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Characterization of 4th–5th century A.D. earthen plaster support layers of Ajanta mural paintings

M. Singh [a,*], B.R. Arbad [b]

[a] Archaeological Survey of India, Science Branch, Bibi-ka-Maqbara, Aurangabad 431 004, India
[b] Department of Chemistry, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad 431 004, India

HIGHLIGHTS

- The raw materials for the earthen plaster of Ajanta was most likely sourced from alluvial soil bed of Waghura river.
- Inclusion of coarse black ferruginous silicate along with rare glauconites and zeolites is the unique feature of plaster.
- Proteic materials added in the plaster works as binder that have now transformed to calcium oxalate.
- Ajanta earthen plaster surprisingly had deliberate addition of lime to enhance the binding properties.

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ABSTRACT

Characterization of decorated earthen plaster has seldom been attempted in India. This paper provides a description of a recent characterization of mud plasters of decorated rock art in India's Ajanta caves by visual as well as instrumental techniques using polarizing microscope; laser scattering devise; sieve analysis; XRF, XRD, CHN, FTIR and SEM techniques on a few micro grams of plaster sample. The properties of high silt, (>75%) low clay (about 15%) plaster support layers seems to have been modified by deliberate addition of lime to enhance cementing characteristics. SEM and FTIR spectra of the plaster show inclusion of coarse black ferruginous silicate along with rarer glauconite–celadonite and zeolites probably bound together with proteic materials that have now transformed to calcium oxalate. XRD and SEM studies indicate that quartz and sepiolite have been added to enhance the performance of the plaster. The shrinkage property of the soil has also been modified by the addition of vegetal matter.

1. Introduction

The Ajanta caves, a World Heritage Site (WHS) with its beautiful murals (from 2nd BCE to 5th A.D.) represents the highest point of artistic and technical achievement in India's great cultural period – the Golden Age [1] and the current conservation approach to wall murals of Ajanta is based on a detailed understanding of the ancient materials technology and causes of deterioration that favors minimal intervention and preventive conservation [2]. The research undertaken at Ajanta is based on the fact that the murals are in their original state and no major restoration interventions have been carried out on them except filling of voids with lime mortar with addition of Portland cement and application of shellac varnish on some portions of the painting of cave 1, 2, 6, 9, 10, 16, 17, 19 and 21 by Italian conservators in 1920 [3]. The conservation studies carried out so far at Ajanta include monitoring of the macro and micro environments of the caves; engineering geological surveys; rock and mineral analysis [4]; together with bio deterioration studies [5]. In addition, investigations have been conducted into pigment and painting techniques [6]. However, few publications are available on the materials and techniques used by ancient Indians to create Ajanta wall murals. Therefore, dedicated investigations of material composition, structural support, plaster and paint layers are required.

Characterization of most cultural heritage materials, conservation materials such as stone, brick, wood, concrete and steel are well established. However, despite notable progress in the last decade, earthen building materials have not been characterized. A detailed understanding of these support layers is essential because many problems associated with ancient decorated surfaces originate in the structural and support layers. Conservation of

* Corresponding author. Tel./fax: +91 240 2400059.
E-mail address: m_singh_asi@yahoo.com (M. Singh).

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decorated surfaces constitutes a specialized area within the field of earthen architecture and heritage conservation. Published research on this topic is quite limited as very few researchers have focused on conservation of decorated surfaces [7,8].

Investigation of wall painting technology is usually restricted by limitation of available resources and availability of samples. Further compounding the problem of deterioration of earthen plaster is the complexity of the earthen system in which diverse materials may be used in different layers [9,10]. The deterioration of wall paintings on earthen support is most often due to loss of cohesion and adhesion of the base layers and consecutive detachment. Laboratory experiments show that earthen plasters begin to absorb moisture at around 67% relative humidity. The principle mechanism by which paint on earthen plaster deteriorates is loss of mechanical strength resulting by the degradation of the binder and causing the paint layer to lose adhesion to the background. In-situ fluctuating climatic conditions and addition of surface coatings can be detrimental to the paint, plaster and earth fabric because of differential dimensional changes (shrinkage and swelling) of the layers and difference in water vapor permeability [11]. Surface barrier films may inhibit transmission of water vapor through various substrate layers to the surface. Painting on the earthen base are mostly water sensitive (liquid water or water vapor) and treatment methods developed for treating painting on a lime base are often not suitable for decorated mud plaster. When active deterioration is observed, repair and strengthening of the material without understanding the causes and the mechanism of deteriorations are only temporary measures and often cause more damage in the long run [12] All factors of deterioration processes affect the original fabric and also the later interventions and hence a critical requirement for a thorough understanding and identification of the components of the original earthen plaster layers, the clay fabric and the deterioration process is required.

Earth, a highly heterogeneous material has been used in construction of shelters for mankind for thousands of years [13] and about 30% of the worlds present population still lives in earthen dwellings [14]. Traditional mud plaster is made with soil composed of sand, silt and clay with straw added sometimes to prevent excessive cracking during drying. For an earthen support to function well, an equal distribution of silt, sand and clay is desirable. Too much silt is neither a good binder nor an aggregate and produces material that is prone to shrinkage and cracking. Clay (also called phyllosilicate) is a term related to grain size (<2 μm), with grain shaped like a sheet much thinner than wider, and the grains are attracted to one another by electrolytic interparticle forces [15]. The non-clays are of grain size greater than clays and are divided into the grain size categories of silt (2–50 μm in diameter) and sand (50 μm–2 mm in diameter). Due to their small surface area, non clays show less attraction for water and are non plastic. The grains of non-clays are more irregular with reduced grain to grain contact surface and contact cohesion much lower than clay [16]. Incorporation of water into a clay structure is reversible, and directly related to ambient water vapor pressure and temperature. Clay minerals in general consist of equal parts of expandable clays (smectite and mixed layer illite/smectite) and non-expandable clays (kaolinite or chlorite) with minor quartz, calcite and feldspar content [17]. The expandable clay minerals are sticky to non-expandable clays and are effective in binding silt and sand particles together. In order to overcome the inadaptability of local resources, other materials such as vegetal fibrous matter [18,19], calcite and lime [20,21] have been added to clay to reduce shrinkages. Shrinkage of the clay is significantly reduced as calcite may also serve as binder. However, the possibility of using reactive fillers in earthen grouts has still not been fully explored. It seems that materials such as calcite, silica (sand) and ferric oxide (iron (III)oxide–Fe_2O_3) act like a cementing agent forming chemical bonds between clay micelles that may reduce swelling [22]. Further observation indicated that some clays are generally frequented by zeolites, glauconites or iron oxide minerals indicating the existence of high silica activity in aqueous solution, affecting silicate crystallization. Iron oxides are also very strong coloring agent for clays.

Proteins may react chemically with clays by an exchange of inorganic cations in the clay with organic one – a mechanism relating to the ability of amino acids to encourage clay flocculation [23]. It appears that egg white used as an additive in earthen grouts promote adhesion, increase plastic & liquid limit and enhance uniaxial comprehensive strength and modulus of rupture [23]. Egg white has a long tradition of use as an additive in lime plasters due to its adhesive properties [24]. Based on these findings and in accordance with an ancient Indian painting recipe written in Sanskrit [25], we feel worth exploring the addition of proteinaceous materials to the mud plaster of Ajanta to enhance its binding properties. Unbleached shellac varnish was applied to about two thirds of the paintings of Ajanta in the 1920s that has now oxidized to an orange red color. The shellac is now masking a clear view of the original paintings as well as inhibiting water vapor permeability of the painted mud plaster. Numerous gaps, ridges, and other lacunae can be observed on the painted surface that have had shellac varnish applied. Additionally, polyvinyl acetate has also been applied during recent conservation treatments for consolidation and fixing of painted surface and as a preservative coating. This film forming material has also inhibit permeation of water vapor to the surface causing deterioration to occur below. Enhanced flow of visitors, wide fluctuations in humidity and insect activity within the mud plaster have further added to deterioration of Ajanta murals [26]. However, many preventive conservation measures have now been initiated by the Archaeological Survey of India to remedy deterioration of the Ajanta murals.

This paper focuses on the painted plaster at the site of Ajanta along with scientific investigations into its nature, composition and characteristics. The analytical techniques used include optical microscopy; laser light scattering; polarized light microscopy; scanning electron microscopy; XRF; XRD; X-ray diffraction; FTIR and sieve analysis. Some on site research with magnifying lens was also carried out relating to earthen plaster and paint layering

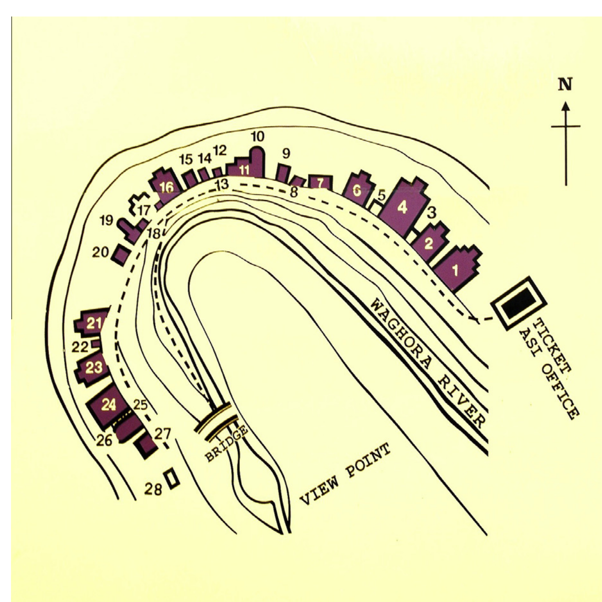

Fig. 1. Schematic representation of location of Ajanta caves and Waghura river.