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An Analysis of Ancient Cinnabar Applications and Its Mineral Sources

Wenting Wang, Dengyi Zhang*

Department of History and Cultural Heritage, Beijing Union University, Beijing 100000, China

Abstract: Cinnabar, also known in ancient times as vermilion or cinnabarite, is the red mineral pigment with the longest history of use and widest range of applications in Chinese history. Since prehistoric times, cinnabar has been extensively employed in burial practices—sprinkled in grave soil, applied to human bones, or spread across tomb floors—carrying significant religious and ceremonial significance. Simultaneously, its vivid color and stable properties made it indispensable in practical daily applications like painting, textile dyeing, document writing, and cosmetic adornment. Notably, major archaeological sites revealing extensive cinnabar usage are concentrated in the Central Plains regions along the Yellow and Yangtze rivers, while the primary mineral deposits of cinnabar are located in China's southwest. This geographical disparity between production and consumption raises a crucial question: How did cinnabar travel such distances to reach the Central Plains? What material exchange networks did this reflect? This paper delves into the ancient applications of cinnabar, examining recent scientific studies on its provenance through the analysis of both advancements and limitations in these methodologies.

Keywords: Cinnabar; Cinnabar Applications; Cinnabar Ore Sources

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1 Introduction

Cinnabar, also known as cinnabarite, is a natural mercuric sulfide (HgS). Due to its vivid color and unique physicochemical properties, it has held a distinctive and enduring position in ancient Chinese culture and beliefs. Domestic research on cinnabar has evolved from simple phenomenological descriptions to in-depth explorations of its sociocultural significance and resource circulation patterns. This progression is closely intertwined with the development of Chinese archaeology. Early studies predominantly appeared in archaeological reports, primarily involving preliminary identification and documentation of red substances [1-3]. However, the excavation of major sites such as the Fu Hao Tomb at Yinxu [4], the Mawangdui Han Tombs [5], the Terracotta Army of Qin Shi Huang [6], and the Taosi Site [7] yielded abundant cinnabar artifacts. This prompted scholars to systematically examine its functions and symbolic meanings across different historical periods and cultural contexts. From the late 20th to early 21st century, deepening research into archaeological cultural lineages and social structures propelled cinnabar studies into a phase of functional categorization and preliminary interpretation. Scholars examined its applications across multiple sites in funerary rites, decorative painting, and writing, integrating textual and ethnographic materials to decipher its conceptual significance [8-10]. Since the 2010s, advancements in scientific archaeology have revitalized cinnabar research. The application of modern analytical techniques such as X-ray diffraction, Raman spectroscopy, and scanning electron microscopy with energy dispersive spectroscopy [11] enabled precise, non-destructive identification of the composition of red pigments excavated from archaeological

*Corresponding author: Dengyi Zhang, wwt04210927@163.com

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sites. This facilitated the differentiation between cinnabar and other red pigments, laying a scientific foundation for subsequent research.

More importantly, the integration of technological methods has spawned new avenues for academic growth. When archaeologists focused on the origins of cinnabar, they uncovered an intriguing phenomenon: many core prehistoric to Xia-Shang-Zhou period sites yielding cinnabar—such as Taosi, Erlitou, and Yinxu—were located in the middle and lower reaches of the Yellow River, while China's primary cinnabar deposits were concentrated in southwestern regions like Guizhou, Hunan, and Chongqing. This geographical disconnect raises a critical question: “How did cinnabar travel hundreds or even thousands of kilometers from its source to consumption sites?” This has spurred research into cinnabar's origins and the underlying exchange networks, becoming a hot topic over the past decade. In summary, domestic research on ancient cinnabar has evolved into a multidisciplinary field characterized by deepening topics and continuously updated methodologies. This paper aims to systematically outline the main threads and core achievements in this field, focusing on the multifaceted evolution of cinnabar's functions and its resource circulation and provenance issues. Based on clarifying the current state of research, it also looks ahead to potential future research directions.

2 Analysis of Cinnabar Applications

Cinnabar was extensively utilized in ancient times, with its usage patterns falling into two categories: non-utilitarian and utilitarian. Throughout the history of cinnabar research, early scholars focused particularly on its non-utilitarian functions, such as its role in religious and ceremonial contexts. As studies deepened, cinnabar's practical applications were progressively uncovered. In certain instances, cinnabar may serve both utilitarian and non-utilitarian purposes simultaneously. For narrative clarity, this paper separately examines these two types of utilization.

2.1 Non-utilitarian Functions

The non-utilitarian functions of cinnabar primarily refer to its use by ancient peoples for symbolic and ritualistic purposes. In archaeology, cinnabar's non-utilitarian role is most prominently manifested in funerary rites, forming one of the most striking and extensively studied cultural phenomena. The earliest practice of burying red minerals dates back to the late Paleolithic Upper Cave Man. Although hematite powder was used at that time, this practice has been widely interpreted by scholars as reflecting primitive human concepts of the soul and the worship of life [1]. Based on existing archaeological discoveries, cinnabar began playing a significant role in the funerary rites of prehistoric nobility in China starting around the mid-Yangshao period, approximately 6,000–5,000 years ago. Its primary uses included the following methods.

2.1.1 Incorporation into Grave Fill Soil

The practice of mixing cinnabar into grave fill soil was relatively common. For instance, two small patches of cinnabar residue were discovered approximately one meter from the grave opening at the southwest corner of Tomb M27 in the Yangshao Culture cemetery at Xipo, Lingbao, Henan [12]; cinnabar traces were also found near the burial goods in Tomb M8 [13]. Red cinnabar pigment was found mixed within the burial fill of Tomb 87M4 at the Lingjiatan site in Hanshan, Anhui [14]. Similarly, cinnabar inclusions were observed in the burial fill of Tomb M10 at the Longwangshan burial ground in Jingmen, Hubei [15].

2.1.2 Human Bone Lacquered with Cinnabar

This phenomenon is relatively common in archaeological findings. For instance, the skull and left humerus from Tomb M45 at the Wangwan site in Luoyang were coated with cinnabar, which had darkened to a reddish hue. Additionally, three other tombs exhibited cinnabar coating on skulls; all these tombs featured wooden coffins and date to the middle-late phase of the Yangshao culture [16]. Large tombs of the Songze Culture, such as Tomb M15 at the Wudun site in Wujin, Changzhou, featured a thin layer of cinnabar applied to the deceased's chest and knee areas [17]. At the Xuejiagang Culture's Ludun site, burials M2 and M21 both exhibited cinnabar coating on the cranial vault [18]. Similar skeletal cinnabar staining, likely caused by cinnabar impregnation, was also observed in the Taosi Culture [19].

2.1.3 Burial Goods Coated with Cinnabar

The phenomenon of burial goods coated with cinnabar is also frequently observed in archaeological records. For instance, thirteen cord-marked pottery shards discovered at the Xianrendong site in Wannian, Jiangxi, were coated with cinnabar [20]. Artifacts such as the jade palette, mortar, and pestle unearthed from the tomb of Lady Fu Hao all bear traces of long-term cinnabar use [21]. A large-mouthed jar unearthed from Tomb M8 at the Yangshao Culture cemetery in Xipo, Lingbao, Henan, showed cinnabar traces on its rim. Analysis confirmed the substance to be mercuric sulfide, i.e., cinnabar [12]. Similar indications of cinnabar use were also found in large-mouthed jars and fill soil in Tomb M27 and others [13].

2.1.4 Cinnabar Lining of Tomb Bases

The custom of applying cinnabar to tomb floors emerged around the middle to late Yangshao period. For instance, Tomb M2 at the Shaoqing Mountain site of the Songze culture in Kunshan, Jiangsu, featured a base covered with cinnabar powder [22]. Similar phenomena were also discovered at the Dawenkou culture cemetery in the northern area of the Huating site in northern Jiangsu [23], Jiangyin Gaochengdun M5 tomb in Jiangsu [24], and the Qingliangsi burial ground in Ruicheng, Shanxi [25]. By the late Yangshao period, the use of cinnabar and burial vessels became more widespread and standardized at individual sites, beginning with the Taosi site of the Taosi culture. Analysis of excavation data indicates that the use of cinnabar and burial vessels in large and medium-sized tombs at Taosi was a widespread practice, applicable regardless of gender [26]. Furthermore, this phenomenon persisted throughout the entire duration of the Taosi culture [27]. Evidently, the use of cinnabar in tombs had become an institutionalized practice, and those permitted to employ cinnabar in funerary rites clearly held a certain social status. This practice persisted through the Erlitou and Erligang cultures, evolving into a crucial component of the burial system for nobility across the Xia, Shang, and Zhou dynasties. However, by the late Shang Dynasty and into the Zhou Dynasty, the custom of cinnabar burial gradually declined. This shift may be linked to the rise of alchemy and the demand for mercury plating in bronze mirrors, as cinnabar increasingly found use in alchemical practices and mercury production. Consequently, the tradition of lining tomb floors with cinnabar disappeared [28].

From a religious perspective, cinnabar's symbolic significance primarily stems from its vivid red color. Red is closely associated with the sun and blood, making it a particularly prevalent belief in early human societies. The religious meaning of cinnabar manifests in two main aspects: first, as a means to ward off disasters and seek auspiciousness. Sprinkling cinnabar on the deceased symbolized bestowing new life, while also embodying protection, disaster avoidance, and blessings [29]; Second, it serves to suppress evil spirits and impurities. Li Dongyuan's Yuan Dynasty text, The Supplement to the Pearl Sack: The Attributes of Medicinal Substances, records cinnabar's efficacy in “dispelling evil and warding off ghostly disturbances” and “stabilizing the spirit” [30]. Cinnabar burial rites embody the fusion of these dual meanings: while hoping the deceased enter a blessed heavenly realm, there is also apprehension about their potential return to cause harm, hence the use of cinnabar as a talismanic charm.

2.2 Practical Applications

Cinnabar's practical applications are evident in multiple aspects. Its vivid red color, stable chemical properties, and wide applicability have made it highly favored in human art, artifact decoration, and daily life.

2.2.1 Artistic Decoration

Cinnabar was extensively used in prehistoric painted pottery [31], Qin and Han dynasty terracotta warriors [32], lacquerware from successive dynasties [33, 34], and cave temple murals such as those at the Dunhuang Mogao Caves [35], Tianshui Maijishan Grottoes [36], and Datong Yungang Grottoes [37]. These Buddhist art treasures have endured for millennia, with cinnabar—renowned for its rich hue, strong coverage, and resistance to fading—serving as a pivotal pigment for depicting central figures, evoking religious ambiance, and signifying hierarchical distinctions. Artisans mastered cinnabar to perfection, employing it alone to render pure red or blending it with white lead ore and calcite to create pinks and flesh tones. Combined with other mineral pigments, it formed a rich chromatic system.

2.2.2 Daily Life

The application of cinnabar permeated every aspect of ancient daily life. Archaeological discoveries indicate that by the Shang Dynasty at the latest, cinnabar had been used for dyeing textiles. For instance, textiles unearthed from the Shang Dynasty tomb at Liujiahe, Pinggu, Beijing, were coated with cinnabar [38], while silk and hemp fabrics from the Fu Hao tomb at Yinxu, Anyang, Henan, were also dyed with cinnabar [39]. The vermilion-red diamond-patterned silk robe unearthed from the Mawangdui Han Tombs was identified as cinnabar [40]. Additionally, cinnabar was employed in cosmetics; for instance, a lacquered cosmetic set from the Western Han tomb at Huohe, Haizhou, Lianyungang, contained a small round box holding red powder identified as mercuric sulfide [41]. Historically, cinnabar was also extensively employed in calligraphy. Traces of cinnabar writing appear in alliance documents from the Spring and Autumn and Warring States periods [42], as well as in Qin bamboo slips, Han bamboo slips, imperial edicts, and imperial approvals throughout successive dynasties. This tradition persisted until the late Qing Dynasty.

In summary, cinnabar's primary practical functions were decoration and marking. It was widely used to adorn vessels, garments, and other objects, and served as an important identifier through its red ink. Cinnabar's vivid vermilion hue not only satisfies humanity's primal aesthetic desire for color but also ensures the longevity of painted art, textile dyeing, and written records due to its stable chemical properties. As an exceptional coloring material, cinnabar held immense practical and artistic value in ancient societies.

3 Exploration of Cinnabar Mining Sources

As archaeological discoveries continue to expand, a thought-provoking phenomenon has emerged: numerous pre-Qin archaeological sites yielding significant cinnabar deposits are concentrated in the core Central Plains region along the middle and lower reaches of the Yellow River and the Yangtze River basin. In contrast, the primary cinnabar deposits currently identified are highly concentrated in China's southwestern regions [43] (See Figure 1 and Figure 2). This marked spatial disjunction has prompted scholars to shift their research focus from consumption to supply. Consequently, the question of cinnabar's “source tracing” and the underlying long-distance distribution networks and control mechanisms it implies have become both a frontier and a challenge in research over the past two decades.

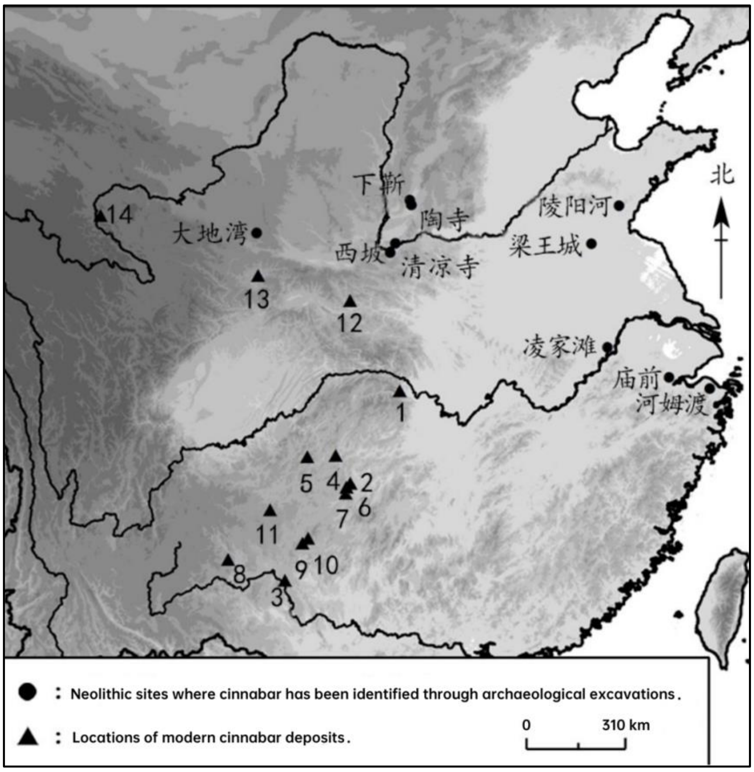

Figure 1 Distribution of Cinnabar Sites Unearthed from China's Neolithic Era and Comparison with Modern Cinnabar Deposits (Redrawn from Dong Yu and Fang Hui, 2017, Figure 1

1. Hubei Province 2. Hunan Province 3. Guangxi Zhuang Autonomous Region 4. Chongqing Municipality 5–11. Guizhou Province 12. Shaanxi Province 13. Gansu Province 14. Qinghai Province

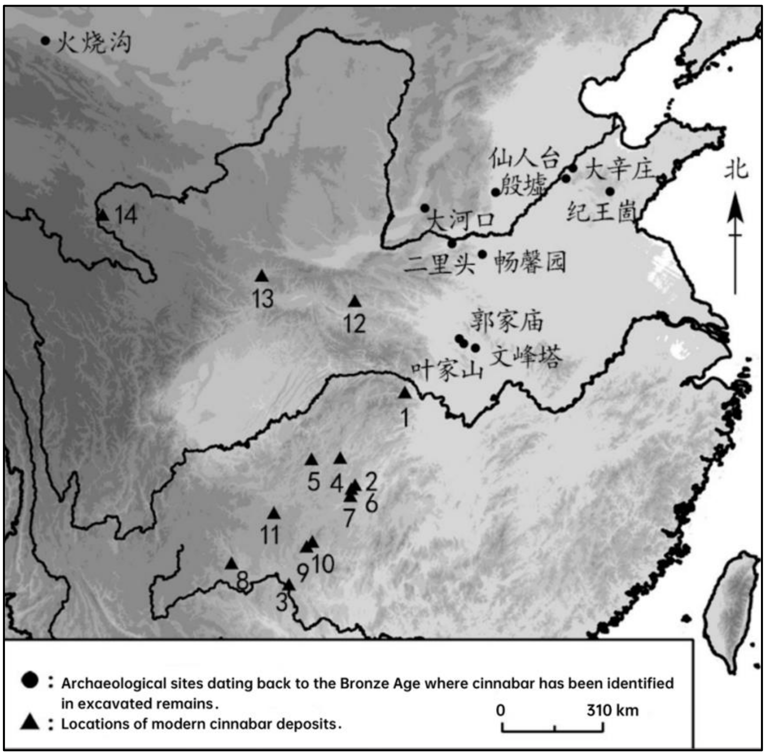

Figure 2 Comparison of the Distribution of Cinnabar Sites Unearthed from China's Bronze Age and Modern Cinnabar Deposits (Redrawn from Dong Yu and Fang Hui, 2017, Figure 2

1. Hubei Province 2. Hunan Province 3. Guangxi Zhuang Autonomous Region 4. Chongqing Municipality 5–11. Guizhou Province 12. Shaanxi Province 13. Gansu Province 14. Qinghai Province

It is difficult to pinpoint the exact origin of cinnabar based solely on archaeological evidence and historical records. Historical texts indicate that early cinnabar deposits were predominantly located in southwestern China. The Classic of History: Yu Gong records that Jingzhou contributed cinnabar, suggesting that the southwestern region once supplied cinnabar to the royal court in the Central Plains. Later herbal compendia frequently evaluated the quality of cinnabar varieties named after their origins, such as “Chen sand” and “Yue sand.” However, similar to archaeological evidence, historical records alone struggle to correlate specific sites with precise production locations. Therefore, scientific methods such as chemistry become indispensable. To overcome this limitation, the integration of scientific archaeology is essential. Researchers must first accurately identify red substances within archaeological remains through scientific means. The widespread application of modern analytical techniques—such as X-ray diffraction analysis, Raman spectroscopy, and scanning electron microscopy with energy dispersive spectroscopy—enables effective differentiation between cinnabar (HgS) and other red pigments with similar appearances, such as hematite (Fe_2O_3) and red lead (Pb_3O_4). This establishes a robust foundation for material identification in subsequent provenance studies, preventing the confusion of different minerals.

Once cinnabar is confirmed, tracing its origin becomes the core challenge. Currently, stable isotope analysis is widely recognized as the most promising method. Among these, sulfur isotope analysis has seen some exploratory applications abroad. Japanese scholars discovered through sulfur isotope analysis that cinnabar unearthed from Japanese tombs dating from the 1st to 6th centuries primarily originated from China during the 1st century, shifting to domestic mineral sources from the 3rd to 6th centuries [44]. Swiss researchers employed the same technique to compare the isotopic signatures of cinnabar used in Roman-period murals against multiple European mineral sources, ultimately determining its origin to be Spain [45]. However, in-depth studies reveal that sulfur isotope values from many major Chinese mercury mines exhibit a wide distribution range with significant overlap, posing substantial challenges for precisely identifying the provenance of specific archaeological samples. Nevertheless, for samples exhibiting extreme or distinctive isotopic signatures, this method still provides crucial constraining information. For instance, it has pinpointed the origins of certain archaeological samples to specific mining regions such as Qinghai, Xunyang in Shaanxi, or Kaiyang in Guizhou [11].

More advanced mercury isotope analysis techniques, with their potentially higher resolution, have demonstrated significant potential in international archaeological research. This technology not only measures mass-dependent fractionation of mercury but also captures non-mass-dependent fractionation effects [11]. This enables the construction of more refined and unique "fingerprint" profiles. Although its application in archaeology is currently limited to analyzing the provenance of cinnabar excavated from Peruvian archaeological sites, researchers have distinguished the sources of cinnabar from different periods by combining $\delta^{202}Hg$ and $\Delta^{199}Hg$ data: pre-Inca and colonial samples primarily originated from the Wankareliquica mine in Peru, while some Inca-period samples may have come from Colombia. This confirms the technique's effectiveness in tracing ancient cinnabar circulation routes [46]. While mercury isotope analysis offers feasibility for determining the origin of cinnabar from archaeological sites, its application in tracing domestic archaeological cinnabar remains in the preliminary exploration and data accumulation phase. Scholar Fang Hui suggests foundational work still needs to be done. The core methodology involves: first establishing an isotopic database of mercury mines potentially exploited during the pre-Qin period; then comparing this with excavated cinnabar samples to infer specific mineral sources; and finally integrating spatial information to reconstruct ancient distribution networks.

4 Summary and Outlook

Throughout the history of cinnabar research, scholars' focus has gradually shifted from simple descriptions of cinnabar as a material substance to deeper explorations of its role in sociocultural contexts and regional exchanges. Cinnabar played a significant role in ancient Chinese civilization due to its vivid red color, stable physical properties, and scarcity. It served as both a symbol of religious belief—an indispensable sacred item in aristocratic funerary rites—and a vital material for artistic creation, decorative arts, and writing, fulfilling practical needs of the ancients. These dual functions were often intertwined, transforming cinnabar from an ordinary mineral into a unique symbol imbued with cultural significance. Simultaneously, archaeological discoveries reveal that many sites yielding cinnabar lie far from its primary mineral deposits. This geographical disparity between "source regions" and "consumption sites" reflects the complexity of resource circulation and social interaction during that era. Consequently, tracing the origins of cinnabar has become a prominent academic focus in recent years.

Modern scientific archaeological methods have provided new breakthroughs for cinnabar research. Techniques such as X-ray diffraction and Raman spectroscopy can accurately identify cinnabar components in archaeological samples, while sulfur isotope and mercury isotope analyses offer new possibilities for tracing cinnabar sources. However, current research still faces challenges, including an incomplete mineral source database, overlapping isotopic signatures across different mining areas, and alterations in samples during burial processes. Therefore, future efforts should focus on refining the database of mining region characteristics. This should be combined with sampling and scientific analysis of potential ancient mining sites, supported by historical records and archaeological clues. Additionally, research should explore whether cinnabar from different sources was intentionally used for specific religious rituals or social classes, and how changes in resource acquisition methods influenced usage patterns and cultural significance at consumption sites. By integrating cinnabar with comparative analyses of circulation systems for other critical resources—such as jade, copper, and salt—we can gain a more comprehensive understanding of its socio-economic role across historical periods. Moving forward, deepening multidisciplinary collaboration in cinnabar research promises to advance our comprehension of ancient resource utilization, symbols of power, and cultural exchange, revealing its unique status and profound influence within ancient Chinese civilization.

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