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REVIEW ARTICLE

THE WHOLE-IMAGE ANALYSIS AND RESEARCH OF ROCK ART DISEASE IMAGE OF HUASHAN MOUNTAIN, NINGMING COUNTY

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ABSTRACT

The Luo Yue people, the ancestor of the Zhuang people, painted ancient historical images on the rock walls of Huashan Mountain in Ningming county between the 5th century B.C. and the 2nd century A.D. They have significant historical, cultural, and aesthetic value because they are artifacts left over from the religious practices people at that time engaged in. The Huashan rock art in Ningming have endured more than 2000 years of historical changes due to geological and natural environmental factors. These diseases include rock cracking, stalactite covering, flaking, and fading, which have caused some of the rock arts to be mutilated and blurred and diffuse, seriously compromising the integrity of the images and creating significant challenges for the research process. In this study, we primarily discuss the two techniques of "inpainting" and "mending old painting" in the restoration of paintings and calligraphy. We also develop a "full image" of the damaged rock art images from an artistic point of view, with the goal of restoring the original appearance of rock art images as much as possible. The objective is to return the pictures on the rocks to their initial form. By examining the image data and evaluating the combination of figures in rock arts, the findings of this research significantly advance our knowledge of the goals of the Luo Yue ancestors. These offered technical references for the identification of related rock art images as well as fundamental analysis and assessment material for upcoming restoration.

KEYWORDS

Ningming Huashan Rock Art, Disease-image, Full Map, Data Statistics

1. INTRODUCTION

Ningming Huashan Rock art is located on the east bank of Mingjiang River in Yao Da hamlet, Tuolong village, Chengzhong Town, Ningming County, Guangxi Zhuang Autonomous Region, 25 km from the county (22°15′42″N, 107°0′37″E). The mountain is 345 m high, with a terrace on the south, northwest and opposite bank of the river. The entire cliff face of the mountain where the rock arts are drawn is obviously inwardly sloping, forming a huge rock mansion with sparse north-to-south inclined laminated fissure lines on the cliff wall (Qin et al., 1987). The whole rock art is facing southwest, about 172 m wide and 40-50 m high in ochre red color. The images are mainly anthropomorphs spotted by zoomorphs (dog-like), bronze drums, knives, swords, sheep-horn bells, boats, roads, suns and other images (Qin et al., 1987; Wang et al., 1988), with the largest image reaching 3.58 m and the smallest only 0.3 m. Except for the blurred ones, there are more than 1900 images recognizable, covering about 8000 m^2. It is the largest single-painted rock art in the world. According to the ^{14}C dating method, it had a history of 1680-4200 years ago (Fang, 2015; Yuan et al., 1986). The Huashan rock art in Ningming presented great cultural, historic, artistic and scientific value, this being announced as the Nationwide Key Cultural Relics Protection Unit (Guo et al., 2007; Liao and Meng, 2009). In July 2016, the Zuojiang Huashan rock art cultural landscape, represented by Ningming Huashan rock art, was approved as a world cultural heritage by the United Nations World Heritage Committee (Figure 1).

Figure 1: The panorama of Ningming Huashan Mountain

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The Huashan rock art in Ningming is subjected to chemical, physical, and biological weathering after undergoing changes brought on by geological and natural climatic variables (Guo et al., 2005; Zhao, et al., 2015) (such as light, temperature, humidity, and atmospheric moisture) for more than 2000 years (Huang and Xie, 2001; Lan et al., 2002). The rock arts as a consequence experienced a number of issues, including karst disease, biological disease, spalling disease, pigment layer peeling, and rock splitting (Figure 2) (Guo et al., 2005; Sun and Wang, 2011; Zhang, 2009). Numerous rock art images have been mutilated, blurred, or dispersed as a result of these illnesses (Guo et al., 2006; Guo et al., 2007; Zhang, 2009), jeopardizing the images' integrity and making it more difficult for scholars to gather picture data. These problems would also impact the long-term protection of rock arts.

In the past, researchers obtained rock art information in two main ways: on-site copying and photography. Due to the special environment, huge area and large number of images, it was very difficult to copy the entire rock arts. Three versions of the rock art images have been copied: the ochre version in the book *Investigation and Researches on the cliff paintings in Zuojiang River Basin* (Qin et al., 1987), the black-and-white silhouette version in the book *Guangxi Zuojiang River rock art* (Wang et al., 1988), and the black-and-white digital topography of the project "Research on the Digital Recording and Application of the rock arts of the Zuojiang River". The first two versions were manually copied on site, while the latter was a computerized image processing based on the photographs taken. Nevertheless, these versions were all copies of the current situation based on the preserved handwriting and brush marks of the rock arts, without

(a) Flaky rock spalling; (b) Pigment layer pulverized off; (c) Dust cover; (d) Calcium carbonate cover

(e) Surface scaling; (f) Pigment layer flake off; (g) Karst coverage; (h) Fading

Figure 2: Part of the rock disease (made by the author)

restoring the images of the rock arts that have been discolored and peeled off. As for rock arts that were lighter in color and covered with dust, identification and investigation work were not enough. There were other defects such as displacement of the copied images and information loss.

In the process of circulation, ancient Chinese paintings and calligraphy were affected by natural factors such as environment, climate or human damage and improper protection, resulting in mold, insects, stains, water stains, fractures, tears, fires, etc. Different damaged degrees thus affected the appreciation, research, identification, collection and preservation for future generations. Therefore, making up the color of the center of the painting where it was broken or lost (i.e., "inpainting"), or completing the painting and calligraphy where the damage (i.e., "mend old painting") could restore and frame its original face, recovering it a perfect work of art for future inheritance. From this point of view, the restoration of ancient paintings and calligraphy was similar in nature to the restoration of diseased rock art images. Therefore, in order to restore the original face of rock art images, this study mainly refers to the two methods of "inpainting" and "mending old painting" in the restoration of ancient paintings and calligraphy (Guo, 2011), and selects a local area of the rock art in Huashan, Ningming, to start the analysis and study of rock art images from the perspective of artistic modeling. The full-image analysis and study were carried out to restore the original appearance of the damaged images to the greatest extent.

2. CURRENT SITUATION OF THE FULL IMAGE AREA

The "full image" of the rock painting refers to the process of restoration of the damaged part of the rock art images through careful observation, careful discrimination and accurate identification based on the handwriting marks left on the cliff wall, combined with the modeling characteristics and combination rules of the rock art image. Through overall observation and comparison of the rock arts of Huashan in Ningming, an area of about 135 m^2 in the lower left corner of the entire rock art was finally selected for the full-image operation, as shown in Figure 3. The area was quadrangular, 18 m long, 7.5 m high, 5.3 m at the lowest point from the ground and 19.5 m at the highest point. The area was on the fracture zone of the cliff wall, with an inclined trend of high left and low right, with concave and convex cliff faces staggered in the area, and a shallow oblique gradational fracture line in the middle (Figure 4). The rock art images in the area maintain the interrelationship with the surrounding rock arts in terms of content, but were relatively independent in terms of location, making them easy to observe in the field.

The survey results show that the rock art diseases existing in the area (Figure 5) mainly include rock flakes, scale-like flaking, overall falling, dust, granular covering, karst covering, water mark covering and fading. The area with diseases reached 112.7 m^2, accounting for 83.4% of the total area of the whole image area. The area of the rock wall without images was 22.3 m^2, accounting for 16.6% of the total area of the whole map area. Among all kinds of diseases, especially the rock surface flake and scale flaking is the most serious, with an area of 65.7 m^2, accounting

Figure 3: The location of the full image area (made by the author)

Figure 4: The preservation status in the whole image area (made by the author)

for 48.7% of the total area. The disease characteristics and statistics of the whole image area are shown in Table 1.

These diseases caused serious damage to the rock art images in the area,

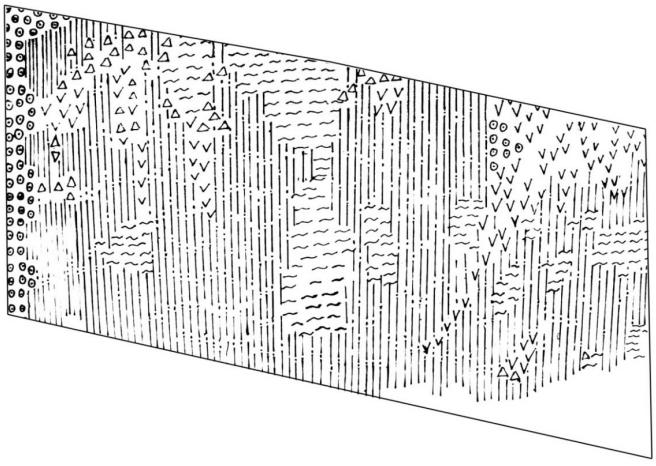


Figure 5: The disease distribution in the whole image area (made by the author)

Table 1: The disease statistics of whole image area

Disease type	Area/ m^2	Degree	Description	Rate/%	Symbol
Flake	65.7	Deep	Flaky, scaly spalling	48.7	‖
Rock falling	8.3	Deep	The whole rock falls off	6.2	∽
Dust, particle cover	27.1	Medium	Yellowish brown	20.0	∨
Karst coverage, water mark coverage	9.1	Deep	Grayish-white banding	6.7	○
Fading	2.5	Deep	Color fades to light red or light yellow	1.8	△

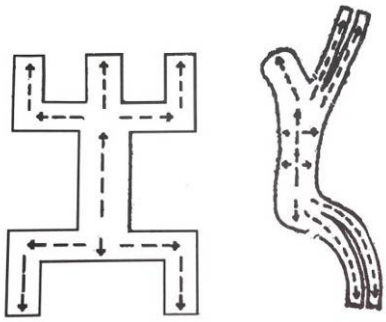


Figure 6: The features of the front and side figures (Source: "Tracking the Rock Art in the Zuojiang River Basin", Tan Cailuan et al., Guangxi People's Publishing House, 1st Edition, 1992, Page 79)

and most of the rock art images left only a few scattered brush marks, with few complete rock art images. There were 37 rock arts were clearly identifiable, including 11 frontal portraits, 15 side portraits, 2 animal figures, and 9 circles. These images provide a stylistic reference for the whole image of the mutilated part of the diseased image.

3. IMAGE RECONSTRUCTION PATTERNS AND ATTRIBUTES

Anthropomorphs dominated the Huashan rock arts, which also depicted dog-like zoomorphs, bronze instruments, artifacts, circles, and so on. The frontal portrait's arms were lifted and bowed symmetrically with the same bending angle, and the thighs were also squatted symmetrically, highlighting its balanced and symmetrical features. The side figures were organized in groups, as seen in Figure 6, with two parallel narrow curves representing the uplifted arms and squatting legs and thick and short vertical lines denoting the head and body (Qin, 2009). The canine-like animal pictures were generally below the frontal headshot. Both the ring-headed sword and the single-character partitioned blade were tilted and either painted on the figure's waist or carried in the hand. There were five different kinds of circular images: solid, hollow mansard, single-ring, double-ring, and three-ring (Qin et al., 1987). These silhouettes used in the rock art had a straightforward structure and a cohesive aesthetic. Analyzing the shape traits and patterns of different kinds of pictures allowed researchers to discover the foundation for harm recovery.

4. MATERIAL PREPARATION AND FULL MAP OPERATION

4.1 Selection of Base Image Version and Preparation of Tools and Materials

The whole-image identification of painted rock arts was only feasible when there were base images, including duplicates and photos of rock arts, much like when repainting and repairing ancient paintings. As a result, researchers were able to compare and contrast the full-image contours with the source pictures. This study directly chose the orthophoto stitching map of the aerial rock arts as the base map, printed a color version of the base map with a length of 8.5 meters and a width of 1.05 meters, and integrated the local area of the full map into the entire rock arts for analysis. This avoided the drawbacks of several versions as mentioned above. In addition to the basic map, other tools used in this operation included a Bushnell rangefinder, a GPSmap621sc locator, a lens, a camera, a computer, and other tools, as well as an orthophoto incomplete map and scale.

4.2 Whole Image Repairing

Recognition is a largely unconscious, automatic memory process. People like to look at pictures of objects because they can learn something new from each component while watching and interpreting it (Gombrich, 2016). The process of recovering the complete image of the rock art disease requires this spontaneous memory function. Four types of disease images will be treated by this whole-image repair.

4.2.1 Small Scale of Image Peeling

Some of the images in the area had a small area of peeling, with peeling or fading on the edges and small broken lines. These images accounted for 48.7% of the whole image area. For the whole image, the shape and location of the damaged images were determined on the high-resolution orthophoto map in the first place. Then, the handwriting shape of the remaining rock arts was sketched on the base map with dashed lines, and the sketched area was filled with color. Next, the shape of the handwriting was compared with the surrounding intact rock arts, the contour line and position of the damaged part were determined based on the patterns, shapes, symmetry, proportion and combinations of each type of image, and the dashed lines were drawn directly from the missing part of the image. Finally, the full-color filling was applied to the newly drawn part. It is easy to mend the rock arts in this way, and what needs attention is to supplement and perfect the image details. For example, in Table 2, the right side of the torso was intact while the left side was missing, so according to the law of symmetry, the left side was filled in with color directly starting from the right side; the ring-headed knife in the waist of the portrait of Group B was filled in according to the tilt angle of the image; for example, the right hand of the portrait of Group B had five fingers and the left hand was missing, so based on this remaining detail and the law of symmetry, the five fingers of the left hand were filled in with color; the side portrait of Group C and the circle image of Group D were also made up from the left hand. Group C side portraits, Group D circle images, etc. were all completed according to the connection method of "starting the mend from where stroke meets".

4.2.2 Large Scale of Image Peeling

The rock arts with large area of image peeling only refer to those with a small of handwriting left on the cliff, accounting for about 6.2% of the total area of the whole area. In the repair, firstly, a high-resolution orthophoto image was selected and the damaged image was locally magnified in the computer to determine the handwriting of the surviving image initially. Secondly, the remaining rock arts were compared with similar rock art images based on the modelling characteristics, scale and combinations, set the general location, shape and size of the damaged images, and initially sketched out the shape of the missing part with dashed lines. Thirdly, the sketched outline shape was compared with the enlarged details to further correct and improve the position and outline of the missing part; finally, the sketched outline part was then filled in with full color to complete the shape of the whole image. In Table 2, both the frontal portrait of Group E and the side portrait of Group F were severely damaged, and it is difficult to see the original shape of the image by looking at the existing handwriting alone. Therefore, based on the above method, missing part of the image can be completed. In this kind of images, we only needed to grasp the dynamic characteristics and identify the general shape and relative position, without paying too much attention to details.

4.2.3 Faded Rock Art Images or Rock Art Images Covered with Dust or Granular Material

The rock art images that faded or were covered by dust and granular materials accounted for 21.8% in the selected area. Due to the long distance and high location, these images usually could not be seen clearly, but with the help of orthophoto images taken by UAV, these images were found to be featured by good integrity, with clear remaining handwriting in some parts of the individual images and combined images, and there was clear relationship between them and the surrounding complete images. In the repair process, we first selected the orthophoto images with high resolution, and determined the complete form and image details of the rock art images after various comparisons and identifications. Then, the edges and positions of the images were outlined with dashed lines. Finally, the whole area within the contour line of the images was flatly painted with red color to restore the original appearance of the images. The animal images in Table 3A were covered by dust and granular material. The two side figures in Group B were affected by fading and lava, but both images were relatively intact, and the rock art image identification can be easily completed by UAV orthophotography, as shown in Table 3.

4.2.4 Other Diseased Images

Some rock art images in the repair area are also affected by water marks

Table 2: The operation process for all kinds of images in the full image (prepared by authors)

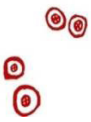
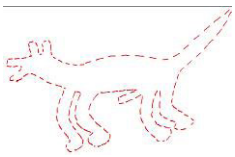
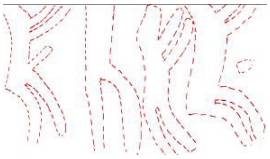
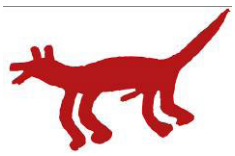
Category	Small scale of image peeling				Large area scale of image peeling	
	Group A	Group B	Group C	Group D	Group E	Group F
Status quo of rock art						
Phase I						
Phase II						
Phase III						

Table 3: The operation process for all kinds of diseased images in the full image (prepared by authors)

Category	Fading or coved by dust		Covered by water mark or lava	Pigment powdering and falling off, or covered by calcium carbonate crystal
	Group A	Group B		
Status quo of rock art				
Phase I				
Phase III				
Phase IV				

or lava, pigment powdering and falling off, calcium carbonate crystal, lamellar shedding of pigment and other diseases, as shown in Figure 2 (b), (d) and (f). These diseases were usually located in the range of painting marks in the rock art images and were distributed in a point-like manner, which has little impact on the overall recognition and contour tracing of the rock art image (Table 3). During this process, we only needed to accurately draw the outline and local details of the diseased images, and flat paint the full color in the outline area. Karst or water mark affected the rock art images from top to bottom, accounting for about 6.7% of the repair area. As shown in Figure 2 (g), the cliff surface was pink or dark brown. As some places became stalactites or stone curtains, a large scale of rock art images was covered and the full images could hardly be restored.

In addition, there were cases where dust cover, rock spalling, and karst cover exist simultaneously in the diseased images. During the repair, it was necessary to grasp image modeling pattern, analyze and compare, and carefully identify, so as to determine the image form of rock arts. According to the aforementioned steps and methods, individual images and combined images were mapped out one by one, so that sometimes a cascade effect was formed and the fragmentary image traces that were originally destroyed and unrecognizable could be linked up little

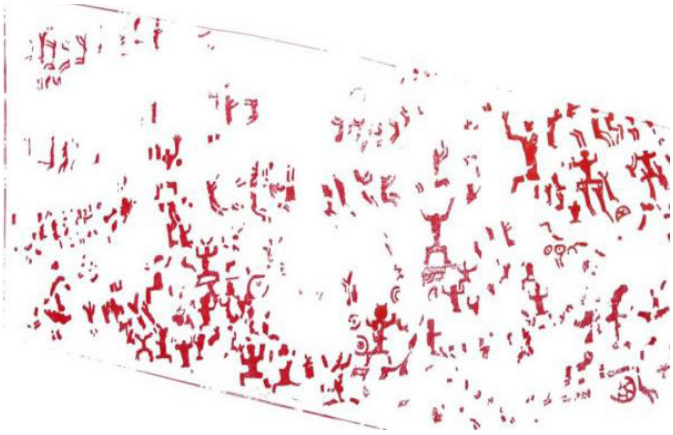


Figure 7: The status of diseased image (prepared by authors)

Figure 8: The contour of the diseased image (prepared by authors)

Figure 9: The completion of the image (prepared by authors)

by little, and finally the rock art images in the whole area became fully identifiable. The relationship of all images in the region before and after the completion of the full image is shown from Figure 7 to Figure 9.

5. DATA STATISTICS AND ERROR ANALYSIS

5.1 Data Statistics

Before the completion of the full image, the number of clearly distinguishable rock art images was 37, including 11 frontal portraits, 15 side portraits, 2 animal images, and 9 circle images. The total number of damaged images completed after the repair of the full image reached 133, including 27 frontal portraits, 101 side portraits, 2 animal images, and 3 circle images. Compared with the identifiable images, the number of frontal portraits increased by 2.5 times, the number of side portraits increased by 6.7 times, the number of animal images increased by 1 time, and the number of circle images increased by 0.3 times; the total number of 170 images increased by 3.6 times.

5.2 Error Analysis

According to the statistics of this full image repair, the number of images in the test area was increased and the integrity of the images was restored. The orthophoto map is used as the base map. As the orthophoto map relies on 3D laser scanning and photogrammetry technology, the spatial coordinate information of the rock arts location was obtained, and the specific size and area of the rock art body were accurately measured after calibrating with the image control points measured by the electronic total station. In this way, the displacement of rock art images and information loss were solved, and the accuracy of relative position of rock art was ensured. The detailed image information of the rock art body was further obtained. However, due to the special drawing techniques and geographical environment of Huashan rock art in Ningming, there were still some difficulties in accurate image restoration, mainly in the following aspects: (1) Due to the unevenness of the cliff surface and the roughness of the ancient brush, some of the rock art images were not neatly drawn, and there were some "hollow strokes" and rough parts. (2) The 2D plan of the orthophoto image failed show the concave and convex relationship of the cliff surface, resulting in a certain degree of deformation of the rock art images drawn on the inclined surface of the rock body after the full image was finished and some deviations in the measurement of dimensional data later on.

6. DISCUSSIONS

Only after we can observe the rock art images as clearly as possible, can we better explore the intention of the ancient people, study the basic information conveyed by the image, and understand the specific content of the rock art. Through the analysis and study of the full image, many blurred and fragmented rock art images were gradually identified and recognized, and the research results further approximated the original state of the rock arts:

1) The rock arts in the area were rigorously modeled, with obvious and regular combinations. The frontal portraits were arranged orderly in parallel in the horizontal direction in the lower part of the area, with large and small sizes, and their heights can reach14.5 m. A few frontal portraits were located in the combinations of side portraits. The closer to upper part of the full image area, the more side portraits could be found. There was a combination of tilted figures that are low on the left bottom but high on the right, and there was no body portrait involved there.

2) In the process of repairing the full image, it was discovered that there was a small area of superimposition. After study, it was found that it is because the images drawn by the ancient people contradicted each other.

3) The method of recovering the full image of diseased rock arts from the perspective of artistic modeling is of great significance for the conservation and research of rock arts in Huashan, Ningming. First, the full image method breaks through the disciplinary barriers, expands the method of cultural relic conservation, and realizes technical innovation. This technique can not only provide basic analysis and evaluation information and technical reference for future restoration of Huashan rock arts, but can also be widely used in the restoration process of damaged images in various shapes and combinations, such as temple murals and architectural murals. Secondly, the full image results enrich the integrity of the image ontology image information. It can not only provide a model reference for the identification of similarly damaged various shapes and combinations of images, but also provide rich image information for the study of image content interpretation, combination analysis, drawing purpose, image promotion and display and other topics.

7. CONCLUSIONS

The full image restoration of some diseased images in Huashan rock arts in Ningming is an effective attempt for the restoration of the painted rock arts and has achieved the expected purpose. The following conclusions have been drawn based on this study.

The number of all damaged images totaled 133, accounting for 78.2% of the total number of identifiable images in the area, which shows that the diseases in some areas of Huashan rock arts in Ningming have not been prevented. Under the prerequisite that no human intervention is advocated, there is an urgent need to carry out detailed status records of the rock art ontology, including close range photography, 3D laser scanning, 360-degreephotography and other technical means.

Based on the modeling characteristics of individual images, the layout and relative position between the combined images, together with the orthophotography and field observation of rock art, the handwriting and brush marks left on the cliff wall are identified, and the restoration of the full damaged images is practical and feasible, which further enriches the ways and means of recording the information of the painted rock arts ontology.

In the process of full image restoration, the dust-covered images and faded images are mainly identified by recognition, and the locally peeled images are mainly made up by the method of "starting the mend from where stroke meets", and these two practical methods provide methodological guidance for the full image restoration of the whole rock arts in the future.

The full image restoration technique can provide important reference for the restoration work of diseased images, and its research results provide image data for the thematic research of related contents.

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