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Pigment Application and Color Matching Rules in Tang Dynasty Murals of the Dunhuang Mogao Grottoes

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Abstract. This study examines the pigment application and color-matching principles of Tang Dynasty murals in the Mogao Caves of Dunhuang, a UNESCO World Heritage site renowned for its vibrant artistic heritage. Building on the historical and cultural significance of these murals, the research integrates color wheel theory, particularly Itten's model, to systematically analyze the use of complementary, contrasting, and analogous colors. The methodology combines qualitative analysis of pigment types, origins, and processing techniques—such as the preparation of azurite, malachite, cinnabar, and ochre—with comparative studies of Renaissance frescoes in terms of artistic concepts, color strategies, and cultural contexts. Findings reveal that Tang artists skillfully balanced symbolic and decorative functions of color, using mineral-based pigments for lasting brilliance and visual impact. Comparative results highlight distinct cultural approaches: symbolic religious color use in Tang murals versus naturalistic representation in Renaissance art. The study concludes that integrating scientific color analysis with cross-cultural perspectives not only deepens understanding of historical art forms but also offers valuable insights for the preservation, innovation, and contemporary application of traditional color aesthetics.

Keywords: Dunhuang Tang Dynasty murals, pigment application, color matching rules, color wheel theory, cultural inheritance and innovation.

1. Introduction

This research will be specifically carried out from four aspects: the types and sources of pigments, the production techniques and color expressions, the color - matching rules based on the color wheel theory, and the cross - cultural comparison with Western Renaissance murals. Methodologically, the literature analysis method is used to systematically search for, organize, and study historical documents, archaeological reports, and research materials related to art history studies and color theory. Combined with the existing pigment detection results of Dunhuang murals and high - resolution digital image analysis, a comprehensive exploration of the characteristics of color application is carried out. The advantage of this method lies in its ability to integrate art history research with color science, analyzing the formation mechanisms and aesthetic characteristics of the colors in Tang - dynasty murals from multiple perspectives and levels. This provides a solid foundation for the further advancement of the research.

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The ultimate goal of this research is to reveal the rules and cultural connotations regarding the use of pigments and color matching in the Tang - dynasty murals of the Mogao Grottoes in Dunhuang, ascertain their unique status in the art histories of the East and the West, and provide theoretical references and practical insights for the protection, restoration, and contemporary innovative application of traditional color aesthetics. To achieve this goal, while sorting out the historical and theoretical foundations, this paper integrates the cross-cultural comparison perspective and color theory analysis, thereby forming a comprehensive research framework that combines both scientific and artistic attributes.

2. Literature review

Regarding the research on the colors and pigments of the Tang - dynasty murals in the Mogao Grottoes of Dunhuang, there has been a relatively systematic accumulation of academic achievements. Fan Jinshi pointed out in The Color Characteristics and Artistic Achievements of the Tang - Dynasty Murals in the Mogao Grottoes of Dunhuang that the color combinations of the murals in the flourishing Tang Dynasty played an important role in creating religious artistic conceptions and highlighting spiritual symbols, providing a theoretical basis for this research to understand the cultural background and aesthetic functions of colors [1]. Tian Weili, in her master's thesis Analysis of Dunhuang Mural Pigments and Exploration of Production Techniques, used mineralogical detection to reveal the compositions, sources and production techniques of pigments commonly used in Tang - dynasty murals, providing reliable data for this research to analyze the material basis of colors [2]. Wang Bomin, in A History of Color in Chinese Painting, made a macroscopic sorting - out of the development vein of the colors in ancient Chinese paintings, pointing out that the maturity of the Tang - dynasty color system was closely related to the prosperity of the society in the flourishing Tang Dynasty, yet there was a lack of in - depth exploration of the specific color - matching rules [3]. Ruan Pu differentiated and analyzed the color concepts involved in art history research in his work Several Concepts in the Study of Chinese Painting History and Theory, which helps this research maintain academic rigor in theoretical expression [4]. Whitfield, in the article "Color Symbolism and Religious Expression in Dunhuang Murals", explored the symbolic meanings of the colors in the murals and their roles in religious narratives. This provides an important reference for this study to analyze the relationship between color and religious culture [5]. Fuchs, in “A Comparative Study of the Differences in Color Cultures of Murals Between the East and the West”, compared the differences in color concepts and expression methods between Eastern and Western murals, pointing out that Eastern murals place more emphasis on symbolism while Western Renaissance murals stress realism, providing a theoretical basis for the cross - cultural comparison in this paper [6]. Katz, in The Basics of Color Theory: From Itten's Color Wheel to Modern Applications, systematically sorted out the development process and application methods of the color wheel theory, and is particularly applicable as theoretical support for this research when analyzing the color matching of murals from the Tang Dynasty [7]. Li Zuixiong, in Analysis of Pigments in Tang Dynasty Murals at Mogao Grottoes, revealed the properties and stability of the pigments in Tang Dynasty murals using chemical analysis methods, providing a data basis for this study to further explore pigment durability [8]. Li Hongyan, in Playing the Movement of Colors: A Study on the Color Art of Dunhuang Murals in the Flourishing Tang Dynasty, analyzed the aesthetic characteristics of the colors of murals in the Flourishing Tang Dynasty and their functions in picture composition, supplementing the research on colors at the artistic expression level [9]. Wu Xingxi, in Exploration and Research on the Color Rules in the Murals and Architecture of Dunhuang Grottoes, discussed

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the interactive relationship between mural colors and architectural space, providing a spatial dimension reference for this study to understand the role of colors in the overall artistic layout [10]. Overall, existing studies have achieved relatively comprehensive results in terms of the cultural symbolism of colors, the material basis of pigments, and the analysis of historical backgrounds. However, there are still shortcomings in two aspects: first, the systematic quantitative analysis of the color matching rules of Tang Dynasty murals based on color science (such as the color wheel theory); second, the exploration of the detailed manifestations of color differences between Chinese and Western murals in a cross-cultural context. Building on previous studies, this paper will integrate color wheel theory, pigment technology analysis, and Sino-Western comparative research to fill this academic gap, thereby providing methodological innovation and a cross-cultural perspective for the study of ancient colors.

3. Analysis of the application of pigments in Tang Dynasty murals of Dunhuang Mogao Grottoes

3.1. Main types and sources of pigments

The commonly - used pigments in Tang Dynasty murals of Dunhuang Mogao Grottoes include azurite, malachite green, cinnabar, ochre, chalk, etc. Azurite and malachite green are derived from natural ores. They are made into pigments through processes such as crushing, grinding, and elutriation. They have strong color stability and remain bright and eye - catching after thousands of years. Cinnabar, as a red pigment, has mercuric sulfide as its main component and is obtained from mineral mining. Its rich red color has become an important color for expressing sacred and solemn scenes in murals. Ochre is mostly sourced from local natural hematite, presenting a warm brown tone and is often used to outline contours and express layers. Chalk, as a white pigment, is composed of calcium carbonate and provides the basic background color and highlight performance for murals.

3.2. Impact of pigment production techniques on color

The craftsmen in the Tang Dynasty accumulated rich experience in pigment production. Different degrees of fineness in grinding ore pigments will directly affect the lightness and purity of colors. For example, azurite that is finely ground has a brighter color and higher purity and is used to represent the sky, costumes, etc., creating an ethereal and gorgeous visual effect; while azurite that is ground somewhat coarsely has a relatively calm color and can be used for background rendering or matching with other colors. The mixing process of pigments also has unique characteristics. Different proportions of azurite and malachite green mixed can produce various blue - green tones, which are suitable for different themes and scene requirements in murals, demonstrating the Tang Dynasty craftsmen's precise control over the subtle changes in colors.

4. Exploration of the color - matching rules of Tang Dynasty murals based on the color wheel theory

4.1. The relationship between the color wheel theory and mural colors

The color wheel theory, especially Itten's color wheel, classifies colors into primary colors (red, yellow, blue), secondary colors (orange, green, purple), and tertiary colors. It emphasizes the role of color relationships in visual effects and emotional expression. The color - matching characteristics

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of the murals in the Mogao Grottoes of the Tang Dynasty highly conform to this theory. Three primary colors, namely cinnabar (red), ochre yellow, and azurite (blue), occupy a core position in the murals, symbolizing solemnity, brilliance, and purity respectively. Secondary colors are obtained through pigment mixing. For example, the orange color made from cinnabar and ochre is used for skin tones and decorations; the turquoise color from the mixture of azurite and malachite green is used for landscapes and plants; the purple color synthesized from cinnabar and azurite, commonly seen in high - grade decorations, conveys a sense of nobility. The craftsmen of the Tang Dynasty did not mechanically follow the color wheel. Instead, they flexibly used colors by combining religious themes and the layout of the murals. In Buddhist scenes, they often used cold - warm contrasts to enhance the sense of sacredness, and in borders and patterns, they preferred adjacent colors to create harmony. The color wheel analysis shows that their color system not only follows scientific laws but also reflects artistic creativity.

4.2. Application of contrasting colors and complementary colors

In the use of colors, the murals in the Mogao Grottoes of the Tang Dynasty are skilled at leveraging the visual tension of contrasting colors and complementary colors to enhance the impact and appeal of the pictures. Contrasting colors refer to color combinations with obvious hue differences and located at the far ends of the color wheel. In contrast, complementary colors are positioned directly opposite each other on the color wheel, featuring opposite hues and a relatively large difference in lightness. In Tang - Dynasty murals, the combination of cinnabar (red) and azurite (blue) is the most typical application of complementary colors. This matching is extremely common in murals with religious themes. For example, the background of Buddha statues is often rendered with a large area of azurite, and the clothing or decorative details are complemented with cinnabar. Thus, the main figure is highlighted in the contrast between cold and warm tones, creating a solemn, sacred, and otherworldly atmosphere. Besides the complementarity of red and blue, high - contrast combinations such as yellow - purple and orange - blue are also frequently seen in Tang - Dynasty murals. For instance, in the treatment of Buddha's light and the background, ochre yellow and purple are often placed side by side, making the radiance appear brighter and more intense; in architecture and decoration, the combination of orange patterns and a blue base color enhances the recognizability of the patterns. It is worth noting that when using contrasting colors, the craftsmen of the Tang Dynasty did not pursue an absolutely balanced proportion of color blocks. Instead, they adopted the “main color - secondary color” mode: one color occupies the main area, and the other color is used as an embellishment. In this way, the visual focus brought by the color conflict is maintained, and the imbalance of the picture is avoided.

4.3. Application of adjacent colors and harmonizing colors

In the color system of the murals in the Mogao Grottoes of the Tang Dynasty, the application of adjacent colors occupies an important position. Adjacent colors refer to colors that are adjacent to each other on the color wheel. Their hue differences are relatively small, and the visual transition is natural and gentle, which can create a stable and harmonious picture atmosphere. For example, the combination of ochre (brownish - brown) and cinnabar (red) has similar hues and not much difference in lightness. It is often used to render the skin color, clothing, and decorative patterns of figures, making the picture have both color changes and maintain overall coordination. The combination of malachite green (green) and azurite (blue) is also typical. The two are adjacent and have the same cool color tone. They frequently appear in the depiction of landscape backgrounds,

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plants, and the decoration of Buddha statues. It not only reflects the real texture of natural scenes but also brings a peaceful and elegant visual experience.

The use of harmonizing colors in Tang - Dynasty murals further enhances the overall aesthetic balance. Neutral colors such as chalk play a transitional and buffering role in the picture. They can not only reduce the visual fatigue caused by highly saturated colors but also strengthen the outline of objects through highlight rendering. For example, on the richly - colored clothing of Buddha statues, using white lines or highlight embellishments not only makes the shapes more three - dimensional but also makes the complex color combinations more orderly. Some murals also form soft transition colors by mixing adjacent colors. For example, by harmonizing azurite with a small amount of malachite green, a turquoise color is obtained, which is used to represent the sky and water surfaces, enhancing the layering and naturalness of the picture.

The combination of adjacent colors and harmonizing colors not only reflects the profound understanding and superb skills of Tang - Dynasty craftsmen regarding color relationships but also shows their ingenious balance between visual psychology and religious aesthetics. It not only satisfies the solemnity and symbolism of the picture but also makes the overall color tone gentle and harmonious, conforming to the spiritual connotations of tranquility and compassion in Buddhist art.

5. Comparison with the colors of murals from the Western Renaissance period

5.1. Differences in color concepts

Murals from the Western Renaissance period were influenced by the trend of scientific rationality. They emphasized the realism of colors and the expression of light and shadow, pursuing the true reproduction of natural colors. For example, in The Last Supper by Leonardo da Vinci, delicate color transitions and changes in light and shadow are used to shape characters and create a spatial atmosphere, with colors serving the purpose of realistic narration

In contrast, the color concept of murals in the Mogao Grottoes of the Tang Dynasty originated from religious beliefs and Eastern aesthetics. It placed more emphasis on the symbolism and decorativeness of colors. Subjective colors were used to express religious artistic conceptions and spiritual connotations. For instance, gold was used to symbolize the divine radiance of Buddhist teachings, and colors became symbols for conveying religious emotions and cultural meanings.

5.2. Comparison of color-matching methods

In terms of color - matching, Renaissance murals often rely on the scientific principle of color perspective to construct a sense of real space. The combination of colors focuses on simulating the color relationships in the natural environment

Tang - Dynasty murals, however, adopt subjective color - matching based on the color wheel. They make freer use of contrast and harmony, breaking free from the constraints of natural colors and creating a surreal color world of the Buddhist land. For example, Michelangelo’s ceiling paintings in the Sistine Chapel, although featuring rich colors, serve the overall purpose of realistic human figure shaping and space creation. In contrast, Tang - Dynasty murals, by virtue of their unique color - wheel - based color - matching logic, present a planarized and decorative color aesthetic. For instance, the splicing of large - area solid color blocks in the murals forms strong visual symbols.

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5.3. Shaping of colors by cultural contexts

During the Western Renaissance, humanism emerged. Colors were used to showcase the beauty of humanity and nature, reflecting the concern for the real world. The Tang Dynasty was at the height of China's feudal society, with a prosperous religious culture. The colors of murals served religion, conveying religious doctrines and spiritual sustenance. Behind the colors was a profound Eastern religious cultural context. For example, the colors in Dunhuang murals carry the imagination and pursuit of the Buddhist Pure Land; while the colors of Renaissance murals reflect the exploration of human reality and the value of humanity. Differences in cultural contexts lead to huge divergences in color art presentation.

6. Conclusion

The research result of this study is that, by systematically sorting out the types, sources, and production techniques of pigments in the Tang - Dynasty murals of Dunhuang Mogao Grottoes, analyzing the color - matching rules in combination with the color wheel theory, and conducting cross - cultural comparisons with Western Renaissance murals, it is found that the Tang - Dynasty murals, in aspects such as the use of primary and secondary colors, the matching of contrasting and complementary colors, and the balance of adjacent and harmonizing colors, present a high unity of scientific nature and creativity. The fine grinding and blending techniques of mineral pigments not only ensure the thousand - year - long durability and vividness of colors but also shape a unique and stable aesthetic pattern. Cross - cultural comparisons further reveal the unique values of Eastern religious murals in terms of color symbolism and spirituality, as well as the fundamental differences from Western realistic art in function and expression. From this, a further conclusion is drawn that the color style of Tang - Dynasty murals is a product of the deep integration of technology, art, and culture. It not only follows the scientific laws of colors but also contains profound cultural and religious symbolic meanings.

This research provides significant reference value for future studies in this direction. Firstly, at the academic level, it breaks through the limitation of traditional art history research that only stays at aesthetic description, and constructs an analytical framework combining "color science + art history". Secondly, at the practical level, it offers theoretical basis and technical references for the protection, restoration, and innovative application of traditional mineral pigments, which can directly serve mural restoration, artistic creation, and cultural and creative design. Thirdly, at the international communication level, the cross - cultural comparison method helps to deepen the comparative study of Chinese and Western art, and promotes the global dissemination and understanding of ancient Chinese art achievements.

Future research should focus more on two aspects. First, introduce high - precision scientific detection techniques such as digital sampling and spectral analysis to conduct quantitative measurement, chromatographic modeling, and long - term change monitoring of the colors of Dunhuang murals, and establish an authoritative Dunhuang color database. Second, combine materials science, art design, and cultural creativity to systematically transform the color system of Tang - Dynasty murals into a modern applicable visual language, and explore its innovative applications in fields such as architectural decoration, public art, clothing design, and digital media. Through continuous scientific research and artistic practice, the thousand - year - old colors of Dunhuang will not only rejuvenate the academic field but also become a cultural bridge connecting the past and the present, and communicating China and the West.

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