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SCIENTIFIC AND ARCHAEOLOGICAL STUDY OF PURPLE OCTAGONAL CYLINDRICAL ITEM EXCAVATED FROM THE HEJIA CEMETERY, XIANYANG, SHAANXI, CHINA AND THE ISSUES RELATED TO IT

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Abstract. In this paper, we chose late war purple octagonal prismatic ware excavated at the Hejia Cemetery in Xianyang as the object of study, and carried out scientific analysis using ultra-deep field microscopy, scanning electron microscopy and energy spectrum analysis, X-ray diffraction, and microscopic Raman spectroscopy. First of all, the features of the formation and weathering process were determined, then the samples of unweathered areas obtained by the sectioning method were examined, and it was confirmed that all 12 samples are barium copper silicate with the main phases of Chinese violet ($BaCuSi_2O_6$) and Chinese dark blue ($BaCu_2Si_2O_7$) colors. Based on compositional characteristics, etc. it was also found that this group of purple octagonal vessels embodies two different manufacturing processes and may represent an evolution of the process from lead-barium glass to cupro-barium silicate. On this basis, issues such as the population, distribution area and functional characteristics of this type of dish are discussed in order to obtain new ideas and evidence for relevant research.

Keywords: Hejia Cemetery, Barium Copper Silicate, Eight Prism, Late Warring States Period, Production Technology

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НАУЧНЫЙ АНАЛИЗ ФИОЛЕТОВОГО ВОСЬМИУГОЛЬНОГО СТОЛБЧАТОГО ИЗДЕЛИЯ, НАЙДЕННОГО НА МОГИЛЬНИКЕ ХЭЦЗЯ, СЯНЬЯН, ШЭНЬСИ, И СВЯЗАННЫЕ С ЭТИМ ВОПРОСЫ

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Резюме. В данной работе в качестве объекта исследования выбрано фиолетовое восьмиугольное призматическое изделие периода поздней войны, найденное на могильнике Хэцзя в Ся-

ньяне, и проведен научный анализ с использованием методов сверхглубокой полевой микроскопии, сканирующей электронной микроскопии и анализа энергетического спектра, рентгеновской дифракции и микроскопической рамановской спектроскопии. В первую очередь были определены особенности формирования и процесса выветривания, затем исследованы образцы невыветрившихся участков, полученные методом секционирования, и подтверждено, что все 12 образцов представляют собой силикат меди бария с основными фазами китайского фиолетового ($BaCuSi_2O_6$) и китайского темно-синего ($BaCu_2Si_2O_7$) цвета. На основании композиционных характеристик было также установлено, что данная группа фиолетовых восьмиугольных изделий воплощает два различных производственных процесса и может представлять собой эволюцию процесса от свинцово-бариевого стекла к медно-бариевому силикату. На этой основе обсуждаются такие вопросы, как популяция, ареал распространения и функциональные характеристики данного типа изделий с целью получения новых идей и доказательств для соответствующих исследований.

Ключевые слова: могильник Хэцзя, силикат меди с барием, восьмиугольный столб, поздний период Воюющих государств, процесс производства

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Introduction

Hejia Cemetery is located in the former site of Hejia Village, Zhouling Town, Weicheng District, Xianyang, Shaanxi Province.,on the second level platform of the north bank of Weihe River, 10.4 kilometers east from the ruins of Xianyang City, Qin Dynasty. At present, more than 1,400 tombs have been excavated, most of which are from the late Warring States Period to the Qin Dynasty, and should be the civilian cemetery in Xianyang City of the Qin Dynasty (Shaanxi Provincial Institute of Archaeology, 2021). A large number of columns were unearthed in the cemetery, made of coal essence, jade, glass etc. Among them, there are a batch of octagonal prisms in the shape is very characteristic, for the octagonal prisms, solid, diameter of about 1 cm and more severely weathered, it is difficult to distinguish the body material. After scientific testing, it was found that both its composition and structural characteristics indicate copper barium silicate Chinese purple ($BaCuSi_2O_6$) is its main raw material. This indicates that by the late Warring States Period at the latest, the craftsmen had been able to skillfully manufacture such artifacts and appeared as burial objects in civilian tombs.

Artificial copper barium silicate pigment system includes rich compounds, three of which are visible at present, namely Chinese purple ($BaCuSi_2O_6$), Chinese Blue ($BaCuSi_4O_{10}$) And Chinese Dark Blue ($BaCu_2Si_2O_7$).They represent the level of science and technology and achievements at that time, and many experts and scholars at home and abroad have paid some attention to and research on it. In 1983, F itzHugh et al. analyzed purple copper barium silicate (Elisabeth et al., 1983, pp. 15) in the pottery and bronze painted paints from the Warring States to the Han Dynasty, and later named it Han Purple (Elisabeth et al., 1992, pp. 145), namely Chinese purple. Based on previous studies on unearthed relics in China, it can be seen that Chinese purple appeared in the early Spring and Autumn Period (Ma Qinglin et al, 2006,

pp. 82; Ma Qinglin et al,. 2008), and was also used in glass products containing lead and barium in the Warring States Period, and was still widely used in the late Eastern Han Dynasty (Ma Qinglin et al., 2012; Gansu Provincial Museum, 2004). In the discovered purple copper barium silicate products, in addition to the shape of cylinders, beads, walls, rings and other objects, there is a kind of eight prism shape.

Eight prism is a special kind of ware unearthed from tombs from the Warring States Period to the Han Dynasty in China. It first appeared in the Central Plains and was popular in the northern areas of China from the late Warring States Period to the Western Han Dynasty (Sun Feng et al., 2020). At present, there are few studies on the purple silicate. On the one hand, most of these objects are covered with regolith, or only partially purple, and are often included in jade; on the other hand, the lack of archaeological excavation data has limited the progress of relevant research. A total of 24 Chinese purple octagonal prisms were unearthed in Hejia cemetery. Since the research objects of previous scholars were mostly samples unearthed under non-strict archaeological conditions, it is very important to use analytical instruments to carry out scientific research on these instruments. Then, this study tries to clarify the weathering appearance, technological characteristics and technical transmission of the purple eight-sided prisms represented by the cemetery from the late Warring States Period to the Qin Dynasty.

Materials and Methods

A total of 24 purple octagonal prisms were unearthed in Hejia cemetery, all of which were regular octagonal prisms and dated in the late Warring States Period. According to the color of the weathering layer, it can be divided into 4 categories, namely white, white, black, yellow and green. 12 of them are selected for scientific analysis in this paper (Table 1), and 3 in each category (Fig. 1). In this study, the weathering products were taken from the weathered hard aggregate layer outside the body, and the raw materials were sampled from the unweathered area in the center of the sample and all samples were well preserved, complete in shape and clear layers. In this study, we first observed the microscopic morphology of the sample under the ultra-field microscope and selected the subsequent element and phase analysis areas; then obtained the chemical composition information of the sample by scanning electron microscopy with energy dispersive spectrometer (SEM-EDS), then analyzed the sample by X-ray diffraction (XRD) to determine the main material; and finally used microscopic Raman spectrometer (micro-Raman) to study the weathering and degeneration process of the samples.

The ultra-deep field microscopy, scanning electron microscopy with energy dispersive spectromete, X-ray fluorescence spectroscopy and X-ray diffraction test in Northwestern university cultural heritage research and protection technology of the Ministry of Education key laboratory, before the start of the experiment using absolute ethanol to clean profile sample surface, powder samples are directly on the slides. The ultra-depth of field microscope is a KH-7700 ultra-depth of field 3D video microscope produced by Haoshi Company, Japan. The MX-5040 RZF lens and metal halogen cold light source are used to microobserve the samples at different magnification times. scanning electron microscopy with energy dispersive spectrometer are VEGA3XM tungsten filament scanning electron microscope produced by Czech TESCAN company, combined with X-ACT X-ray spectrometer produced by Oxford company, using conductive adhesive samples without spraying. For X-ray diffraction analysis, Smart LAB X-ray diffrtometer produced by Japan Corporation, metal copper target, standard Z sample

table, test conditions: scanning range 5°~90°, step length 0.01°, scanning speed 10s, voltage 40kV and current 150 mA.

Microscopic Raman spectrometer analysis was conducted at the School of Chemistry and Materials Science, Northwestern University, with the samples on a slide using a Thermo Fisher Scientific DXR 2 microscopic Raman imaging spectrometer produced by Thermo Fisher, USA, equipped with a 532nm laser, grating slit 25 μm, and a spectral range of 50 to 3500 cm^{-1}. Microscope ocular magnification was 10 x magnification and objective 50 x magnification.

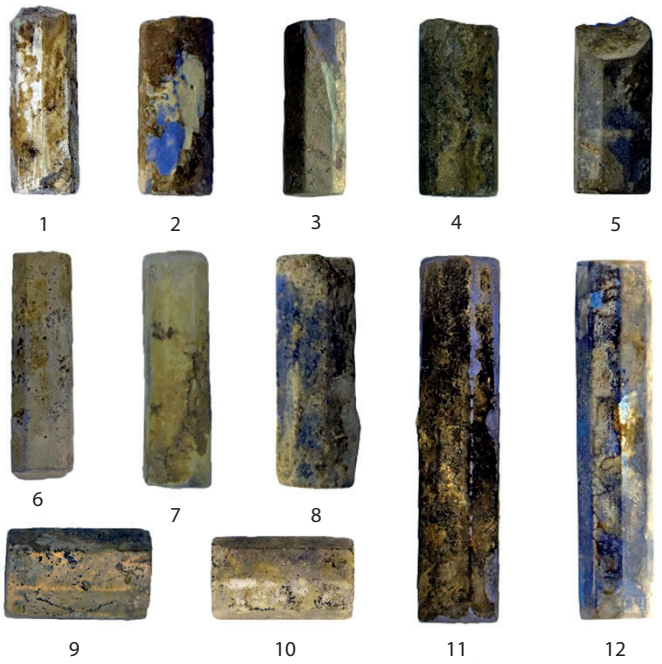

Fig. 1. Purple octagonal prisms unearthed in Hejia Cemetery: 1 – M336:6; 2 – M428:3; 3 – M442:1; 4 – 611:2; 5 – M615; 6 – M409:1; 7 – M874:3; 8 – M632:1; 9 – M145:3; 10 – M442:4; 11 – M740:6; 12 – M489:3

Рис. 1. Фиолетовые восьмигранные призмы, обнаруженные на могильнике Хэцзя: 1 – M336:6; 2 – M428:3; 3 – M442:1; 4 – 611:2; 5 – M615; 6 – M409:1; 7 – M874:3; 8 – M632:1; 9 – M145:3; 10 – M442:4; 11 – M740:6; 12 – M489:3

Test and Analysis Results

1 Reolith Detection and Analysis

(1) Microscopic Observation

Typical regolith samples with white (M336:1), black (M145:2), yellow (M611:3) and green (M874:3) were selected for microscopic observation (Figure 2). After comparison, it is found that the white sample is slightly yellow material; the black sample is a large amount of black material mixed with white, yellow and blue-purple particles; the yellow sample under the microscope is not significantly different from the macroscopic color; the green sample

has no green particles under the microscope, but consists of white, yellow and blue-purple particles. The analysis results show that there are at least white, black and yellow substances, and the green regolith may be produced by the mixture of yellow and blue-purple particles.

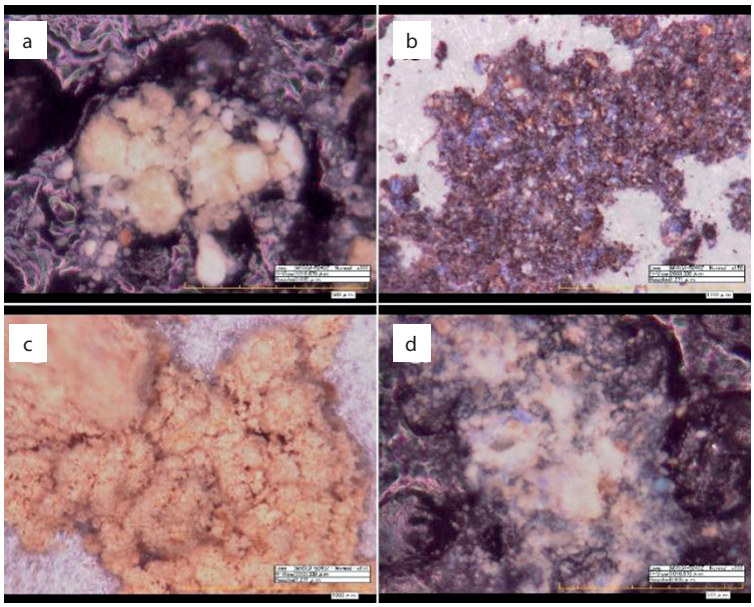

Fig. 2. Micrographs of the regolith samples: a – M336:1, white, 200; b – M145:2, black, 150; c – M740:8, yellow, 200; d – M874:3, green, 300

Рис. 2. Микрофотографии образцов реголита: a – M336:1, белый, 200; b – M145:2, черный, 150; c – M740:8, желтый, 200; d – M874:3, зеленый, 300

(2) Phase Composition

The above 4 typical samples were tested for weathered crust powder, resulting in Raman spectra and solution spectra. The picture in the upper right corner is the micrograph of the test area, and the test point falls on the positive central particle (Fig. 3).

The white particles are indicated for $PbSO_4$ (Fig. 3-*a*). The natural mineral of $PbSO_4$ .lead sulfate ore is formed by the oxidation of galena (PbS), which belongs to the common secondary mineral, with white, yellow, blue, gray and other colors. Galena is one of the main lead raw materials used in the ancient solid phase sintering process (Wang Yingzhu, 2019). In Chinese purple firing, lead raw material as a catalyst and cosolvent, Pb will not enter the final product, so the Chinese purple eight prism actually mainly consists of $BaCuSi_2O_6$, Lead compound and a small amount of the finished raw material and intermediates. During burial, Si, Ba, Cu and other elements are lost, leaving an insoluble lead salt, making the outer regolith white or light yellow.

The analysis shows (Fig. 3-*b*) that the black particles in the microfield field are amorphous carbon. Because there is no amorphous carbon source itself, and the occurrence of the black regolith has no correlation with the content of Pb, Ba and Cu, considering that the black on the regolith is contaminated from the outside.

Yellow particles contain two leadsalts, $Pb_{21}Cu_{20}Cl_{42}(OH)_{40}\cdot 6H_2O$ take part in $Pb_3O_2Cl_2$ (Fig. 3-*c*). According to the elemental analysis, the Cl content of yellow powder is 0.92% and S content is 5.22%, much higher than Cl. Therefore, Cl element should be introduced from the soil and react with the original Pb compound to form chlorine lead compound. Similar chlorine and lead compounds were also found in the analysis of Chinese blue beads unearthed from M21 in Majiayuan (Wang Ruosu et al., 2022).

In the Raman spectrogram (Fig. 3-*d*), the most obvious 460.81cm^{-1} With the 989.22cm^{-1}, The peak at belongs to lead sulfate ($PbSO_4$), Lead sulfate is the main component of lead alum or lead sulfate ore, the natural crystal color is colorless to white, sometimes blue, gray and yellow, transparent to translucent, this component appears yellow in the regolith. In addition, 355.47 cm in the spectrum of the green powder^{-1}, 518.06 cm^{-1}, 586.89 cm^{-1}With 1,054.47 cm^{-1} Chinese purple ($BaCuSi_2O_6$) Signal, should be from blue particles chimered in the microvisual field. According to the analysis results, we believe that the weathering degree of green particles is not high, which is the previous stage of yellow weathering layer. In this stage, Cu and Ba are lost, blue and purple Chinese purple crystals still account for a certain proportion, mixed with yellow makes the overall green, so it is often included in the jade category.

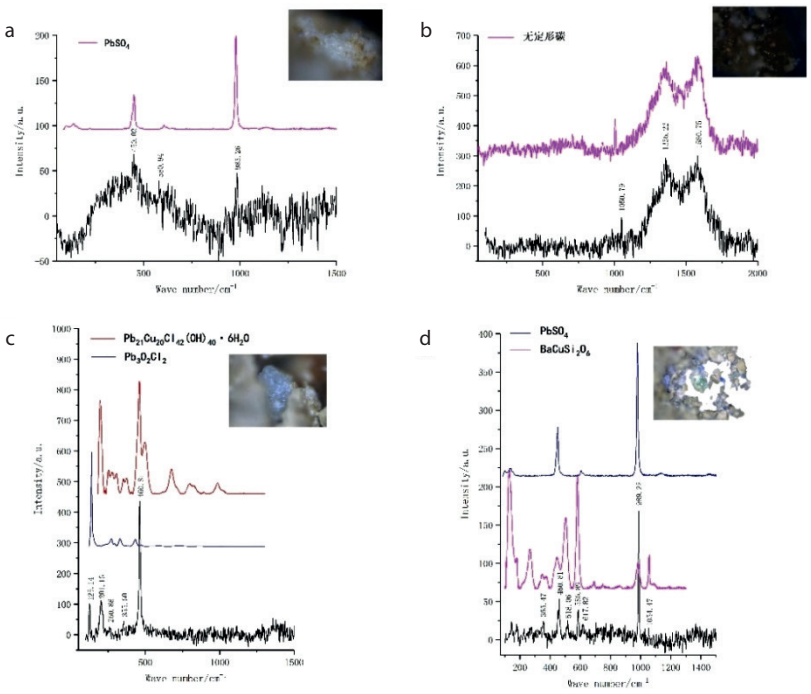

Fig. 3. Raman spectra of the four color weathering products: a – white; b – black; c – yellow; d – green

Рис. 3. Спектры комбинационного рассеяния четырех цветных продуктов выветривания: a – белый; b – черный; c – желтый; d – зеленый

Tab. 1

Energy spectrum analysis results of regolith samples, wt%

Таблица 1

Результаты энергетического спектрального анализа проб слоя выветривания, wt%

Sample number	Pigment	C	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Cu	Ba	Pb
M489: 9	white	13.82	33.14	0.28	0.38	1.16	4.95	4.74	0.8	0.55	0.48	5.62	1.2	0.97	5.92	26.01
M428: 6	white	3.89	25.44	\	\	\	\	6.85	\	1.54	\	4.39	\	\	\	57.89
M336	white	7.93	20.92	\	0.26	0.45	1.91	\	\	\	\	0.72	0.16	2.45	2.13	63.07
M611: 3	black	8.73	33.96	\	0.35	1.76	7.65	2.03	2.07	0.31	0.35	2.09	1.13	2.62	15.65	21.29
M145: 2	black	10.5	31.82	\	0.28	1.11	3.06	3.42	1.27	0.49	\	2.51	3.55	2.12	9.09	30.77
M615: 4	black	13.11	28.14	\	\	0.58	1.63	3.27	0.91	0.67	0.34	3.45	0.53	0.7	5.19	41.47
M632: 1	yellow	6.56	29.74	0.28	0.21	0.53	6.87	1.57	2.76	0.45	\	1.44	0.53	2.10	21.76	25.20
M740: 8	yellow	10.3	32.39	\	\	0.67	4.82	3.51	1.48	0.66	0.46	3.18	0.63	0.65	8.56	32.7
M442: 4	yellow	\	27.15	\	\	\	2.18	2.99	5.22	0.92	\	2.05	\	2	20.72	36.77
M874: 3	hispid arthraxon	7.64	36.21	0.75	\	2.06	10.85	2.83	\	\	\	2.35	1.07	3.83	12.2	20.21
M442: 1	hispid arthraxon	12.43	31.22	\	\	\	4.33	0.49	3.33	\	\	0.85	\	6.99	18.38	21.98
M409: 1	hispid arthraxon	6	31.52	\	\	0.96	3.08	2.9	3.02	0.56	\	2.35	0.71	1.69	18	29.22

(3) Chemical Composition

Twelve regolith samples were tested multiple times using the SEM-EDS, and the universal results were selected (Table 1). The results showed that the main elements of weathering products of different colors are the same, including O, Pb, Ba, Cu, etc., which conform to the characteristics of lead barium glass or barium copper silicate. The content of Pb was between 20.21% and 63.07%, that of Ba was between 1% and 20.72%, and the content of Cu was obviously insufficient between 0% and 6.99%, which is the result of external weathering of the feeder. In addition, the average Pb content of different weathering samples is significantly different, namely the low Pb content in the green weathering; the yellow Pb content is medium; except for M489:9, the poor. This shows that it underwent at least three stages during the weathering process. The Pb content in the black regolith samples is more dispersed and may come from external contamination.

The composition analysis showed that the Ca content of the 12 samples ranged between 0.72% and 5.62% and P content between 0.49% and 6.85%. Ca and P are regarded as external permeable ions, coming from the exchange process between the relic body and the external buried environment. These two elements are high in human bones, and the higher content of Ca and P can reflect the penetration of body solution (Ma Qinglin et al., 2012), while the low content of Ca and P may mark the use of plant ash raw materials or the penetration of soil solution (Lin Yixian et al., 2018). The samples with high content were unearthed near the remains, which should be the result of the penetration of the body rot solution.

2 Detection and Analysis of the Unweathered Areas of the Ontology

(1) Microscopic Observation

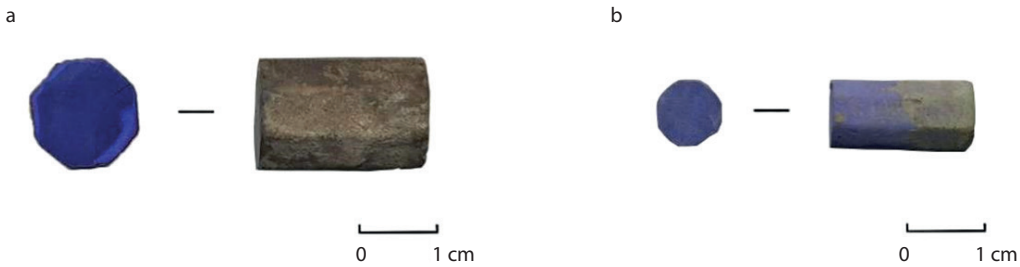

Fig. 4. Photos of purple octagonal prisms of two different materials: a – M442:1 and its section; b – M632:1 and its section)

Рис. 4. Фотография двух разных материалов фиолетовой восьмигранной призмы: a – M42: 1 и его сечение; b – M632: 1 и его сечение)

In order to study the purple eight-prisms with obviously different appearance and material characteristics, one typical sample (M442:1, M632:1) was selected based on the principle of scientific research and cultural relic protection, and about 1mm thick thin section sample (Figure 4) was cut at one end to study the internal situation..5 Observed at different magnification times by super depth of field microscope (Figure 5). After comparison, it is found that sample M 442:1 has light color, obvious surface particles, texture close to the pigment rod, light blue purple, dark blue purple, white and yellow particles mixed with each other; sample M 632:1

has dark body color, glass luster, texture close to glass, uniform color but a large number of air cavity in the middle, which may be produced during burning, representing the better liquidity of the sample, with obvious light purple weathering interlayer, the outer layer is yellow crust.

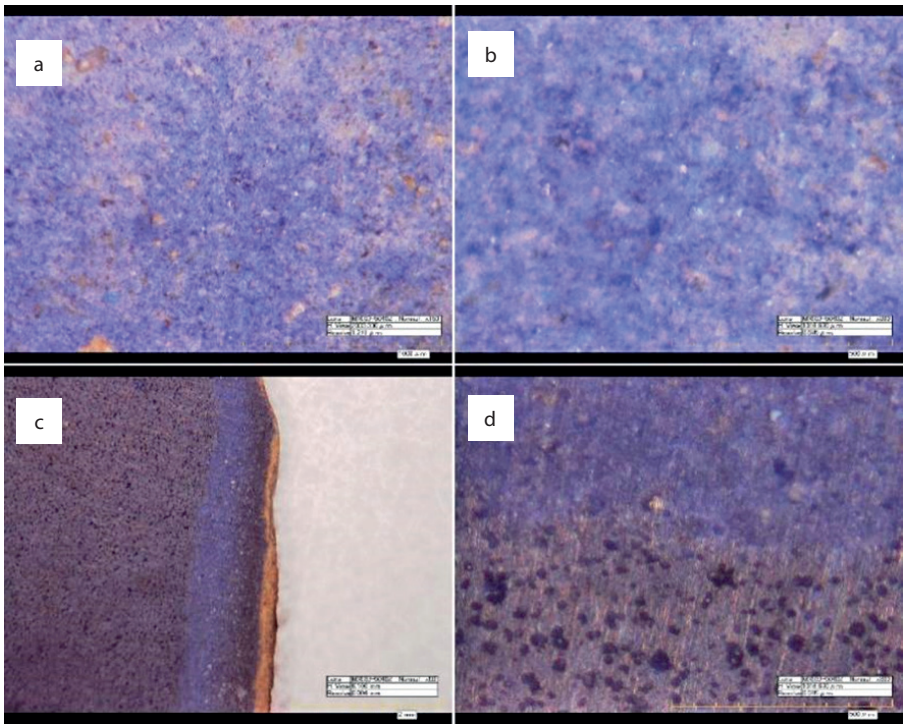

Fig. 5. Micrographs of two different materials:
a – M442:1,×150; b – M442:1,×300; c – M632:1,×50; d – M632:1,×300

Рис. 5. Микрофотографии двух разных материалов:
a – M442:1,×150; b – M442:1,×300; c – M632:1,×50; d – M632:1,×300

(2) Phase Composition

X-ray diffraction analysis of M442:1 and M632:1 profiles. The analysis results show that the M442:1 solution spectrum is mainly Chinese purple ($BaCuSi_2O_6$), Chinese Dark Blue ($BaCu_2Si_2O_7$) And lead carbonate ($PbCO_3$) (Figure 6), Chinese Dark Blue ($BaCu_2Si_2O_7$) is considered as being derived from Chinese Blue ($BaCuSi_4O_{10}$) to Chinese Purple ($BaCuSi_2O_6$) Of the intermediate product. The spectral diagram spectrum of M 632:1 is mainly Chinese purple ($BaCuSi_2O_6$) And the Chinese Deep Blue ($BaCu_2Si_2O_7$), There is also a considerable amount of SiO_2take part in $Al(OH)_3$ Composition (Figure 7), combined with the glassy appearance presented by microscopic observation, it is judged that the composition of this sample is closer to lead and barium glass, while Chinese purple and Chinese dark blue are its color rendering components.

(3) Chemical Composition

Tab. 2

EDS analysis results of 28 prism samples, wt%

Таблица 2

Результаты EDS-анализа 28 проб призмы, wt%

Number	Position	C	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Cu	Ba	Pb
M442:1	border	4.25	19.7	0.29	\	1.10	9.77	\	\	\	\	\	0.62	16.32	33.67	14.28
M442:1	outboard	5.92	29.39	\	\	0.45	10.44	\	\	\	\	0.47	1.08	7.68	22.46	22.11
M442:1	centrality	6.50	27.05	\	\	0.40	6.81	\	\	\	\	0.36	0.44	5.87	16.64	35.93
M632:1	border	27.57	34.45	0.25	0.38	1.01	7.29	0.50	0.43	\	0.25	1.83	0.50	2.09	9.39	14.06
M632:1	outboard	17.54	31.81	\	0.47	0.98	9.80	\	0.28	\	0.21	1.80	0.64	5.51	16.56	14.41
M632:1	centrality	24.35	45.23	1.3	0.28	0.55	7.33	\	\	0.62	0.24	0.39	0.23	0.84	7.70	10.92

Backscattering electron imaging images and some areas of the two sections were detected by SEM-EDS (Table 2, 3). According to previous studies, when the Pb content in the raw material is about 10.42%~22.30%, the Chinese purple samples with good hair color can be produced (Xu Huipan, 2020), which is consistent with the results of this test. The test results show that the M442:1 sample profile is uniform, the surface scan image shows the group distribution of Pb elements, and Cu, Ba and Si elements are evenly distributed. The normalized results show that the content of Pb elements generally decreases from inside to outside, while the content of Cu and Ba elements increases from inside to outside. M632:1 Pb elements and Si elements; the normalized results show that Cu and Ba elements are less distributed in the center, clustered in the light purple weathered interlayer, the most edge is reduced, more Pb elements in the center, and the most edge content rises again. According to previous studies on the weathering of copper barium silicate octaprism, the lead glass phase in the octal prism is first decomposed, followed by $BaCuSi_2O_6$. Disposition of isocrystalline matter, and loss of elements such as Cu and Ba (Ma Qinglin et al, 2012). Therefore, the M 442:1 sample with a low degree of vitrification has higher lead content due to the direct loss of Cu and Ba, the deep purple center of the sample, the lead glass decomposition in the light purple weathered interlayer, and the Pb content of the outermost layer increases due to the loss of Cu and Ba.

In addition, the Cu, Ba and Pb content of M442:1 samples are higher than M632:1 sample, M632:1 sample has higher C than M442:1 sample, also contains a certain amount of Na and Mg, and may add plant base raw materials (Lin Yixian et al., 2018; Wang Ruosu et al., 2022; Huang Xiaojuan et al., 2018), combined with the material, indicating that there are two different processes at that time, which may represent a process evolution process from lead barium glass to barium copper silicate.

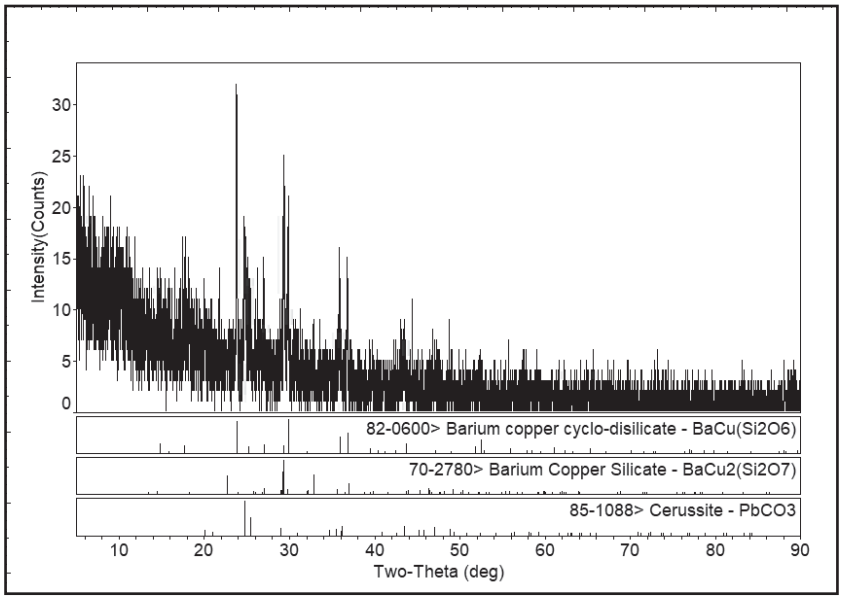

Fig. 6. M442: X-ray diffraction spectrum of the 1 profile

Рис. 6. M442: спектр дифракции рентгеновских лучей в профиле1

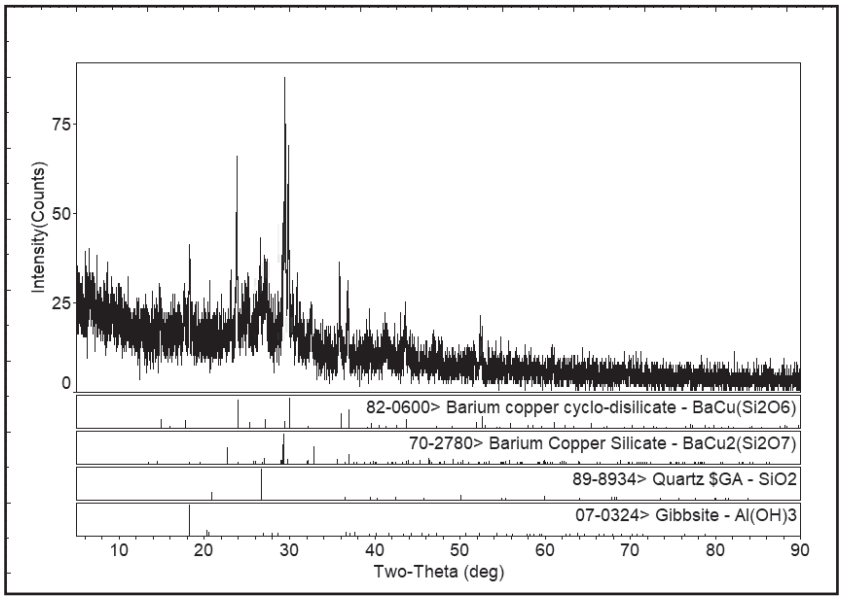

Fig. 7. M 632: X-ray diffraction spectrum of the 1 profile

Рис. 7. M 632: спектр дифракции рентгеновских лучей в профиле1

Tab. 3

Normalized results of Si, Cu, element content of Ba and Pb, wt%

Таблица 3

Результаты нормализации содержания элементов Si, Cu, Ba и Pb, wt%

Number	Position	Si	Cu	Ba	Pb
M442:1	border	13.20	22.04	45.48	19.29
M442:1	outboard	16.65	12.25	35.83	35.27
M442:1	centrality	10.44	9.00	25.50	55.07
M632:1	border	22.21	6.37	28.60	42.83
M632:1	outboard	21.18	11.91	35.78	31.14
M632:1	centrality	27.36	3.14	28.74	40.76

Chemical Composition Characteristics and Production Process Analysis

According to the results of SEM-EDS analysis, this batch of octagonal prisms contain considerable amounts of O, Si, Cu, Ba, Pb, and are advantages in the composition of material elements, and belong to copper barium silicate products. From the results, the 12 copper barium silicate octaprisms can be divided into two categories according to the different texture:

Category A: 6 pieces. Take M442:1 as an example, the purple color is lighter, the surface particle sense is obvious, and the texture is close to the pigment stick.

Category B: 6 pieces. Take M632:1 as an example, the purple color is dark, the surface is glass, the texture is close to glass, and there is a large number of bubble cavity inside.

The obvious difference in texture may be due to the different production process of the two copper silicate, which leads to the different internal components, which makes the objects show distinct features. The results show that the M442:1 phase mainly consists of a large amount of Chinese purple ($BaCuSi_2O_6$) And a small amount of Chinese deep blue ($BaCu_2Si_2O_7$), And also contains a certain amount of $PbCO_3$, among $PbCO_3$ It is the raw material for preparing Chinese purple (Ma Qinglin et al., 2016, pp. 499–514). In contrast, M632:1 composition except Chinese purple ($BaCuSi_2O_6$) And the Chinese Deep Blue ($BaCu_2Si_2O_7$) Besides, there is also a considerable amount of SiO_2 take part in $Al(OH)_3$. It should be noted that the silica melt is the basic unit of the glass phase. At present, it is known that the element composition of lead barium glass and copper barium silicate products is very similar, mainly Si, Pb, Ba, Al, O, etc. The most direct difference between the two is that the Si content of lead barium glass is more than 50%, and the content of Cu and Ba and Si in copper barium silicate is lower (Han Feng et al., 2017; Gan Fuxi et al., 2010; Huang Xiaojuan et al., 2022). Some scholars proposed that lead glass phase or lead barium glass phase in copper barium silicate products, which was also confirmed in this study. SiO obtained in class B samples represented by M632:1.It should be the raw material for producing the glass phase, and the higher Si element content also reveals the existence of the glass phase, and $Al(OH)_3$It may come from natural silicon raw materials.

Changes in firing temperature also cause copper silicate to produce different combinations of phases. According to previous studies, when the pure copper barium silicate crystal prepared by hydrothermal is roasted, it will be transformed in the sequence of Chinese purple Chinese deep blue as the temperature changes, and the first conversion temperature is about

900 ℃ ~1000 ℃, and the stability temperature threshold of Chinese deep blue is 1000 ℃ (Yan Qingqing, 2022); when the preparation of copper barium silicate by simulated ancient solid sintering process, it is found that the appropriate lead solvent reduces the reaction temperature of the reaction and affects the reaction product. 900 ℃ is the median of the reaction temperature, and at 900 ℃ (Xu Huipan, 2020). According to the phase composition obtained from the analysis of this study, the two samples should be fired within the temperature range of 900 ℃ ~1000 ℃, which is consistent with the firing temperature of lead barium glass and lead barium Feens products (Li Qinghui et al., 2007; Wang Yingzhu, 2019), enabling the Chinese purple and Chinese deep blue crystals to coexist with the glass phase. For the high density class B eight prism containing more glass phase represented by M632:1, the ratio of raw materials may be the key factor to determine the production of glass phase. The use of a lower proportion of copper raw material limits the production of copper barium copper silicate crystal, while a higher proportion of silicon raw material provides conditions for the generation of glass phase, which may represent the process evolution process from lead barium glass to barium copper silicate.

Discussion on Related Issues

At present, due to the lack of excavation data, many problems about the purple octagonal prisms have not yet been concluded. In fact, the study of such artifacts should not only pay attention to the scientific problems such as their weathering, appearance and production technology, but also analyze the relevant archaeological phenomena. This paper intends to explore the use of population, transmission route and use function.

1 Use of People and Transmission Routes

Based on the current archaeological excavation data, the purple eight-prisms that can be clearly identified were unearthed in northern China, reaching Dingxi in Gansu province in the west and Siping in Jilin Province in the east. The largest number of unearthed is the Hejia cemetery in Xianyang, accounting for about 71% of the total (Fig. 1). Due to the few related relics disclosed in the previous archaeological excavations, the discussion on the users of such artifacts has not been concluded.

The study of the use of people in the archaeological sense mainly includes the discrimination of people class and clan, the latter is the most commonly used cultural factor analysis . Hejia cemetery is the main unearthed site of the purple eight-prisms found in archaeological excavation. Among the 11 tombs sampled, about 64% are vertical pits. Except for the decayed and difficult human bones, the main burial type of the tomb is limb burial. Since the middle of the Western Zhou Dynasty, limb burial was the traditional burial style in the Qin tombs. Until the middle and late Warring States Period, this unique limb burial was still common in the Qin tombs, which became a clear mark distinguishing the Qin tombs and the regional tombs of other countries, and also became one of the most important features of the Qin tombs (Teng Mingyu, 1997). At the same time, the unearthed pottery of this batch of tombs is mainly pot, kettle, tripod, pot, etc. The discovery of cocoon-shaped pot in this tomb adds evidence to the determination of the nature of its family genus. Cocoon-shaped pot was produced in the State of Qin in the Warring States Period. It is a pottery with typical Qin cultural factors, and continued to be used until the middle of the Western Han Dynasty, and then gradually declined (Zhang Mengyuan, 2021). At present, the discovery of cocoon-shaped pot is mostly found in the qin cultural ruling center and its cultural radiation area. Among the 11 tombs

sampled in Hejia cemetery, M428 and M629 have niches, and cocoon-shaped pots were unearthed. It is worth noting that, from the geographical point of view, Hejia cemetery is close to Xianyang City of Qin, and the number of archaeological excavation is very large, most of which are small civilian tombs in the late Warring States Period. It is speculated that the users should be the bottom civilians of Qin Xianyang City, which is deeply influenced by Qin culture.

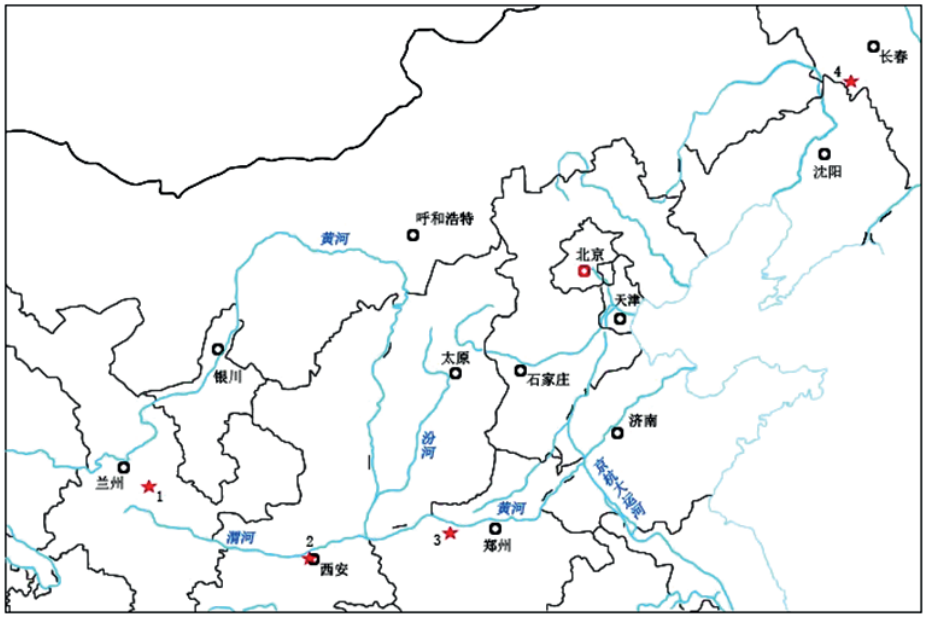

Fig. 8. Schematic diagram of purple octagonal prisms in the Warring States Period: 1 — Dingxi Weiyuan Baozui Cemetery; 2 — Xianyang Hejia Cemetery; 3 — Luoyang Xigong District C1M3943; 4 — Siping Erlong Lake Site

Рис. 8. Схема находок фиолетовой призмы периода Воюющих царств: 1 — могильник Баоцзуй в Динси Вэйюань; 2 — могильник; 3 — район Западной промышленности города Лоян C1M3943; 4 — Сипин Эрлун, руины озера

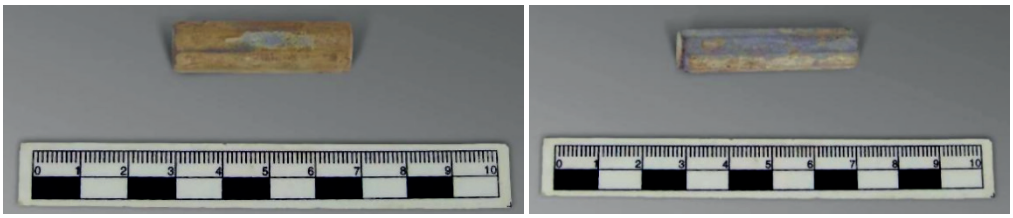

Fig. 9. M 4:1, M 4:2; photo of item

Рис. 9. M 4: 1, M 4: 2: фотографии изделия

In addition to the Hejia cemetery, purple octagonal prisms were also unearthed in Xishan District, West Weiyuan, Luoyang City, C1M3943 tombs in the late Warring States Period, both

dated in the late Warring States Period. Two pieces of such objects in M 4 have not been disclosed (M4:1, M4:2) (Fig. 1), but according to the description of the excavation, from the burial system of the tomb and the pottery unearthed from the tomb, the Qin culture factors are very obvious, and there are some hooks of the Qin system. It can be seen that the owner of the tomb is very likely to be the Qin people. There are also a few tombs in Baozizui cemetery that may bury the descendants of the Rong people. According to their relative age and geographical location, if related to Rong, it should be Rong, but in the late or late Warring States Period, even if the cultural factors of the Rong people are not obvious.

Luoyang City, C1M3943 purple eight prism unearthed 6 tomb, the tomb is located in the northeast of the east Zhou King City ruins, is the key area of the East Zhou King Mausoleum in the king city. It is speculated that the tomb is the burial tomb of the Zhou royal family, and the woman's identity is a noble of the doctor (Huang Jibo, 1999). It should be noted that M3943 also unearthed a beautifully made gold belt hook. This kind of instrument originated in the Qin culture area of Shaanxi Province, was popular from the Spring and Autumn Period to the Eastern Han Dynasty, and then gradually disappeared (Bai Yu, 2021). It can be seen that the owner of the M 3943 tomb should be the Zhou royal family and nobles influenced by the Qin culture.

Two purple eight-prisms found at the site of Erlong Lake in Siping were unearthed in the cultural layer and the house site respectively, dating from the late Warring States Period, and the lower limit was not later than the early Western Han Dynasty (Yu Jing et al., 2012). The site is rich in cultural factors, including Yan culture, indigenous culture and Han culture, and the former two were dominant in the late Warring States period. This kind of artifacts appeared here or spread from the Central Plains, but because there is no more archaeological evidence, temporarily do not repeat.

As can be seen above, the purple eight prissor should be the first to appear in Guanzhong area, and the users were deeply influenced by Qin culture, and also influenced by Taoist religious culture. In the late Warring States Period, with the dispersion of people, these artifacts were brought to Longxi, Central Plains and other areas. However, due to the large difference in the number of unearthed areas, most of which appear in Hejia cemetery, it is speculated that such artifacts are mainly produced in Guanzhong area, and some findings in other areas are the result of crowd flow and the spread of cultural factors.

2 The function of Purple Silicate Copper Barium Octagonal Prism Unearthed in the Hejia Cemetery

The analysis results showed that most of the external regolith of the 12 samples had high Ca and P content, which should be the result of the penetration of the body rot solution. It can be seen that these purple octagonal prisms are buried close to the tomb owner. Combined with the archaeological excavation data, the 12 samples are burial burials, which can be divided into plugs and hand grip according to the different unearthed locations:

(1) Orifice Plugs

Including mouth Han, earplugs, nasal plug, anal plug.

A. Mouth gems: solid eight prism, unearthed in the tomb master skull above or near, common single case, length is about 2cm. As M615:4, M874:3, M409:1.

B. Earplugs: solid octagonal prisms, generally located on both sides of or near the skull of the tomb, are often unearthed in pairs, one on each left and right sides, with a length close to 2.5cm. See found in M428, M611 and M632. Among them, the two octagonal prisms of M632

are similar in shape and are located on the chest of the tomb owner when unearthed, which may be due to the offset unearthed location caused by disturbance.

C. Nasal obstruction: a solid eight prism, unearthed above the skull of the tomb owner, is generally unearthed in pairs, and the two objects are close to each other, and the length is roughly 2cm. For example, the two purple octagonal prisms with similar shapes unearthed in M442 are all unearthed on the skull of the tomb owner.

D. Anal plug: solid eight prism, seen near the main pelvis of the tomb, uneven length, M740:8 and M442:4 respectively long 2.23,3.81cm.

(2) Hand Hold

Generally located in or near the tomb master's hand, the length of the object is slightly longer than the orifice plug. For example, M145:2, unearthed near the right hand of the tomb owner, is 4.18cm long.

Most of the purple eight-prisms unearthed in Hejia cemetery are body plugs. The function of the body plug is to prevent the soul from getting lost. The ancients believed in witch ghosts, "Bao PuZi — to the vulgar" contained: "gold and jade in the nine orifice, the dead are immortal". Taoism believes that jade is the spirit of the mountains and rivers, collecting the essence of the sun and the moon, the living jade can ward off evil spirits, the dead can protect the body to prevent the essence from escaping (Xu Lin, 2008). Thus it can be seen that the role of the body plug is to prevent the leakage of the essence of the body, and help the tomb Lord soul rise to heaven. In addition, the Taoist is still purple, too wei for the upper wall, crape myrtle for the wall, the sky for the lower wall, the ancient to the expensive, crape myrtle wall for the center of the sky, is the emperor of heaven living place, not called "purple palace" or "purple house". In addition, the classic theory of Yin and Yang and five elements in Taoism during the Warring States Period gradually matured (Yan Long et al., 2016). The theory of Yin and Yang with the Eight Diagrams as a continuation was an important method for people to speculate the connection of all things, explain natural phenomena and cosmology, among which the most typical was the use of octagonal elements. In general, influenced by the strong view of life and death, religion and aesthetics at that time, the purple eight prissor appeared in this period and was widely used as a plug. On the other hand, the late Warring States Period was also the embryonic period for the use of jade plug, but generally speaking, the grade of unearthed tombs is higher (Hou Xiaonan, 2021, p. 35). According to the above research results, more civilians are buried in the Hejia cemetery, and the tomb owner uses the purple eight prism as a body plug. In addition to the influence of religious factors, it may also be to replace the more expensive jade plug.

Conclusion

In order to analyze the artifacts more comprehensively, this paper on Hejia cemetery unearthed purple copper barium silicate octagonal prisms into the weathering analysis, in addition to the predecessors involved yellow weathering, also found a white, green, black weathering, including green particles weathering degree is not high, should be yellow regolith before stage, white regolith should be the third stage, black weathering may come from outside pollution. In addition, the different production process leads to the difference of texture, class B samples have more glass phase, A samples are closer to pigments. The same style of eight prism in China is also found in Longxi, Central Plains and other areas, mostly used as burial vessels, in the late Warring States Period, and the users were seriously affected by the Qin culture. Except for

24 pieces of such artifacts unearthed in Hejia cemetery, there are only 2~6 pieces in each site. Therefore, they should be spread from Guanzhong area to other places through trade or crowd flow. In fact, due to the protection of relics, the number of scientific analysis samples in this study is limited, and it is not possible to judge the specific production site and firing process of such artifacts. Expect this paper can attract the attention of this kind of purple copper barium silicate octaprism, so as to conduct in-depth study on its origin and related issues.

Tab. 4

Information table of the purple octagonal prism unearthed in the Hejia cemetery

Таблица 4

Информационная таблица фиолетовой восьмиугольной призмы, раскопанной на кладбище Хэцзя

Sample number	length (cm)	diameter (cm)	Side diameter (cm)	weight (g)	mantle rock pigment	Excavated location	graves	Tomb Lord burial type	type	function
M489:9	2.25	1.26	0.53	9.80	white	—	Vertical hole pit	Raise your body and bend your limbs	B	—
M428:6	2.48	0.87	0.36	3.80	white	The east side of the skull	Straight hole room	—	A	earplug
M336:1	1.93	0.69	0.28	2.20	white	—	Vertical hole pit	Raise your body straight	B	—
M611:3	2.31	1.14	0.47	12.60	black	The east side of the skull	—	—	B	earplug
M145:2	4.18	0.89	0.37	8.00	black	Next to the right ulna	Slant hole room	Raise your body and bend your limbs	A	manual hold
M615:4	2.04	0.99	0.39	5.80	black	The skull on the south side	Vertical hole pit	Raise your body and bend your limbs	B	The mouth Han
M632:1	2.40	1.14	0.47	11.26	yellow	Tomb owner chest	Vertical hole pit	Raise your body and bend your limbs	B	earplug
M740:8	2.23	1.44	0.57	11.30	yellow	Above the pelvis	Vertical hole pit	Side body flexion limb	B	Anal plug
M442:4	3.81	0.79	0.39	5.40	yellow	Above the pelvis	Vertical hole pit	Raise your body and bend your limbs	A	Anal plug
M874: 3	2.18	0.60	0.26	1.40	hispid arthraxon	Above the skull	Straight hole room	—	A	The mouth Han
M442: 1	2.15	0.75	0.32	2.60	hispid arthraxon	Above the skull	Vertical hole pit	Side body flexion limb	A	rhinobyon
M409: 1	2.05	0.53	0.24	1.40	hispid arthraxon	The skull on the south side	Slant hole room	Side body flexion limb	A	The mouth Han

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