Research

Identification of Coloring Materials in Mortar and Hidden Motifs of the Architectural Ornaments of the Verjuy Temple Maragheh (Mongol Ilkhana Era)

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Abstract

The Varjuy Temple is a monument with an imprecisely documented pre-Islamic history, featuring additions attributed to the Mongol Ilkhanid period, located in East Azerbaijan Province, Iran. This temple belongs to a group of underground structures carved directly into the bedrock. The present study aims to characterize the structural composition and identify the pigments within the mortar layers, as well as to investigate the color of the inscribed architectural features of the rock-cut Varjuy Temple in Maragheh. Laboratory investigations included X-ray diffraction (XRD), X-ray fluorescence (XRF), and scanning electron microscopy coupled with energy dispersive spectroscopy (SEM-EDS) performed on samples collected from the identified layers in the main ceiling chamber of the temple. Based on the results of these analytical techniques, the composition of different mortar samples used in the rock-cut architecture of Varjuy was examined and compared with the bedrock substrate. For the first time, this study provides structural evidence of pigment use in rock-cut architecture on the slopes of Mount Sahand. The results indicate that iron oxide (used for red pigment) and carbon black (used for black pigment) were applied as coloring agents in the Varjuy Temple.

Keywords: colored mortar, inscription, rock-cut architecture, Maragheh.

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Introduction

The study of historical mortars and plasters provides valuable insights into ancient construction technologies, raw materials, and the technical skills of past builders. Simultaneously, the identification of pigments used in cultural heritage monuments—whether architectural or archaeological—has gained significant attention over recent decades. Pigments are crucial for understanding technological history, authenticity assessment, and even forensic studies of artworks. In Iranian architecture, particularly during the early Islamic centuries, the use of color on internal and external plaster surfaces was not very common. However, rock-cut architecture presents a special case.

The Varjovi Temple, located on the slopes of Mount Sahand in East Azerbaijan Province, near Maragheh, is one of the few examples of Ilkhanid rock-cut architecture where colored decorations and inscriptions have been identified. The temple is part of a larger underground complex carved into volcanic tuff, with later additions attributed to the Mongol Ilkhanid period. Previous studies mentioned the existence of plasters and pigments, but no scientific identification had been carried out. This research aims to characterize the colorants used in the mortar layers and the written inscription within the main chamber (Chalekhaneh) of the Varjovi rock-cut temple. The study provides the first evidence of color application in the rock-cut architecture of the Sahand slopes, identifying red and black pigments and revealing a previously unknown painted inscription.

Research Methodology

This research adopts a combined field and experimental approach. Following detailed on-site observations and macroscopic documentation, sampling was carried out purposefully to obtain representative and minimally weathered specimens from the plinth area of the main circular chamber (Space V6). Three samples were collected: V6-S2 (gray mortar from the ribbed vaulting), V6-S5 (reddish-brown mortar from the plinth), and V6-S6 (black pigment from a hidden inscription underlying both mortar layers).

The samples were analyzed using three complementary laboratory methods: (1) Powder X-ray Diffraction (XRD) using a Philips PW1800 diffractometer (Cu Kα, 40 kV, 30 mA, 2θ range 5–60°) for phase identification; (2) X-ray Fluorescence (XRF) spectroscopy for bulk elemental composition (reported as major oxides); and (3) Scanning Electron Microscopy coupled with Energy Dispersive X-ray Spectroscopy (SEM-EDS) using a Phenom ProX instrument (accelerating voltages 5, 10, and 15 kV) for microstructural imaging and point elemental analysis. The combination of these methods allowed for the identification of crystalline phases, elemental composition, and the distribution of colorants within the mortar matrix.

Discussion

1. Composition of the Gray Mortar (V6-S2) – A Unique Gypsum-Lime-Volcanic Ash Mix

The XRF analysis of the gray mortar (V6-S2) revealed high SiO_2 (37.46%) and CaO (14.14%), along with significant SO_3 (16.45%). The XRD analysis identified major phases including gypsum ($CaSO_4 \cdot 2H_2O$), bassanite ($CaSO_4 \cdot 0.5H_2O$), cristobalite (a high-temperature silica polymorph), albite, microcline, and mica-illite. Notably, quartz was absent. The presence of cristobalite, albite, and microcline indicates the deliberate addition of crushed local volcanic tuff (from Mount Sahand) as aggregate. The binder is a mixture of lime and gypsum, which is unusual; such a gypsum-lime-pozzolanic ash composition has not been previously reported for Ilkhanid mortars. The cristobalite and volcanic glass fragments likely acted as natural pozzolans, improving the hydraulic properties and durability of the mortar. The bassanite phase suggests partial dehydration of gypsum, possibly due to historical heating or environmental conditions. SEM images of V6-S2 showed a fine crystalline texture with evidence of multiple troweling and polishing actions, indicating careful surface finishing.

2. Composition of the Reddish-Brown Mortar (V6-S5) – Iron Oxide as a Colorant

The reddish-brown mortar (V6-S5) showed a different composition: lower SiO_2 (22.52%) and Al_2O_3 (3.18%), but higher CaO (22.18%), SO_3 (28.65%), and significantly higher Fe_2O_3 (1.02%) compared to V6-S2 (0.23%). The high loss-on-ignition (LOI ~20%) indicates the presence of organic matter or hydrated minerals. XRD analysis identified gypsum, bassanite, calcite, cristobalite, albite, microcline, quartz, and dolomite. The presence of calcite and dolomite indicates carbonates derived from lime binder or aggregate. The elevated iron oxide content, together with the visual reddish-brown color, confirms that hematite (α-Fe_2O_3) or ochre was intentionally added as a pigment. Red ochre (iron oxide) is one of the oldest known pigments. SEM imaging of V6-S5 revealed that some gypsum crystals had lost their original angular habit

and appeared rounded and deformed, likely due to dissolution-recrystallization processes caused by water ingress. The red pigmented mortar represents the uppermost decorative layer, which has largely eroded away except for protected areas beneath the ribbed vaulting.

3. The Hidden Black Inscription (V6-S6) – Carbon-Based Ink

The most significant discovery was the black inscription running continuously around the plinth of space V6, beneath both the gray and reddish-brown mortar layers. This inscription, written in a script similar to Naskh or Thuluth, had been completely hidden and was only revealed through careful stratigraphic observation. EDS analysis of sample V6-S6 showed very high carbon (C: 22.1 at%, 42.83 wt% as CO) and nitrogen (N: 15.4 at%, 24.36 wt% as NO), along with oxygen, sulfur, calcium, and minor copper. The dominance of carbon indicates that the black pigment is carbon-based, specifically soot or lamp black. Nitrogen may derive from organic binders or from environmental contamination. The presence of calcium and sulfur likely results from mixing with the underlying gypsum-lime plaster substrate. This carbon-based black pigment corresponds well with soot/dark pigments reported in other Ilkhanid monuments such as Soltaniyeh Dome, Pir-e Bakran, and other Yazd monuments, where black was used for outlining decorations, inscriptions, and combining with other colors.

4. Stratigraphic Interpretation and the Priority of the Inscription

The layer sequence in the plinth area of space V6 is now clear: (1) First, the rock-cut bedrock; (2) then, a thin gray plaster (with gypsum-lime binder and volcanic ash aggregate) was applied, and the black carbon-based inscription was written directly on this surface; (3) later, a second gray mortar layer containing plant fibers (such as straw and rush) was applied; (4) finally, the red ochre-pigmented mortar was applied as the uppermost decorative coating. This stratigraphy demonstrates that the black inscription belongs to the earliest Islamic phase of the temple, likely contemporary with or slightly later than the initial rock-cut construction. The inscription is therefore one of the oldest painted Islamic inscriptions in Iranian rock-cut architecture, dating to the Ilkhanid period (7th–8th centuries AH / 13th–14th centuries CE). The red pigmented mortar was a later decorative addition, possibly associated with the conversion of the space into a Khanqah (Sufi lodge) after Ghazan Khan's religious reforms.

5. Comparative Context with Other Ilkhanid Monuments

Comparison with previously studied Ilkhanid monuments (e.g., Soltaniyeh Dome, Isfahan Jameh Mosque, Pir-e Bakran, Yazd monuments) shows that the use of red ochre and carbon black was standard practice during this period. Blue pigments (azurite, lapis lazuli) and green pigments (malachite, atacamite, celadonite) were also common but were not detected in Varjovi, possibly due to the limited decorative scheme of a rock-cut hypogeum. The use of gypsum-lime mortars with volcanic ash is technologically distinctive and reflects local adaptation to available geological resources (Sahand volcanic tuffs). The Varjovi temple thus contributes valuable data on Ilkhanid mortar technology, pigment usage, and epigraphic practices in northwestern Iran.

Conclusion

This study provides the first scientific identification of colorants in the rock-cut architecture of the Varjovi Temple in Maragheh. Through XRD, XRF, and SEM-EDS analyses, it has been demonstrated that the gray mortars are a unique gypsum-lime mixture with crushed volcanic tuff (containing cristobalite, albite, and microcline), representing an unreported technological tradition for Ilkhanid mortars. The reddish-brown mortar owes its color to intentionally added iron oxide (red ochre/hematite), while the black inscription pigment is carbon-based (soot/lamp black). The stratigraphic sequence reveals a previously unknown painted Islamic inscription in Naskh/Thuluth script, hidden beneath later plaster layers, which constitutes one of the oldest painted inscriptions in Iranian rock-cut architecture. These findings confirm that the use of color for decorative coatings and inscriptions was practiced even in remote rock-cut monuments of the Ilkhanid period, aligning with broader traditions observed in major brick monuments of the time. For future research, the authors strongly recommend the use of infrared and ultraviolet photography to enhance the legibility of the hidden inscription, which remains largely unreadable to the naked eye. Conservation efforts should prioritize the stabilization of the remaining red-pigmented plaster and the documentation of the black inscription before further deterioration occurs.