Wall paintings salt induced decay in residential buildings in Hierapolis of Phrygia (Turkey)

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Abstract

Hierapolis of Phrygia (Turkey) was an ancient city located on hot springs in south western Anatolian peninsula. The site was designated as a UNESCO World Heritage Site in 1988. It comprises an archaeological museum and most of the ruins are currently under excavation and studied by archaeologists and specialists from different countries, under the auspices of the Italian archaeological mission.

Inside the wide archaeological site, Insula 104 is a residential area dated back at proto-byzantine period. Many buildings were excavated starting from 1989, and the presence of several rooms with painted walls illustrating coloured marble columns and panels suggests the attribution to high-level residences. Currently, the wall paintings of some rooms of great historical and artistic importance, present tangible damages due to salt crystallization and therefore, new conservative interventions, besides some actions that already took place in the last years, are necessary.

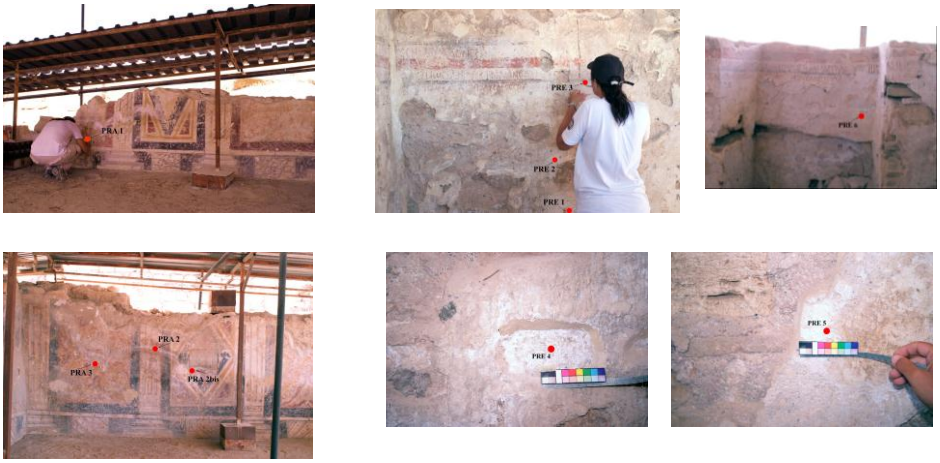
Keywords: salt induced decay, wall paintings, efflorescence

Experimental procedures

In order to plan pertinent and focused actions, different analytical techniques were used to determine the nature and the origin of the soluble salts present on the wall paintings in two different areas of the Insula 104.

Samples were scratched out from the efflorescence on the surface of the wall paintings in The *House of the Doric Courtyard* (room A 1207, probably utilized for feasts and banquets till to VI century), and in the

House of the Painted Inscription (room A 1267, known as *Room of the Prayer of Manasseh*). Four samples were collected from room A 1207, *House of the Doric Courtyard*, and six samples from room A 1267, *Room of the Prayer of Manasseh* (see Figure 1).



a b

Figure 1: Location of collected samples in room A 1207 (a) and room A 1267 (b).

Collected samples were investigated by means of optical microscopy (OM), X-ray diffraction (XRD) and Ion Chromatography (IC).

Detailed images were acquired *in situ* using a digital microscope Scalar DG-2A instrument, equipped with an optical zoom ranging from 25x to 200x. All shots were recorded with a 25x magnification (corresponding to a 13x8 mm^2 area).

X-Ray Diffraction (XRD) was performed with a PANalytical X'Pert Diffractometer, using a Cu Kα1 radiation (λ=1.545 Å), an X-ray tube 40 KV, 30 mA, the investigated angular range was $3°<2\theta<70°$.

For chromatographic analyses, a given amount of water was added to a weighted amount of the sample. Then, the solution was stirred for 24 hours, decanted and filtered with hydrophilic PTFE filters (pore size 0.45 µm). Ion Chromatography (IC) was performed on the extract with a Dionex ICS-1000 Instrument, equipped with a suppressed conductivity detector, IonPac® columns and ion self-generating suppressors.

Results and discussion

The efflorescence on the mural paintings of the studied rooms of Insula 104 consists of sulfates (mainly thenardite, aphthitalite and syngenite), nitrates and chlorides (halite and sylvite).

In room A 1207, sulfates are prevalent in the efflorescene of the lower part of the wall, whilst nitrates are prevailing at higher levels. In room A 1267 chlorides and nitrates are prevalent: from bottom to the top of the wall, the amount of chlorides increases, while that of nitrates decreases. In Table 1 the main results of XRD and IC analyses are presented.

Table 1: Main constituents of analyzed samples.

ID SAMPLE	XRD	IC
PRA1	Sulfates (thenardite (Na_2SO_4), aphthitalite ($(K,Na)_3Na(SO_4)_2$), syngenite ($K_2Ca(SO_4)_2 \cdot H_2O$)); carbonates (calcite (tr))	Na^+; K^+; Ca^{2+} (tr); SO_4^{2-}, NO_3^- (tr); Cl^- (tr)
PRA2	Nitrates: (sodium nitrate, potassium nitrate); silicates (quartz (tr))	Na^+; K^+; Ca^{2+} (tr); NO_3^-; Cl^- (tr); SO_4^{2-} (tr)
PRA2bis	Nitrates: (sodium nitrate and potassium nitrate); sulfates (gypsum); silicates (quartz (tr) and micas)	K^+; Ca^{2+} (tr); Na^+ (tr); NO_3^-; Cl^- (tr); SO_4^{2-} (tr)
PRA3	Sulfates (thenardite, picromerite ($K_2Mg(SO_4)_2 \cdot 6H_2O$), aphthitalite, syngenite; carbonates (calcite (tr))	Na^+; K^+; Mg^{2+}; Ca^{2+}; SO_4^{2-}; NO_3^- (tr); Cl^- (tr)
PRE1	Chlorides (halite); nitrates (potassium nitrate); sulfates (gypsum (tr))	Na^+; K^+; Ca^{2+} (tr); Mg^{2+} (tr); Cl^-; NO_3^-; SO_4^{2-} (tr)
PRE2	Chlorides (halite); nitrates (potassium nitrate and ammonium and potassium nitrate)	Na^+; K^+; Ca^{2+} (tr); Mg^{2+} (tr); Cl^-; NO_3^-; SO_4^{2-} (tr)
PRE3	Chlorides (halite, sylvite); nitrates (potassium nitrate); sulfates (gypsum)	Mg^{2+}; Ca^{2+}; Na^+ (tr); K^+ (tr); SO_4^{2-}; Cl^- (tr); NO_3^- (tr)
PRE4	Sulfates (gypsum, magnesium sulfates with different hydration)	Ca^{2+}; Mg^{2+}; Na^+ (tr); K^+ (tr); SO_4^{2-}; Cl^- (tr); NO_3^- (tr)
PRE5	Chlorides (halite); sulfates (gypsum)	Na^+; K^+ (tr); Mg^{2+} and Ca^{2+}; Cl^-; SO_4^{2-} (tr); NO_3^- (tr)
PRE6	Sulfates (hexahydrite - $MgSO_4 \cdot 6H_2O$, starkeyite - $MgSO_4 \cdot 4H_2O$, gypsum); silicates (quartz)	Mg^{2+}; Ca^{2+}; Na^+ (tr); K^+ (tr); SO_4^{2-}; Cl^- (tr); NO_3^- (tr)

Note: (tr) = in trace elements

Conclusion

A correct definition of the provenance of salts present in the studied mural paintings of Insula 104 is essential in order to plan an appropriate removal of the decay reasons and a good conservative intervention.

The deposition of sulfates and nitrates can be ascribed to rising damp or to infiltration from filling soils that are in contact with the wall. The presence of significant amounts of chlorides is instead quite unusual in a place that is far from the sea-side (at least at present time), and could be due to the particular re-utilization of the room as a building materials warehouse.

Further investigations are foreseen in order to better understand causes and dynamics of soluble salts contamination in Insula 104.

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