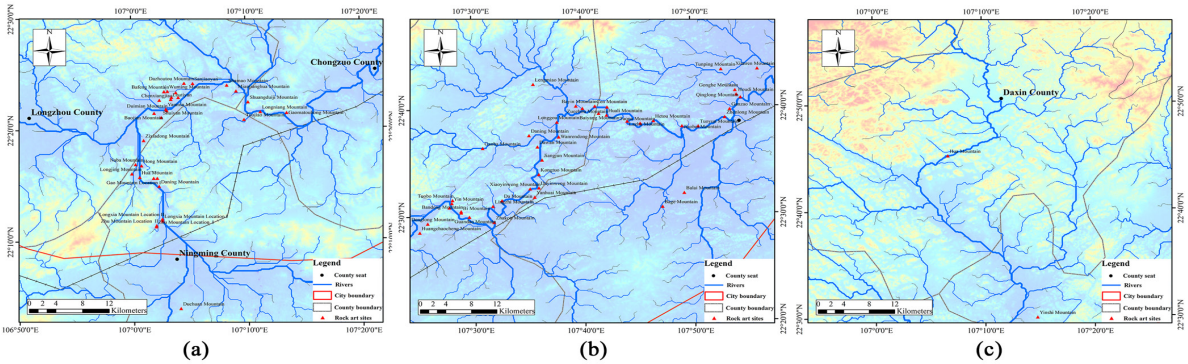



**Figure 7** Distribution of Various Rock Art Groups in the Zuojiang River Basin: (a) Distribution Map of Rock Art Groups in the Upper Zuojiang River and its Tributary, The Mingjiang River; (b) Distribution Map of Rock Art Groups in the Lower Zuojiang River; (c) Distribution Map of Rock Art Sites Along the Heishui River, a Tributary of the Zuojiang River.

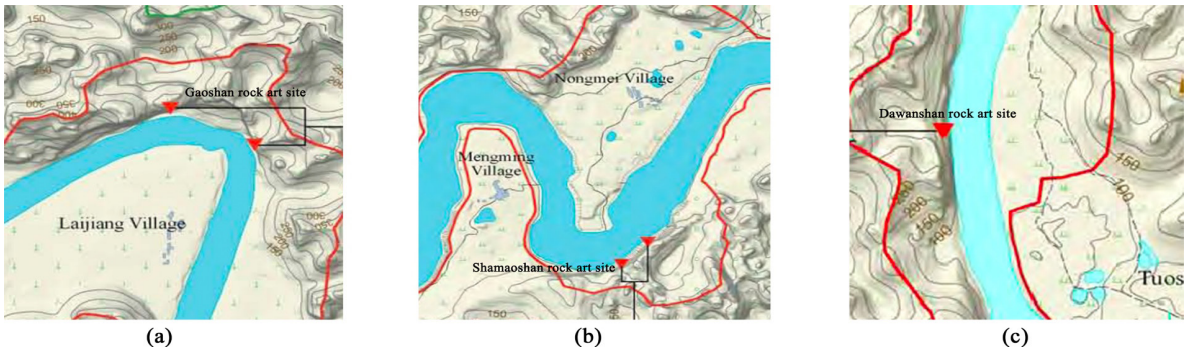



**Figure 8** Schematic Diagram Showing the Relationship Between Rock Art Site, the River, And the Opposite Terrace: (a) Schematic Diagram of the Gaoshan Cliff Rock Art Site; (b) Schematic Diagram of the Shamao Mountain Cliff Rock Art Site; (c) Schematic Diagram of the Dawan Mountain Cliff Rock Art Site.

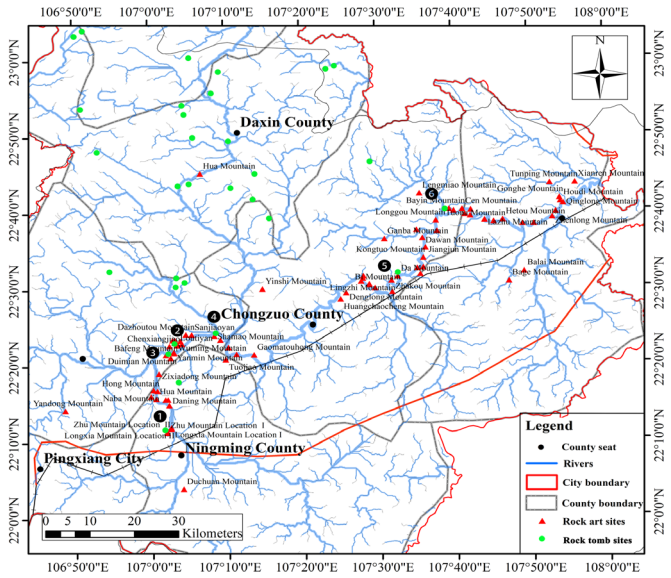



**Figure 9** Distribution Map of Cliff Rock Art Sites and Rock Tomb Sites in the Zuojiang River Basin: (1) for Zhushan Second Site; (2) for Chenxiangjiao; (3) for Baojian Mountain; (4) for Mianjianghua Mountain; (5) for Baiguihong Mountain; (6) for Tuona Mountain.

mainstream of the Zuojiang River, flowing from southwest to northeast, totaling 58 sites. Additionally, some rock art sites are located on the Mingjiang, a tributary of the Zuojiang, totaling 12 sites; a very small number are found on other tributaries, totaling 2 sites. There are also 9 rock art sites not adjacent to water, varying distances from the Zuojiang River (approximately 2-14 kilometers), including Xianren Mountain, Tunping Mountain, Houdi Mountain, Bage Mountain, and Balai Mountain in Fusui County; Danning Mountain, Ganba Mountain, Lengmiao Mountain, and Yinshi Mountain in Chongzuo. About 70 rock art sites are located on riverbanks facing the river, accounting for about 88.6% of the total, and are often found under cliff overhangs; 54 of these sites are located at river bends, accounting for 68.3% of the total rock art sites and 77.1% of the riverside sites (70 sections). However, not all riverside cliffs, especially those at river bends where conditions seem favorable for painting, have rock art, a phenomenon that remains unexplained.

Figure 6 shows that the most densely distributed regions are mainly in two areas: from Ningming County to Fusui County, from the upstream Zhushan rock art site to the downstream Qinglong Mountain rock art site. One of these areas includes Zhushan, Longxia Mountain, Ningming Huashan, Gaoshan, etc., located in the upstream of the Zuojiang River and on the Mingjiang tributary (Figure 7 (a)); the other area consists of 18 sites densely distributed in the downstream area of the Zuojiang River (Figure 7 (b)), where the distance between neighboring rock art sites is reduced, and the distribution becomes denser, with an increase in the number of non-riverside rock art sites.

The rock art images are generally situated 20-40 meters above the usual water level, with the highest reaching approximately 120 meters (Tang, 2004). From the analysis above, it's clear that most rock art sites are located at the bends of the cliffs along the river, while the opposite bank usually consists of one or two levels of beaches or terraces, typically ranging in height from 10-20 meters. These terraces often project into the river in an arc shape (Figure 8). Serving as observation points, these terraces allow for the viewing of multiple adjacent rock art images, creating a unique cultural landscape under the "barrier" of the river water between the terrace and the observable rock art. Some rock art sites currently do not display a clear feature of "opposite terraces," as shown in Figure 8 c for the Dawan Mountain rock art site, but such cases are less common. Additionally, the mobility of the river is a factor to be considered in the analysis; people on boats can also enjoy the rock art, making the river a natural, mobile observation point.

### 4.4 Correlation with Other Archaeological Sites

Rock art sites in the Zuojiang River Basin often coexist with other remains, representing "a regional archaeological culture that is not yet clear" (Tang, 2021). Other important cultural relics in the Zuojiang River Basin mainly include Shell Midden sites, Dashichan sites, Tonggu culture sites, and rock tomb sites. The distribution characteristics of rock tombs and rock art are similar; both located above cliffs. In a few sites, rock art even surrounds rock tombs, hence this section discusses the relationship between rock art sites and rock tomb sites.

According to statistics, up to now, 138 rock tomb sites have been discovered in the Guangxi Zhuang Autonomous Region (Tang, 2004). Within the Zuojiang River Basin, cases of coexistence between rock art and rock tombs are not numerous. There are only six instances where Zuojiang cliff rock art sites coincide with rock tomb sites in Guangxi (Figure 9), and these six sites are all located on the same cliff face. Some rock art images are even distributed around the entrances of the rock tombs (Table 3). Scholars hold different views on the spatial relationship between cliff rock art and rock tombs in the Zuojiang River Basin. Some believe that the distance maintained between rock art and rock tombs is because cliffs can be considered as a boundary between the living and the dead (Yang, 2021); others argue that the spatial relationship between the two on the cliff is very close, with rock art almost always found near the entrances to rock tombs. However, a comprehensive investigation of rock art sites without adjacent rock tombs reveals that the close relationship is not necessarily between rock art and rock tombs, but rather between the grey-yellow cliff face and the rock art (Peng, 2013).

### 4.5 Site Visibility Analysis

As visual markers fixed on rocks, rock art reflects specific forms of social spatial construction, necessitating visibility at various levels (Fairén, 2010), which may vary according to purpose and theme (Zheng, 2012).

In this study, DEM data for the Zuojiang River Basin was analyzed using ArcGIS's visibility analysis within the surface analysis tools, extracting the main rivers within the area as potential lines of sight: the Zuojiang River and its tributaries, the Mingjiang River and the Heishui River (main pathways for the rock art groups in the Zuojiang River Basin), to simulate the visible range for ancient people observing rock art from the river and opposite terraces.

The visibility analysis demonstrated that cliff rock art from the opposite terraces and from the river is generally visible. As previously discussed in sections 4.2 and 4.3, rock art sites in the Zuojiang River Basin are typically located on steep cliffs that rise 3 to 130 meters above the river surface. Therefore, observing the rock art from the relatively lower elevation of the river surface and opposite terraces is generally possible, aligning with the visibility analysis results. This proves that the cliff rock art group in the Zuojiang River Basin often need to be situated in noticeable locations (Demattè, 2012), intentionally chosen by the artists as reflected by the themes of the rock art.

For rock art sites not adjacent to the river—Xianren Mountain, Tunping Mountain, Houdi Mountain, Bage Mountain, and Balai Mountain in Fusui County; Daning Mountain, Ganba Mountain, Lengmiao Mountain, and Yinshi Mountain in Chongzuo—among these 9 sites, only Yinshi Mountain is visible from the Heishui River, a potential line of sight. The remaining 8 sites are not visible from established lines of sight. These rock art sites share common characteristics: they are located in areas

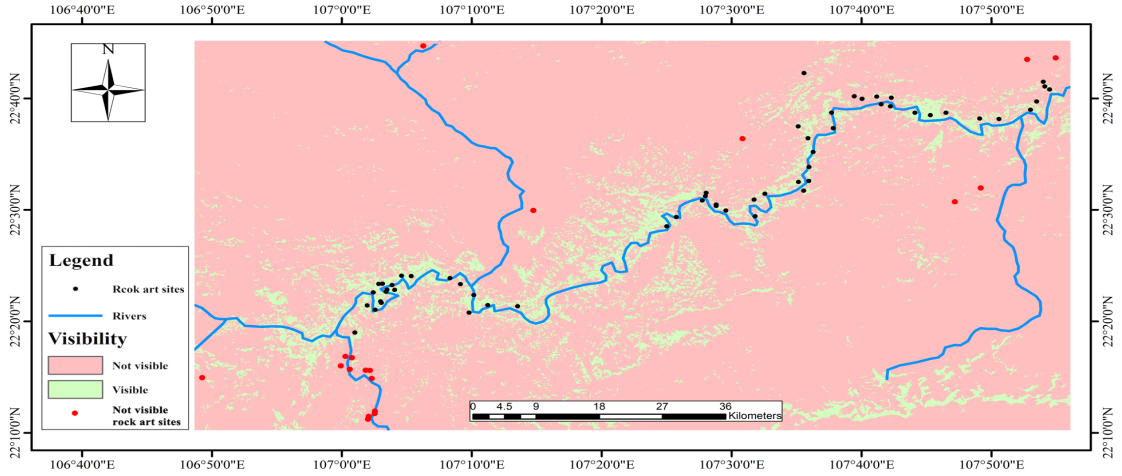



**Figure 10** Visibility Map of the Zuojiang River Basin

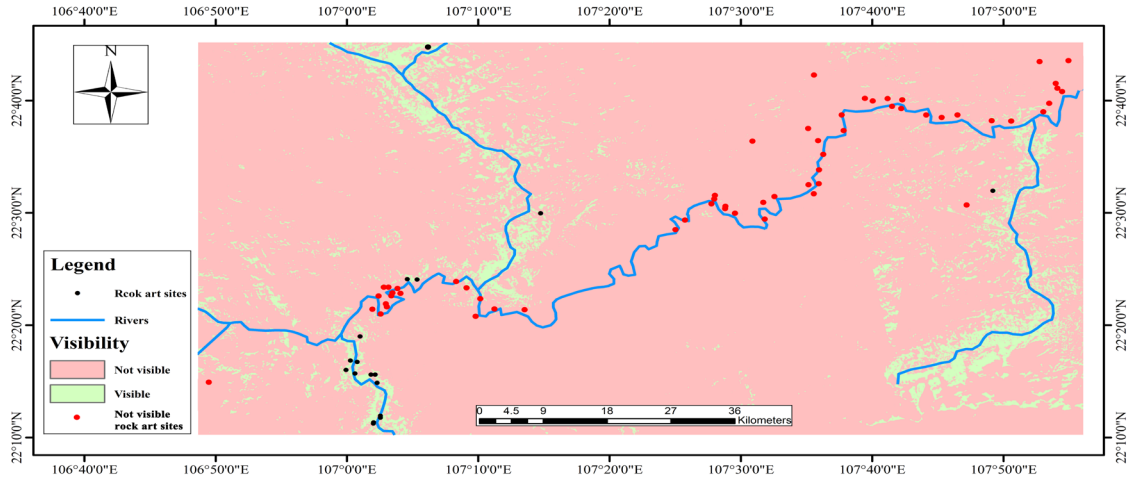



**Figure 11** Visibility Map of the Heishui River and Mingjiang River Basin, Tributaries of the Zuojiang River

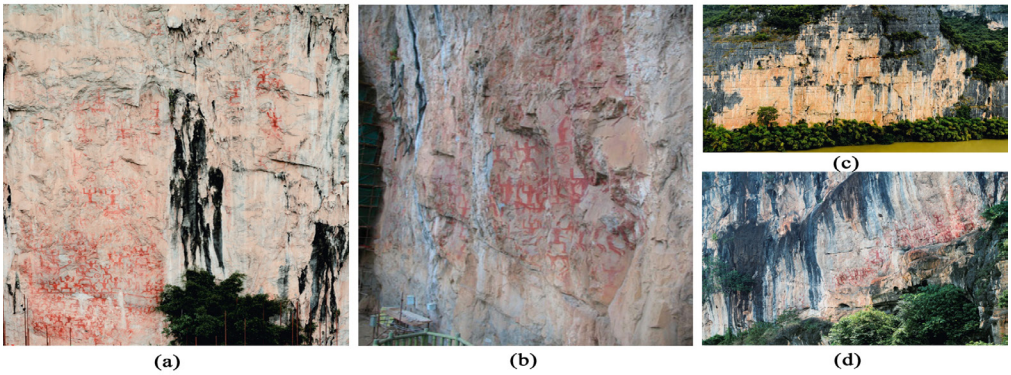



**Figure 12** Real-Life Images of Facade Colors in the Zuojiang River Basin: (a) and (b) Represent the Facade Setting of Huashan Rock Art Sites in Ningming County; (c) Represents the Facade Setting of Sanzhou Weishan Rock Art Site in Longzhou County; (d) Represents the Facade Setting of Mianjiang Huashan Rock Art Site in Longzhou County.

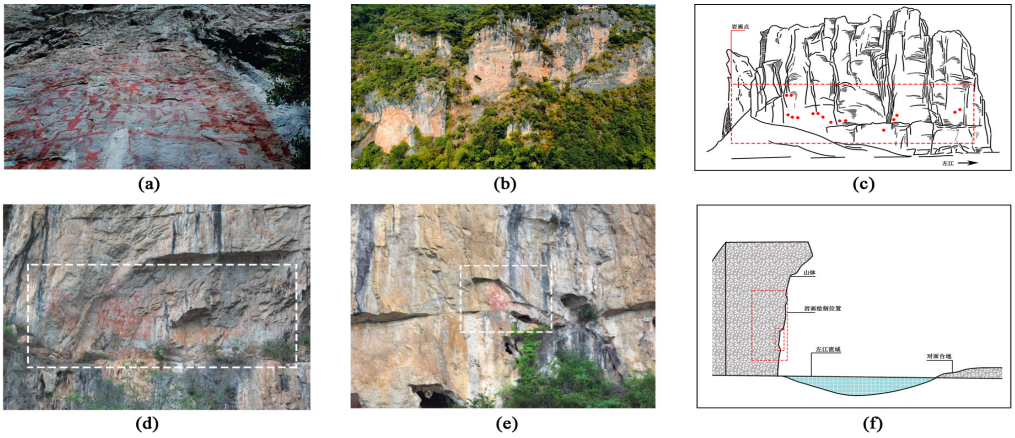



**Figure 13** Images of Rock Cliffs in the Zuojiang River Basin: (a) The Shaded Facade Setting at the Huashan Rock Art Site in Ningming County; (b) The Dazhoutou Rock Art Site in Longzhou County; (c) a Schematic Diagram of the Chenxiangjiao Rock Art Site in Longzhou County; (d) The Rock Art Site at Gaoshan First Site in Ningming County; (e) The Chenxiangjiao Rock Art Site in Longzhou County; (f) a Elevation Drawing of a Shaded Facade Setting.

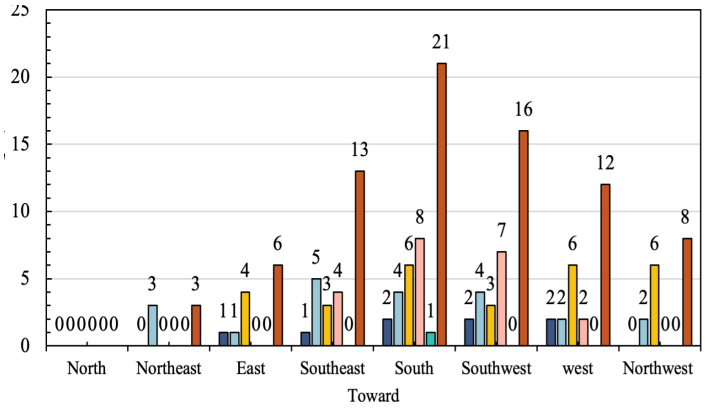



**Figure 14** Orientation Statistics of Rock Art Sites in the Zuojiang River Basin

where rock art density is sparse, rivers are inaccessible, and no opposite terraces are observable for potential viewing, thus their visible areas are relatively limited.

### 4.6 Cliff Face Characteristics and Rock Art Placement

It has been found that the cliffs in the Zuojiang River Basin are primarily limestone. Limestone surfaces can develop white, yellow, or black water stains after being washed by rainwater. Different colors of the cliff surface can affect the creation of rock art; black surfaces are not conducive to the display of painting, thus nearly all paintings are located on yellow or gray parts of the cliff—areas that highlight the content drawn with red pigments (Figure 12), and typically on flatter sections to maximize the visibility of the paintings. Rock art sites downstream of the Zuojiang generally have caves or large cracks nearby; larger rock paintings are mostly located upstream, where the facades are relatively flat.

In addition to the color of the cliff faces, the sites chosen for painting are often in shaded environments. The cliffs slope slightly from top to bottom towards the river, with the upper part protruding outward and the lower part recessing inward, which helps protect the rock art images from water erosion (Figure 13 (a)). Furthermore, around the rock art images, there are often narrow stone steps or slopes of fallen rocks formed due to joint development (Figure 13 (b), (c), (d)), with rock art images typically distributed along these stone steps or slopes of fallen rocks, which also hints at the methods of rock art creation in the Zuojiang River Basin (Tong, 2016).

### 4.7 Orientation Patterns of Rock Art Panels

The orientation of rock art sites, defined as the direction in which the rock art faces, is a crucial aspect of this study. For analytical purposes, orientations were categorized into eight cardinal and intercardinal directions: north, northeast, east, southeast, south, southwest, west, and northwest. Analysis of the orientation statistics for rock art sites in the

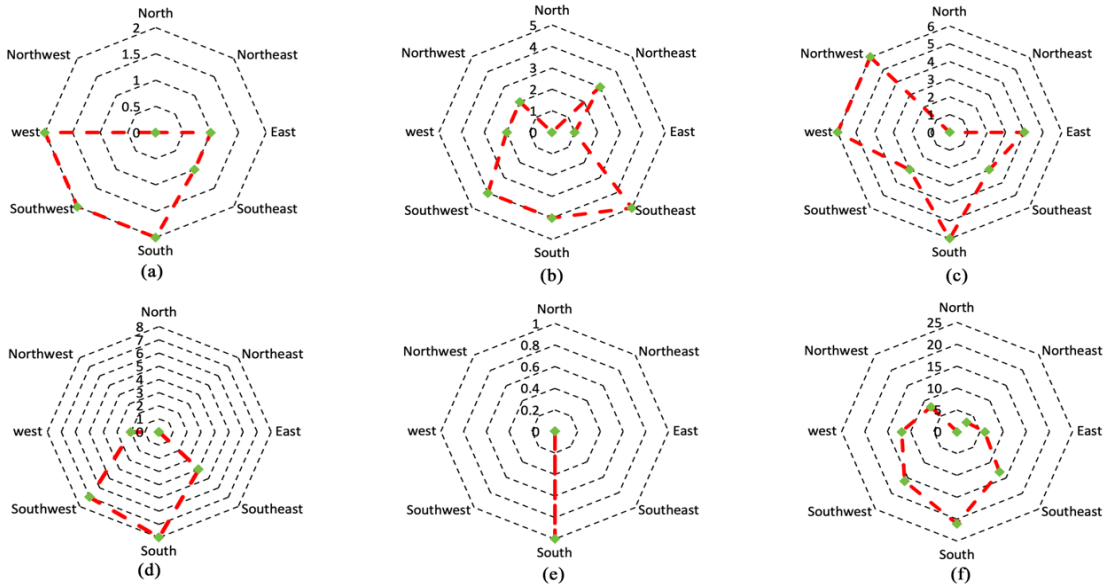



**Figure 15** Orientation Information of Rock Art Sites By County: (a) Orientation of Rock Art Sites in Ningming County; (b) Orientation of Rock Art Sites in Longzhou County; (c) Orientation of Rock Art Sites in Chongzuo County; (d) Orientation of Rock Art Sites in Fusui County; (e) Orientation of Rock Art Sites in Daxin County; (f) Orientation of Rock Art Sites in Zuojiang River Basin.

Zuojiang River Basin (Figure 14) reveals a predominant concentration in the southeast (13 sites, 16.5%), south (21 sites, 26.6%), and southwest (16 sites, 20.3%) directions, with the highest frequency directly facing south. Cumulatively, south-facing rock art sites constitute 63.4% of the total. Additionally, 12 sites (15.2%) face west, 8 (10%) face northwest, and 6 (7.5%) face east. Only 3 sites face northeast, and notably, no sites face directly north.

The preponderance of south-facing rock art sites in the Zuojiang River Basin can be primarily attributed to favorable temperature and sunlight conditions, which enhance the visibility and impact of the red rock art images. Geological observations indicate that many fault zones in the rock art distribution area run southwest to east, resulting in cliffs formed along these fault zones typically facing east or west. However, the presence of numerous north-facing cliffs along both sides of the Zuojiang that offer suitable painting conditions suggests that the absence of north-facing rock art may be related to ancient people's mystical beliefs regarding the northern direction.

The overall southern trend in rock art site orientation exhibits minor variations across different jurisdictions within the Zuojiang River Basin (Figure 15 (f)). Analysis of these variations yields the following conclusions:

Ningming, Chongzuo, and Daxin Counties exhibit the highest frequency of directly south-facing rock art sites.

Longzhou County demonstrates a predominance of southeast-facing sites, followed by southwest and directly south-facing orientations.

Detailed analysis by county reveals:

Ningming County (Figure 15 (a)): Rock art sites primarily face west, southwest, and directly south, accounting for 75% of the sites, aligning with the general southwestern orientation trend of the Zuojiang River Basin.

Longzhou County (Figure 15 (b)): Sites are distributed in all directions except due north. The most common orientation is southeast (24%), followed by southwest (19%). Notably, this county contains the only three northeast-facing sites in the entire Zuojiang River Basin, comprising 14.2% of its total. The overall distribution trend leans westward.

Chongzuo County (Figure 15 (c)): Rock art sites are predominantly concentrated in the northwest, west, and directly south directions, each accounting for 21.4% of the sites.

Fusui County (Figure 15 (d)): Site orientations are primarily concentrated in the southwest (33.3%) and due south (38.1%) directions, with secondary concentrations in the southeast and due west. No sites face northwest, due north, northeast, or due east. The overall distribution trend is southward and westward, with a concentrated distribution pattern.

Daxin County (Figure 15 (e)): Contains only one rock art site, which is oriented due south.

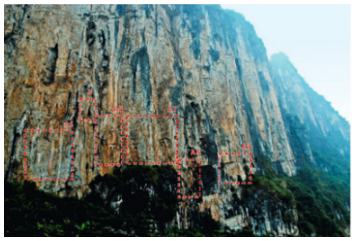
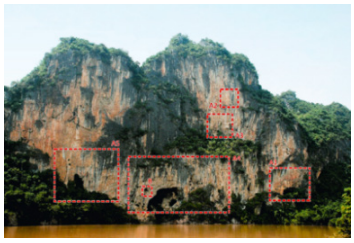
## 5. DISCUSSION

The interaction between multiple factors played a crucial role in shaping the distribution of rock art. Elevation not only conditioned site accessibility but also determined the degree of visibility when combined with hydrological features such as river bends. Similarly, the presence of fractures provided both practical rock surfaces and symbolic liminal spaces, whose significance was amplified when associated with south-facing orientations that maximized solar exposure. These findings suggest that the formation mechanism of rock art patterns cannot be reduced to single-factor explanations but rather reflects a dynamic interplay between geomorphological, hydrological, and cultural-symbolic dimensions. This interpretation is further reinforced by applying the theoretical framework of landscape archaeology, which highlights how natural features were culturally encoded into meaningful places.

The prehistoric human capacity to modify the natural environment was limited, rendering geomorphology a critical factor in the selection of habitation sites by early humans (Gai, 1995). The Zuojiang cliff rock art sites are uniquely positioned and exceptionally challenging to create, representing a rarity in the global rock art landscape. In antiquity, when transportation and tools were rudimentary, the creators of these rock paintings relied solely on their physical capabilities and natural conditions. Access to the cliffs was achieved through climbing, scaffolding, rappelling from mountaintops, or reaching the sites by boat during flood periods. Observational analysis of the cliffs revealed that rock art sites are frequently located near overhangs, shelves, cracks, or

natural gullies, which served as natural "handles" or "footrests," despite the inherent dangers of such activities without modern safety measures. Consequently, the geographical environment played a significant role in constraining ancient human activities and influencing the selection of rock art sites.

**Table 3:** Location Relationship Map of 6 Cliff Rock Sites and Rock Tomb Sites in the Zuojiang River Basin

| Cliff Rock Art Site | Rock Art and Rock Tomb Location Map | Description of Section Relationship |
|---|---|---|
| Zhushan Second Site |  | There are 7 rock art sections (A1-A7), covering almost all suitable painting areas on the cliff face. A large cave with a wide entrance near the ground in the north-eastern part of the cliff contains coffin remains. |
| Chenxiangjiao |  | There are 16 rock art images, with images 5 to 9 (A5-A9) visible in the figure. Wooden poles were once found on the cliff, presumed to be remains of rock tombs; however, since the poles were removed, the exact location is unclear, possibly near the small cave in the upper left of A6. |
| Baojian Mountain |  | There is only one rock art image located on the lower part of the cliff face, about 10 meters above the river surface. Below it to the right, there's a cave with a flared entrance, containing both a burial site and a shell midden, with the former overlying the latter, and both periods of culture roughly contiguous. |
| Mianjiang Huashan |  | There are 5 rock art images (A1-A5), distributed on the grey-yellow cliff face facing the river, with A1, A4, and A5 covering almost all the lower painting-suitable areas. Inside cave B, two overlapping coffins were found, and according to staff from the Guangxi Cultural Heritage and Archaeology Research Institute, fragments of coffins were also found inside a large cave below to the right. |
| Baigui Hongshan |  | The middle part of the cliff has a group of conical protruding stone ridges, with 4 groups of rock art images (A1-A4) distributed at the junction of the stone ridges and the cliff face. Above the A2 image in a cave, 3 wooden poles were found, but no coffins remain. |
| Tuona Mountain |  | There are 2 rock art images (A1, A2), located in the grey-yellow area of the cliff facing the river. The specific location of the rock tomb is difficult to confirm due to the only remaining wooden pole being removed. |

In the images, A1-An represents the locations of rock art images, with their grouping based on the book "Investigation and Research on Cliff Rock Art in the Zuojiang River Basin of Guangxi"; B indicates the location of rock tomb sites.

A macro-characteristic of the Zuojiang rock art group is its distribution along the river. The creators of the Zuojiang rock art intentionally selected locations based on specific traditional ideologies (Xiang, 1999). Analyses in sections 5.2 and 5.5 indicate that the optimal observation points for Zuojiang rock art are twofold: primarily, the flowing water surface, allowing viewing from boats, and secondarily, the opposite terraces. As observation points, these terraces facilitate the viewing of multiple adjacent rock art images, creating a unique cultural landscape with the rock art across the river's "barrier".

The viewpoint study analysis in section 5.5 demonstrates that most rock art sites along the Zuojiang River are visible, suggesting that these images were intended for public consumption, accessible to both terrestrial observers and those on the water (Ingold, 1993). This inclusivity implies that the cliff rock paintings were widely shared among people, extending the public landscape and conveying multifaceted messages to diverse audiences. Rock art sites with sparse distribution (further from the Zuojiang River) exhibit greater privacy, potentially correlating with the significance of the messages conveyed (Zhang, 2016). Conversely, larger and more conspicuous rock art sites, such as Ningming Huashan and Mianjiang Huashan, appear designed to attract the attention of all residents or travelers along the Zuojiang. In these instances, cliff rock art might signify the site's sacredness or proclaim the local village's strength. Furthermore, the concentration and visibility of rock art at river bends, where currents are swift, could serve as warnings to travelers about hazardous areas, particularly after heavy precipitation and flooding events.

Analysis of the surrounding and facade settings, as well as the themes of Zuojiang cliff rock art, reveals their multilayered meanings, showcasing both public and private, sacred and secular aspects. Beyond environmental determinants, the spatial distribution of the Zuojiang cliff rock art also reflects ancestral cultural cognition of living space. The predominance of south-facing orientations, clustering at river bends, and proximity to caves suggest deliberate choices that integrated practical needs with symbolic meanings. These spatial patterns indicate that rock art functioned as a medium through which communities perceived, structured, and culturally encoded their living environment.Rock art represents an interaction between humans and the landscape, reinforcing landscape symbolism and strengthening group memory and cultural identity (Zhang, 2019). These artifacts are products of the intersection between sacred spaces and ritual practices, as well as representations of cultural symbols, social practices, rights relations, and social structures.

## 6. CONCLUSION

Based on the perspective of landscape archaeology, this study combines the latest cultural relics census statistics and field surveys, as well as the collation of previous writings and documents, to statistically identify the latitude and longitude coordinates of rock arts and the specific information of each rock art sites, to establish a database of rock arts in the Zuojiang Basin of Guangxi by using ArcGIS, and to carry out a quantitative analysis, so as to make the archaeological data visualized, and to intuitively reveal the effects of different landscape variables on the distribution of rock arts site. The results intuitively reveal the influence of different landscape variables on the distribution of rock art sites, and the distribution of rock art sites varies from large to small, which also enables us to better understand the motives of the ancient ancestors in the Zuojiang Basin for creating rock arts and displaying the scenes of primitive social life, and at the same time provides a certain reference for the further planning and protection of the current rock art sites in the Zuojiang Basin.

The results of this study do not differ much from the results of previous qualitative studies on the distribution of rock arts in the Guangxi Basin, the limitation of this study is that the results may have a certain degree of bias due to the limitations of the complex geomorphological environment and the poor accuracy of data collection. Future research should employ high-precision methods such as LiDAR and UAV-based mapping to improve data quality and broaden analytical perspectives, including comparisons across different site types and cultural periods. For heritage conservation, we recommend specific measures such as digital documentation, UAV monitoring, and community-based protection initiatives, which will contribute to the sustainable preservation of cliff rock art in the Zuojiang Basin.

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## AUTHOR CONTRIBUTIONS

Conceptualization, A.S., Y.T. and N, G; Methodology, A.S.and Y.T.; Software, A.S.; Validation, A.S.; Formal Analysis, A.S. and N,G; Investigation, Y.T.; Resources, Y.T.; Data Curation, A.S.; Writing-Original Draft Preparation, A.S.; Writing-Review and Editing, A.S.; Visualization, A.S. and N,G; Supervision, Y.T.; Project Administration, Y.T.; Funding Acquisition, Y.T. All authors read and approved the final manuscript.

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## AVAILABILITY OF DATA AND MATERIALS

All research data obtained during this study are included in this article. The raw data are available upon request.

## COMPETING INTERESTS

The authors declare that they have no competing interests.

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