

# A Study of the Damaged Frescoes and Restoration in Zhulin Temple in Lingbao

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**Abstract:** This data paper mainly elaborates the preservation of frescoes in Zhulin Temple in Lingbao, where a detailed investigation into the deterioration was carried out on May 2020 by using X-ray diffraction (XRD), micro confocal Raman spectrometer (Raman), and scanning electron microscopy- energy dispersive spectrometer (SEM-EDS) to detect and analyze the pigments. After the field protection and experiments for repairing have been conducted for ridding the damages, the dataset obtained is as follows: (1) high resolution photographs of the frescoes and CAD drawing of the mural's location; (2) the statistical table of the pictures under investigation; (3) the area statistics of the damaged frescoes; (4) the results of pigment test. Meanwhile, this paper analyzes the preservation of frescoes in Zhulin Temple, the results of investigation and pigment detection, and then summarizes the influence of environment on mural painting. Finally the on-site protection and restoration have been carried out for different damages. The dataset, consisting of 39 data files with a data size of 232 MB (compressed into one file of 231 MB), is archived in .jpg, .dwg, .pdf and .xls formats.

**Keywords:** frescoes in Zhulin Temple; deterioration investigation; environmental survey; sampling; repair test

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**CSTR:** <https://cstr.escience.org.cn/CSTR:20146.14.2021.04.14>

**Dataset Availability Statement:**

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: <https://doi.org/10.3974/geodb.2021.08.05.V1> or <https://cstr.escience.org.cn/CSTR:20146.11.2021.08.05.V1>.

## 1 Introduction

Zhulin Temple, located in Guxian, Lingbao city, Henan province, was built in the first year under the reign of Emperor Yongchang (689 AD) in Tang dynasty, 1,328 years ago. It was named Bodhisattva Temple and renamed Zhulin Temple in Ming dynasty. Surrounded by high mountains and hidden in the verdant pines and cypresses, it is not easy to be found so that free from war and other catastrophe, it has survived more than one thousand years. Discovered in 1980s, the temple was respectively granted as the county-level cultural heritage site by People's Government of Lingbao county in 1989, the municipal-level site by

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[2] Su, D. L. *In situ* data of mural paintings in Zhulin Temple, Lingbao, Sanmenxia of China [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2021. <https://doi.org/10.3974/geodb.2021.08.05.V1>. <https://cstr.escience.org.cn/CSTR:20146.11.2021.08.05.V1>.

Sanmenxia People's Government in January 2006 and the provincial-level site by Henan Provincial People's Government in June 2008.

The main buildings in the temple should be the three Buddha halls, with two rows of guest halls on both sides. Behind the halls is the Hall of Jiuku (helping people in distress), where a niche for Buddha, in a three-tier layout, can be found, on the east, west and north walls of which are painted with murals, the hallmark treasure of Zhulin Temple. There are also frescoes on the head wall, which tell the stories of Creation of the Gods. The Taoist paintings come out with Buddhist shrines in one hall, which is worth studying. The Hall of Jiuku was built in the 47<sup>th</sup> year during the reign of Emperor Kangxi, and renovated for the last time in the 3<sup>rd</sup> year of Emperor Xuantong. More than 300 years ago, the hollowed-out carving of the local timber-made shrine is so exquisite that it is rarely seen. Painted by hand, this shrine has the pattern that looks diverse and delicate, with each having its' own connotation. More than 3 m in width and nearly 4 m in height, the four-layer shrine is installed with the brackets on each layer that look exquisite as well. In spite of the small size, this shrine contains all the themes of Buddhism. On both sides of the shrine are the four heavenly kings painted in the style of Song dynasty.

For long years out of repair, the frescoes are seriously damaged (Figure 1). In order to repair and restore frescoes as they are, it is necessary to have this dataset completed based on the investigation of the frescoes in terms of the situation, causes, components and scheme.



**Figure 1** Water stain, pigment layer and spot-like shedding in Jiuku Hall of Zhulin Temple in Lingbao, Sanmenxia of China (No.3)

## 2 Metadata of the Dataset

The metadata information of *In situ* data of mural paintings in Zhulin Temple, Lingbao, Sanmenxia of China<sup>[1]</sup> is summarized in Table 1.

## 3 Main Contents of Dataset

The temple mural has a long history in China because temples are scattered all over the country. Due to the long duration, most of murals are badly damaged. In 2010, Wu had a study on the murals in tombs in Guyuan<sup>[3]</sup>; Wang had an investigation into temple murals in ancient villages in Datong in 2011<sup>[4]</sup>; Ma had a research into the present situation of temple murals in Yulin in 2018<sup>[5]</sup>; and Wang studied how to restore the temple murals in western Inner Mongolia in 2020<sup>[6]</sup>. All of their studies provide learning experience for the restoring temple murals for Zhulin Temple in Lingbao.

This dataset, on the basis of detailed investigation into the frescoes in Zhulin Temple in Lingbao, Henan province, provides us with the general information of the frescoes, including their historical, artistic and scientific value, and the existing damage and

**Table 1** Metadata summary of the *In situ* data of mural paintings in Zhulin Temple, Lingbao, Sanmenxia of China

Item	Description
Dataset full name	<i>In situ</i> data of mural paintings in Zhulin Temple, Lingbao, Sanmenxia of China
Dataset short name	MuralPaintingZhulinTemple
Author	Su, D. L., Luoyang Museum of Ancient Arts, 1229670959@qq.com
Geographical area	Lingbao, Henan province
Year	Qing dynasty (1636–1912)
Data format	.jpg , .dwg, .pdf, .xls
Data size	232 MB, a total of of 39 data files (compressed into one of 231 MB )
Data publisher	Global Change Research Data Publishing System, <a href="http://www.geodoi.ac.cn">http://www.geodoi.ac.cn</a>
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	<b>Data</b> from the Global Change Research Data Publishing & Repository includes metadata, datasets (in the <i>Digital Journal of Global Change Data Repository</i> ), and publications (in the <i>Journal of Global Change Data &amp; Discovery</i> ). <b>Data</b> sharing policy includes: (1) <b>Data</b> are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use <b>Data</b> subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute <b>Data</b> subject to written permission from the GCdataPR Editorial Office and the issuance of a <b>Data</b> redistribution license; and (4) If <b>Data</b> are used to compile new datasets, the ‘ten per cent principal’ should be followed such that <b>Data</b> records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset <sup>[2]</sup>
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

deterioration upon the frescoes in detail after the environmental investigation has been done. After that, it analyzes the production mechanism and the pigment element of the frescoes. Finally, the detailed experimental data has been collected after the experiments have been done for detecting the damage and deterioration. The general contents of this dataset include the geographical environment where murals are located, the shape and structure of temples and halls, the general situation of murals, value evaluation, types of damage and deterioration, environmental investigation, mechanism analysis of the damage and deterioration, sampling and testing of mural components, experiments on eliminating damage and deterioration, etc.

### 3.1 Overview of the Murals

Peony, chrysanthemum flower and two characters are painted on the upper part of the eastern gable. Most coatings on the north side of the peony fall off and there are a lot of scratches on the mural (Figure 2). There are 15 characters in the lower part of the picture, among which 6 are riding horses, one riding a unicorn and 2 riding unnamed beasts. Each of them holds either a weapon out of the ordinary or a magic item, very much alike the scene in the war described in Creation of the Gods. There are long cracks from top to bottom in the middle of the mural, a lot of water stains, layer and point-like pigment shedding. For the mural is stuck to the newspaper, there are a lot of coating layer shedding in the lower part of the mural, pulverized pigment layer and dusty mural surface.

There are plum blossoms, lotus flowers and two figures painted on the gable at the upper part of the western wall. A large area of coating falls off the upper part of the lotus flower, and there are a lot of water and mud stains in the plum blossom. There are 14 figures in the mural at the lower part of the western wall, among which 12 are riding horses or mythical beasts, one has wings, and the other holds a gankun circle. Everyone holds weapons or a magic item in their hands, very much alike the scene in the war described in Creation of the Gods. In the lower part of the mural are cracks, a large number of water stains and mud stains from top to bottom, many places where the coating and pigment layer fall off a lot, layer and point-like pigment shedding (Figure 3), pulverized pigment layer, scratches and

dusty mural surface.



**Figure 2** Mural cracks on the upper part of the east gable (No.9)



**Figure 3** Excerpt from mural on the west side of the north wall-pigment layer shedding (No.37)

There are five figures in the mural painting on the west side of the north wall, with three riding a god beast, one stepping on a hot wheel and one born with long wing who flies in the sky. Each person holds a weapon or a magic item in their hands, very much alike the scene in the war described in Creation of the Gods. There are water stains running from top to bottom, pulverized pigment layer, dusty mural surface and a lot of pigment layer falling off the edge of mural painting (Figure 4).



**Figure 4** Excerpts from murals on the west side of the north wall-spot-like shedding and pulverization of pigment layer (No.22)

### 3.2 The Geographical Environment of the Murals

Lingbao belongs to the continental monsoon climate zone in warm temperate semi-humid region, featuring adequate illumination and great temperature difference between day and night. Moreover, the wind is strong all the year round, which could exert the strong erosion upon the external of building and the murals in the temple, causing the murals to fall off. In this study on frescoes in Zhulin Temple, T625 precision thermometer has been used to monitor the on-site temperature and humidity. E7640 ultraviolet ray meter and luminance meter are used in this study for measuring temperature and humidity changes inside and outside the temple. From May 5 to May 9, 2020, the minimum and maximum of the indoor temperature were minus 12.5 and 22 °C, with the temperature difference amounting to 19.5 °C. The highest humidity is 65.3% and the lowest is 19.4%. During a certain period of time, little difference of temperature and humidity can be found between indoor and outdoor. Though situated in the north wind zone, Lingbao is not particularly windy all year round but the temperature and the humidity difference is great during the morning and evening, which is not conducive to the preservation of murals. When it is good, the brightness of the eastern and western walls of Jiuku Hall is 97.4 lux at the highest and 34.8 lux at the lowest, indicating that the impact of illumination on frescoes is not the major contributing factor.

### 3.3 Evaluation of the Murals

Due to its superb location at the junction of the Henan province, Shaanxi province and Shanxi province, there was an unending stream of pilgrims to Zhulin Temple who contributed to the improvement and renovation of the temple after the Tang dynasty. A large-scale maintenance occurred in Qing dynasty, for example, a painted woodcarving

niche installed in the main hall, which has the same architectural style of the Forbidden City, showcasing the form of the classic building of Ming and Qing dynasties. In the Hall of Jiuku in Zhulin Temple are kept a considerable amount of frescoes in Qing dynasty, which truly represent the constantly enriched mural art in ancient China, and provide us with important images for understanding the local religions, folk beliefs, lifestyles, aesthetic preferences and mural art.

The mural kept in the Hall of Jiuku in Zhulin Temple may have been drawn by folk painters, closer to the common people and their expression of art style. Out of the shackles of religious rituals, the way of expression looks rather inclusive in that to interpret the religious teachings seems less serious and open-ended. The elements, including Confucian ethics and secular lifestyle, are adopted to cater for the lower classes in terms of the psychological and aesthetic needs. Therefore, its value in the elements then can never be ignored. As for its color manifestation, the frescoes in Zhulin Temple are mainly painted in white, black and gray, with the freehand and fine brushwork in traditional Chinese painting applied in. The figures in the mural appear vivid, interesting and rich in facial expressions, and the drawing lines for the clothing turn to be smooth. In general, the lines are soft in stiffness and varied in contrast. The artist seems to be particular about the way of expression before, while and after-handwriting. It is obvious to spot the transition from the emptiness to actuality. On the walls of monasteries built in Qing dynasty always appeared the fresh and elegant flower-and-bird painting. Therefore, the plum blossoms, lotus flowers and others were painted on the upper part of the gable of Jiuku Hall while many figures, rocks and running water were painted on the lower part, which reflected the diversity in painting. The mural painting, architecture, Buddhist niches and other artistic forms in Zhulin Temple constitute a whole picture for the unique culture.

### **3.4 Damage of the Murals**

#### **3.4.1 Classification**

Completely covered with dust, the mural painting cannot be available for exhibition. Due to the cracks and shedding on the eastern and western walls of Jiuku Hall, the integrity and safety of murals may be affected. Hollowing, pigment layer crack, pulverization, pigment layer shedding, coating shedding, point shedding and the dissolution of alkali and salts have negative impact on the safety of frescoes, among which pulverization is regarded as the greatest. Through the on-site investigation and analysis, there are mainly the following factors which lead to the damage and deterioration of mural paintings in Jiuku Hall of this temple: pigment layer crack and shedding, pulverization, dust-fall, point shedding, cracks, scratches, covering, man-made damage, hollowing, coating shedding, dissolution of alkali and salts, mud stains, water stains, animals' damage, etc. According to the degree of damage on the physical relics and artistic value in terms of order from highest to lowest, they can be respectively divided into changes in integrity, morphologic change, color change, biological deterioration and man-made damage.

#### **3.4.2 Factors**

The contributing factor of the damage is as follows. In a semi-illumination environment for a long time, the mural paintings on the western wall of Jiuku Hall in Zhulin Temple are strongly illuminated in the morning while the murals on the eastern wall strongly illuminated in the afternoon, which has exerted the negative impact on the pigment layer on the mural surface that deserve our attention. The organic cementing material will undergo photo-aging and the protein will be decomposed into oligomers of small molecular, thus gone is the crosslinking effect, which naturally results in pigment shedding and pulverization.

After the side door of the front hall of Beiji Hall of Zhenwu was blocked, it was re-painted. On the other hand, there are sedimentation, deformation and column slanting in Beiji Hall, which mainly contribute to the cracks, hollowing and falling off of murals. In addition, placed in an environment where the relative temperature and humidity change greatly, the murals would absorb water when the humidity is high, and the water in the mural evaporates rapidly outward when the humidity is low, which will cause the mural to shrink and produce dry cracks. Finally, due to the shedding of coating with no bonding strength, hollowing occurs. All kinds of dust and the condensed water lead to the pulverization of pigment layer and coating layer of murals. In addition, due to the negative impact of capillary water, the salty water inside the mural moves outside, with the salt precipitated in vaporization, which leads to the crack and the dissolution of alkali and salts from the pigment layer. The rain leakage from the roof and the side wall may lead to the flowing of rainwater and mud stains, which would further spoil the murals and the falling of painted layer.

4 Composition of the Murals

The dataset mainly includes the following four parts, which provide the basis for the restoration of murals:

- (1) the distribution map of murals in temple;
- (2) photographs of damaged parts of murals;
- (3) statistics of damaged area of murals;
- (4) composition of murals’ raw materials.

4.1 Distribution Map of Murals in Temple

There are a total of CAD-made distribution maps of murals in temple, including the map of mural in Jiuku Hall (see Figure 5; No.2), location plans No.10, No.18 and No.25. The length and width of murals and their walls on the floor plan have been accurately marked.

4.2 Photographs of Damaged Murals

There are 32 pictures of damaged murals in total in this dataset (Figure 6, 7). The damages recorded in these photos include pigment layer crack and shedding, pulverization, dust-fall, point shedding, cracks, covering, man-made damage, hollowing, coating shedding, dissolution of alkali and salts, mud stains, water stains, repair marks, smoking, covering, scratches, scribbles, animals’ damage, etc.

4.3 Damaged Area

To figure out the specific damaged area of mural disease area plays a vital role in judging the type and degree of mural deterioration, and also provides a reliable basis for program budget. In this study, all frescoes were photographed, and the specific damaged area has been accurately worked out according to the national industry standard and statistical standard of Auto CAD. The existing mural area of Jiuku Hall in Zhulin Temple amounts to 47.14 square meters, and the statistics of the damaged area and the proportion of the total area are shown as follows.

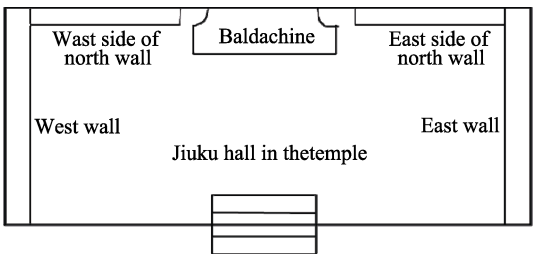


Figure 5 Distribution map of the four walls (east wall, east side of north wall, west side of north wall and west wall) of Jiuku Hall in the Temple





Figure 6 Coating shedding (No.26 excerpt)



Figure 7 Crack (No.31)

Table 2 Statistics of the damaged area and the proportion

Name	Gross area (m <sup>2</sup> )	Proportion (%)	Name	Gross area (m <sup>2</sup> )	Proportion (%)
Pigment layer shedding	21.2	45.0	Dust-fall	47.14	100
Pulverization	47.14	100	Crack	12.21	
Coating shedding	8.74	18.5	Point-like shedding	37.79	80.17
Hollowing	12.6	26.73	Flaking	10.26	21.76
Dissolution of alkali and salts	6.2	13.15	Mud stains	12.36	26.22
Water stains	10.71	22.72	Smoked area	0.01	0.02
Animals' damage	0.24	0.51	Covering	10.89	23.10
Scratches	13.68	29.02	Scribbles	0.53	1.12
Repair marks	5.13	10.88			

4.4 Composition of Murals

The composition of mural and the data are obtained by use of testing instruments, including X-ray diffraction (XRD), micro confocal Raman spectrometer (Raman), and scanning electron microscopy-energy dispersive spectrometer (SEM-EDS).

The research object in this study refers to the murals of Jiuku Hall in Zhulin Temple. The mural structure from outside to inside is as follows: the wall acts as the supporter which is made of blue bricks and adobe bricks; consisting of two layers, the coating is thick, under which is a coarse grass-mixed mud layer of 1–2 cm in thickness, making the wall a plane, and above which is a delicate 0.8–1 cm layer of grass and mud. On the coating is a thin layer of lime, on which frescoes are drawn. For the lime layer is thinner than that of mud layer, traces of wheat straw can be seen everywhere on the surface of frescoes, especially in the blank areas.

The mural walls in the east, west and north of Jiuku Hall are made of adobe admixture. The brick walls are first daubed with coarse grass and mud, and then with a fine grass-mud layer, on which is a thinner lime coating layer painted with the mural. Due to the different positioning of the whole wall, the thickness and bonding of the coating layer are different as well, for example, especially the layer of the mural at the gable is thick and not closely bonded with the grass-mud layer.

The *in-situ* nondestructive investigation has been conducted in terms of microscopic morphology and element composition, in hope of obtaining the information of mural production, material composition, characteristics of the damage, etc. By analysis of the sample of coating layer of the murals of Jiuku Hall with X-ray diffraction, the fine grass-mud layer mainly contains SiO<sub>2</sub>, calcite Mg<sub>x</sub>Ca<sub>1-x</sub>(CO<sub>3</sub>), CaCO<sub>3</sub>, AlSi<sub>3</sub>O<sub>8</sub>, potash

feldspar or  $\text{AlSi}_3\text{O}_8$ ,  $\text{MgSiO}_3$ ,  $\text{K}_x\text{Na}_y$ ,  $\text{Mg}_m\text{Al}_n\text{Fe}_l\text{Mn}_o$ ,  $\text{Al}_a\text{Si}_b\text{O}_{10}(\text{OH})_2$  and  $\text{Mg}_{2.96}\text{Fe}_{2.91}\text{Al}_{1.275}(\text{Al}_{1.376}\text{Si}_{2.622}\text{O}_{10})(\text{OH})_8$ . SEM images show that the shell of plant seeds and plant fibers are mixed in the coating layer, with the soil evenly distributed, which is mainly composed of Silicon, Aluminum, Calcium, iron and other elements, consistent with the major proportion of  $\text{SiO}_2$ , calcite and feldspar in the XRD analysis results. XRD and micro laser Raman spectrometer were used to analyze some samples, indicating that the main coloration elements of black, white, and gray pigment were carbon, calcium carbonate and carbon black plus calcium carbonate respectively (Table 3).

**Table 3** Composition Statistics of Murals in Zhulin Temple

No.	Location	Color	Test objective	Means	Results
1	Lower part of crack in the middle east wall	White	Ingredient	Raman	Calcium Carbonate
2	Lower part of crack in the middle east wall	Black	Ingredient	XRD	Magnesium chloride, gypsum, calcium carbonate, carbon
3	Lower part of crack in the middle east wall	Gray	Ingredient	XRD	Calcium carbonate, gypsum, muscovite, Aluminum hydroxide, carbon
4	Lower part of crack in the middle east wall	Ground floor	Composition plus ingredient	XRD SEM-EDS	Quartz, calcite, spheroidal calcite, albite, potash feldspar, clinoptilolite Stone, biotite, chlorite
5	Lower part of north east side of wall	White	Ingredient	Raman	Calcium Carbonate
6	Lower part of north east side of wall	Black	Ingredient	XRD	Calcium carbonate, gypsum, Shi Ying, boehmite, albite, carbon
7	Lower part of north east side of wall	Gray	Ingredient	XRD	Calcium carbonate, gypsum, Shi Ying, boehmite, carbon
8	Lower corner of north east side of wall	Ground floor	Composition plus ingredient	XRD SEM-EDS	Quartz, calcite, kaolin, albite, potash feldspar, anorthite, chlorite
9	Lower boundary of west wall	White	Ingredient	Raman	Calcium Carbonate
10	Lower boundary of west wall	Black	Ingredient	XRD	Carbon
11	Middle of west wall	Gray	Ingredient	XRD	Calcite, gypsum, Shi Ying, aluminum magnesium carbonate, dawsonite, carbon
12	Outer wall on the east side of Bodhisattva Hall	White	Composition plus ingredient	XRD SEM-EDS	Quartz, calcite, potash feldspar, Mica, feldspar, chlorite

5 Application of Data and Mural Restoration

According to the data of the murals in Zhulin Temple, the restoration measures including clean-up, filling and repairing are put forward as follows.

5.1 Cleaning-up before Repairing

The major tasks before repairing refer to the dust cleaning, lime cleaning and newspaper-covered cleaning.

(1) Dust cleaning

Dust cleaning is the first step for mural restoration. The frescoes in the experimental area are in the lower part of the north side of the east wall, with an area of  $30\times30\text{ cm}^2$ . There are many dust-falls on the surface of this restoration area, with a few pigment layers falling off and mud stains on the surface. Due to the wide coverage of dust-fall, the materials used include Tween 20, deionized water and ethanol. There are three steps for repair, namely, applying tissue paper, uncovering tissue paper and removing Tween residue.



To clean up dusts, Tween 20 works very well, and is convenient to operate while 2A has better performance to clean mud stains on murals by rolling with cotton swabs.

### (2) Lime cleaning

Lime cleaning is mainly conducted on the belly of the horse, the first one on the east side of the north wall. The mural is mainly in white, gray and black, with the repaired area of about 2.5 m<sup>2</sup>. The types of damages in this area are: lime pollution and shedding, pigment layer shedding, spot-like shedding, scratches, the retention of a lot dust-falls, etc. It is very difficult to remove the lime pollution, which requires more experienced technicians to handle.

The materials used include deionized water, EDTA and ethanol. There are four steps for repair, namely, applying cotton paper, uncovering cotton paper, mechanically removing lime and removing EDTA residue.

Using EDTA to soften lime will not cause the mural to break open again. Such operation is difficult and must be carried out by professionals.

### (3) Paper covering and cleaning

The mural in the experimental area is on the middle of the east wall, with an area of 20×20 cm<sup>2</sup>. The damages on the mural in the area include newspaper covering and shedding, pigment layer shedding, spot-like shedding, scratches, the retention of a lot dust-falls, etc. It is very difficult to remove the covered newspaper, which requires more experienced technicians to handle. The materials used include deionized water and ethanol. There are three steps for repair, namely, steam softening, newspaper removal and glue residue removal.

To softening newspaper with steam will not cause the mechanical damage on mural painting. It is very difficult to remove, which requires more experienced technicians to handle.

## 5.2 Filling and Repairing

Filling and repairing are mainly conducted on the first figure on the east side of the north wall, with an area of 20×20 cm<sup>2</sup>. The damages on the mural in the area include coating layer shedding, pigment layer crack, hollowing, retention of dust-falls and etc. It is very cumbersome to fill and repair fallen coating layer, which requires more materials and more experienced technicians to handle. The materials used include deionized water, ethanol, SF-016, hydraulic lime and mineral pigment. There are five steps for filling and repairing, namely, reinforcing the hollowed part, grouting, crack repairing, filling the coating layer and coloring.

To follow the compatibility principle, the mud filling is adopted, which secures the safety of murals. Coloring mural (slightly lighter than the original) can ensure the mural's integrity and identifiability, and improve the artistic value as well.

## 5.3 Grouting and Repairing

Grouting and repairing are mainly conducted at the lower boundary on the east side of the north wall, with an area of about 20×20 cm<sup>2</sup>.

The damages on the mural in the area include hollowing, pulverization of coating layer, pigment layer pulverization, retention of dust-falls and etc. It is cumbersome to fill and repair hollowed part, which requires more materials and more experienced technicians to handle. The materials used include deionized water, ethanol, SF-016, hydraulic lime and mineral pigment. There are five steps for grouting and repairing, namely, reinforcement of the hollow part, grouting hole open, grouting, supporting and coloring.

To make the best of the fluidity, hydraulic lime grouting is used, which secures the safety and the stability of murals.

### 5.4 Crack Repairing

Crack repairing is mainly conducted below the cracks in the middle of the east wall, at the boundary bar, with one crack about 20 cm in length. The damages on the mural in the area mainly include cracks, shedding of the ground layer, cotton filling in the cracks, pulverization of the pigment layer, etc. It is cumbersome to repair crack, which requires more materials and more experienced technicians to handle. The materials used include soil powder, deionized water, ethanol, SF-016, hydraulic lime and mineral pigment. There are four steps for crack repairing, namely, reinforcement of the crack, crack filling, bottom layer preparing and coloring.

To follow the principle in terms of compatibility, the mud filling is adopted for crack repairing, which secures the safety and the stability of murals.

## 6 Conclusion

By establishing a scientific dataset, this study has made us understand the damages, the spatial distribution and types of mural damages, craftsmanship, pigment elements and environment of mural paintings in Zhulin Temple. A variety of information of mural paintings has been accurately collected and recorded and the ways to eliminate the damages have been discussed. As an all-around investigation on the present situation and protection of the murals, this study is of significance to prolong the lifespan of cultural relics.

### Conflicts of Interest

The authors declare no conflicts of interest.

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