Dr Sölve Johansson
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Analysis of mortar samples from the Church of Yəmrəhannä Krəstos in Lasta, Ethiopia

Comments

The analysis of mortar at the Church of Yəmrəhannä Krəstos in Lasta, Ethiopia involved two mortars from the church. (YKET 1 and 2) and two from the "Palace" (YKPAL 1 and 2). The mortar samples from the church are both external and internal (YKET 2 and YKET 1 respectively), while the two mortar samples from the palace are both external. Mortar sample YKPAL 2 comes from the original building, and mortar sample YKPAL 1 from an early addition.

All mortar samples were taken by Dr Ewa Balicka-Witakowska. They are from the lower parts of the buildings, which had been treated externally with a yellowish-brown material, which had not been applied on the facade surfaces in general or on the inside surfaces.

The analyses, which were carried out by Dr Jan Erik Lindqvist of Swedish Cement and Concrete Research Institute, show that gypsum mortar was used as plaster/render on both the church and the palace, and on both the original palace building and the additions. The yellowish-brown surface treatment is probably beeswax.

On the church and on the extensions to the palace, a gypsum mortar of a similar composition was used, with approximately 60-65 percent by volume of gypsum paste, 30 percent by volume of gypsum particles and 5% air voids. Mortar sample YKPAL 2, i.e. from the original part of the palace, has a different composition. It contains gypsum and organic fibres.

The use of gypsum mortar as a plaster/render rather than lime mortar is not surprising, given that gypsum has been widely used as a mortar in the eastern Mediterranean and Egypt since prehistoric times. The advantages of gypsum are that it is a commonly-occurring mineral, it is burnt at a low temperature (approx. 100 ^{o}C) and it consumes much less fuel than limestone, which is burnt at a high temperature (700-1100 ^{o}C) using a considerable amount of fuel. Lime mortar was used in parallel with gypsum mortar in the region, especially during Roman times and later. In Ethiopia, both limestone and gypsum are found in the valley of the Blue Nile (the Abbai) between Lake Tana and Addis Ababa.

The use of beeswax as a surface finish, obviously with the intention of protecting the plaster/render from water penetration, is, however, surprising. Beeswax has been known since ancient times as a material with a wide range of applications, including mummification and the production of wax figures and candles. Modern uses of wax include its use in restorations as a moisture barrier on limestone and marble, as well as an ingredient in anti-graffiti coatings on surfaces such as plaster.

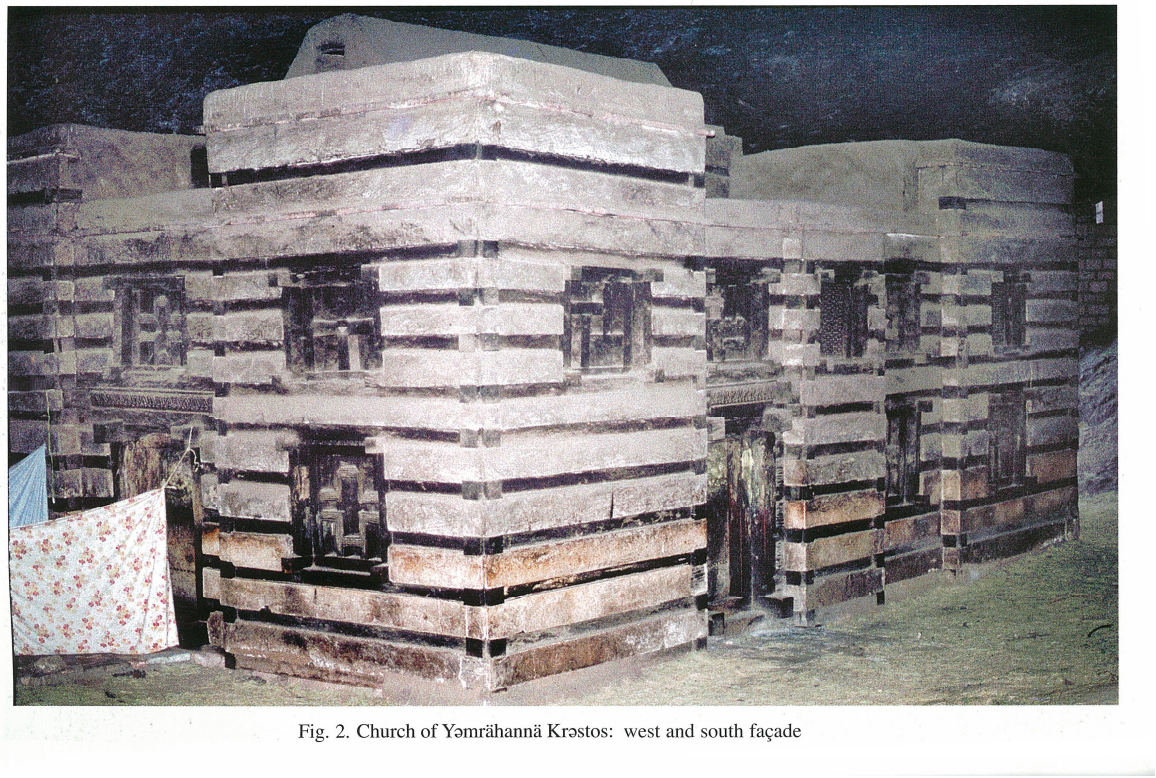

Fig. 2. Church of Yəmrähannä Krəstos: west and south façade

Analysis of mortar samples from the Church of Yəmrəhannä Krəstos in Lasta, Ethiopia

Commission

Analysis of four mortars from the Church of Yəmrəhannä Krəstos in Lasta in Ethiopia. The analysis includes the composition of the mortars and the composition of the surface of the sample YKET 2.

Sampling

Four samples were delivered to CBI on 10-04-2008 by Dr Sölve Johansson.

Method

The quantitative determination of the mortar composition was performed by optical microscope using point counting on thin sections. Semi-quantitative microchemical analysis was performed using a low-vacuum scanning electron microscope equipped for micro-analysis (LVSEM/EDS).

Results

The microchemical analysis of the samples YKET 1 and YKET 2 shows that the mortars are composed of gypsum (table 1). Analysis by optical microscope also showed that YKPAL 1 is composed of gypsum (figure 1). These three gypsum-based mortars are similar in appearance and composition (figures 2 and 3). The analysed samples contain about 5% air voids and about 30% by volume of un-dispersed gypsum particles. About two-thirds of the volume is composed of finely dispersed gypsum (table 2). Microchemical analysis of the surface of sample YKET 2 shows that it is composed of carbon, nitrogen, sodium, magnesium, aluminium, silicon, phosphorus, sulphur, chlorine, potassium, calcium, titanium and iron (figure 4 and 5). This implies that the surface has been treated possibly with beeswax.

The sample YKPAL 2 has a different composition. LVSEM/EDS analysis shows that this sample is composed of gypsum and organic fibres dispersed in an organic material, figure 6.

Table 1. The table shows the content of sulphur (S) and calcium (Ca) by weight % of gypsum particles in the sample YKET 2.

Element	S	Ca
Spectrum 1	13	14
Spectrum 3	10	12
Spectrum 7	11	13

Table 2. Shows the results from point counting of the mortar samples.

	YKET 1		YKET 2		YKPAL 1	
	Volume %	±	Volume %	±	Volume %	±
Air voids	5	1.7	5	2.0	7	2.8
Gypsum particles	34	3.6	34	4.5	26	4.7
Gypsum paste	60	3.8	62	4.6	67	5.1
Number of points	652		425		332	

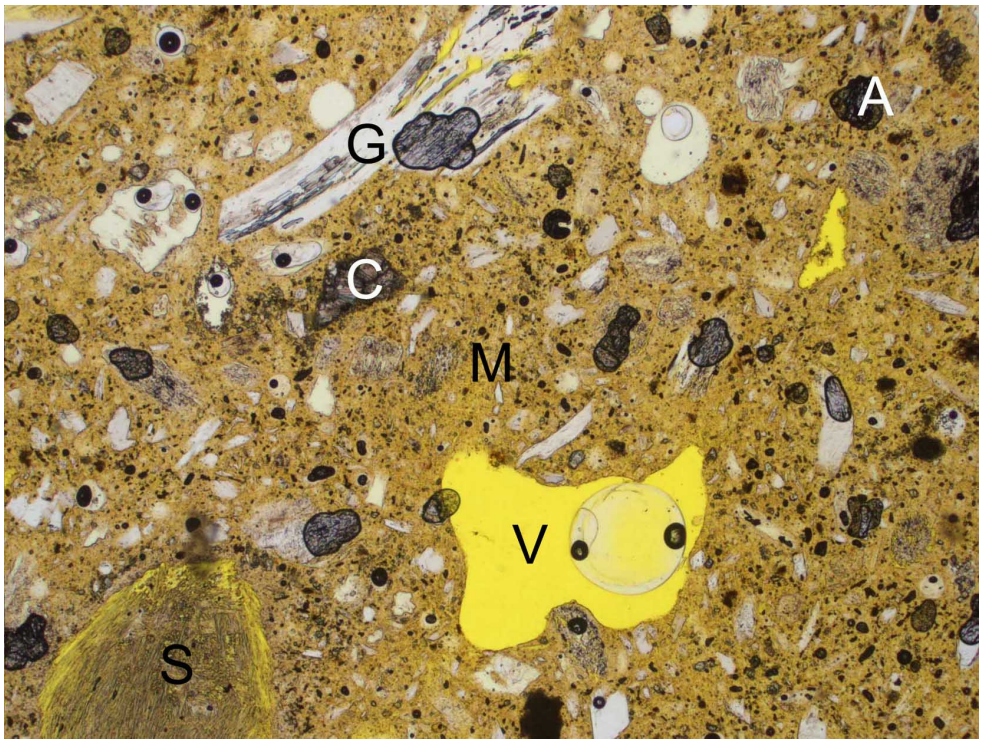

Figure 1. Optical microscopy image of the sample YKPAL 1. Gypsum particles (G) are white, the gypsum matrix is yellow-brown and air voids are yellow. A calcite grain (C) is also seen in the image. In the lower left area is a partly filled air void (S). The letter A marks air voids in the thin section. The image is taken in plain light, size of the images is 2.7*2.1 mm^2.

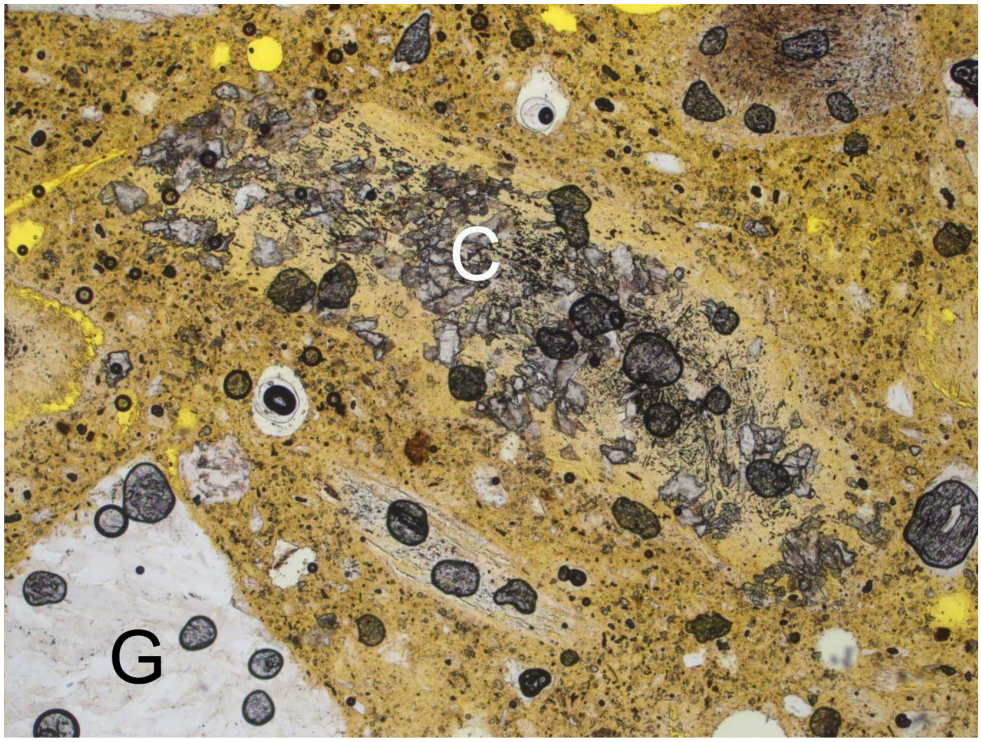

Figure 2. Optical microscopy image of the sample YKET 1. The image shows the formation of new calcite crystals (C) and gypsum particles (G) in the gypsum matrix. The image is taken in plain light, size of the images is 2.7*2.1 mm^2.

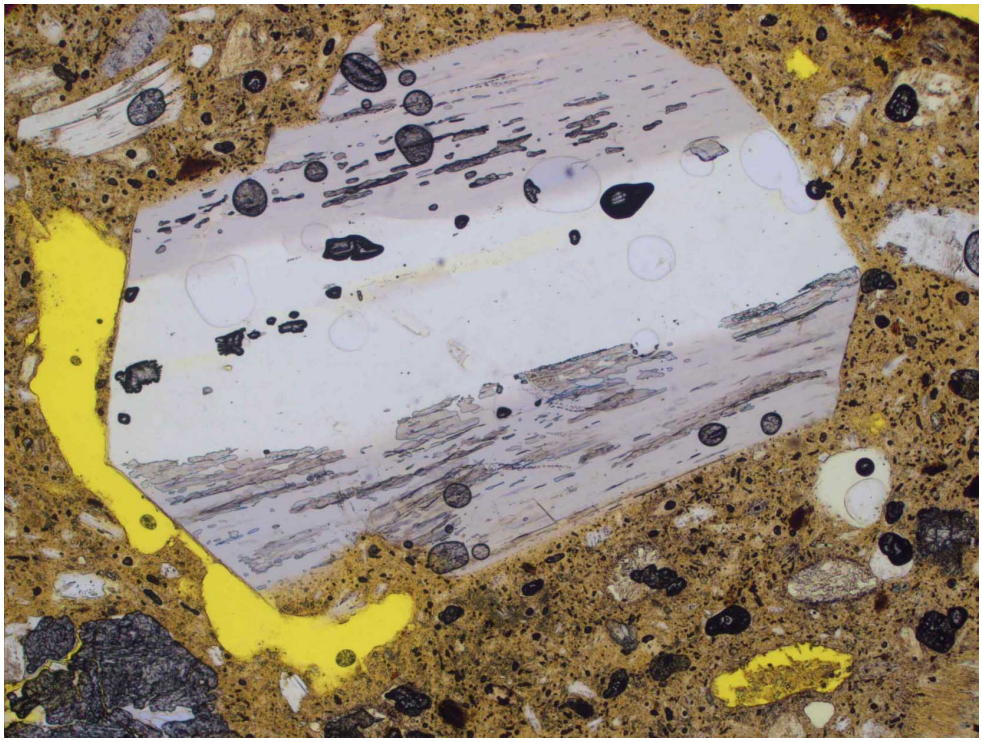

Figure 3. The image shows a large gypsum crystal in the sample YKET 2. The image is taken in plain light, size of the images is 2.7*2.1 mm^2.

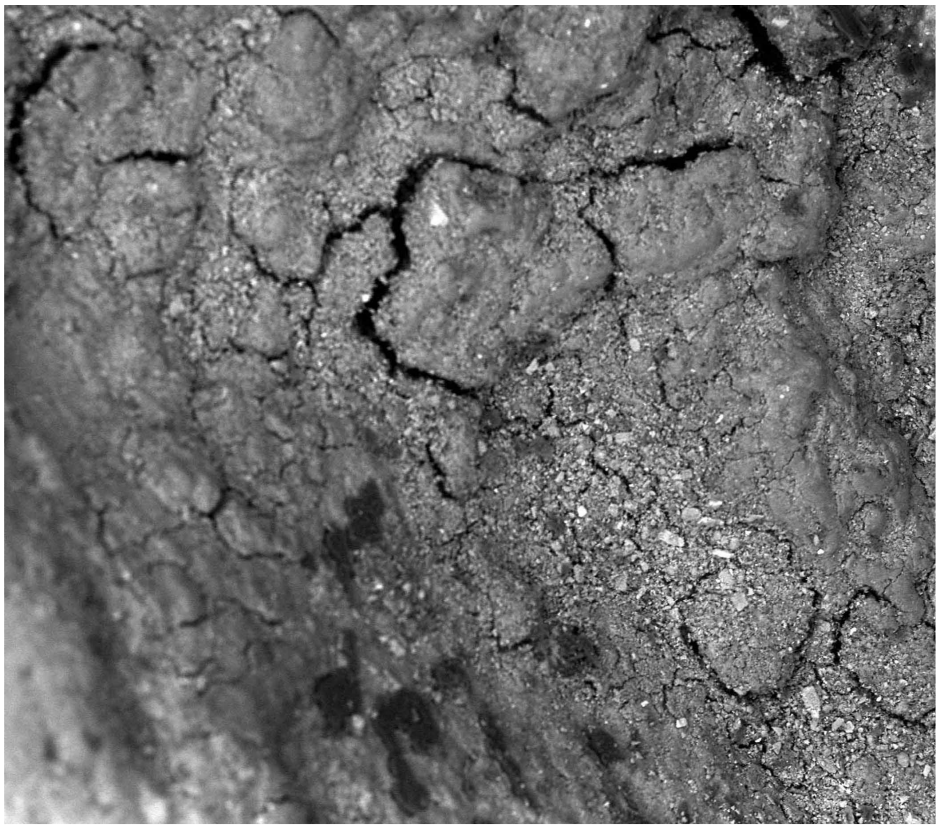

Figure 4. The surface analysed using LVSEM/EDS on sample YKET 2. Instrumental magnification 100 times.

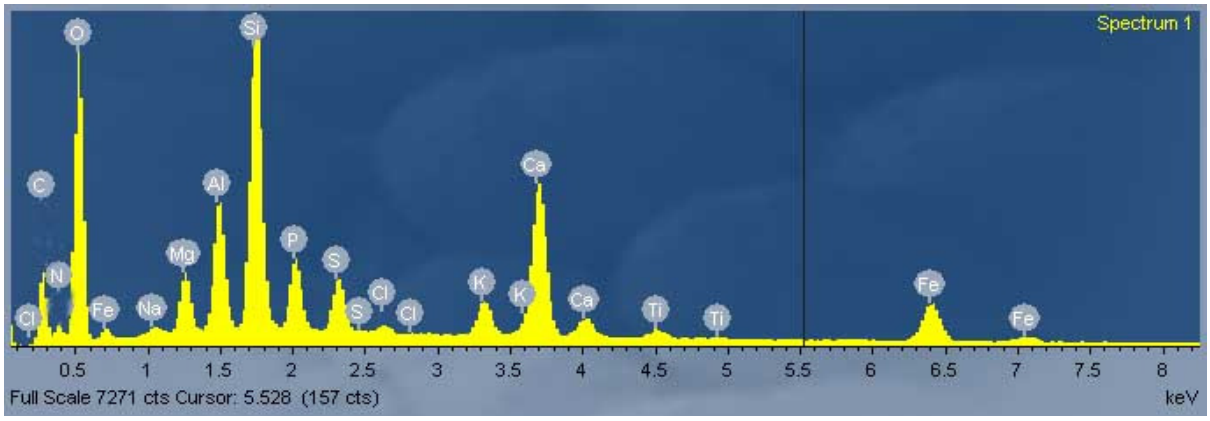

Figure 5. Shows the EDS spectrum from the analysed surface of sample YKET 2. (C carbon, N nitrogen, Na sodium, Mg magnesium, Al aluminium, Si silicon, P phosphorus, S sulphur, Cl chlorine, K potassium, Ca calcium, Ti titanium, Fe iron).

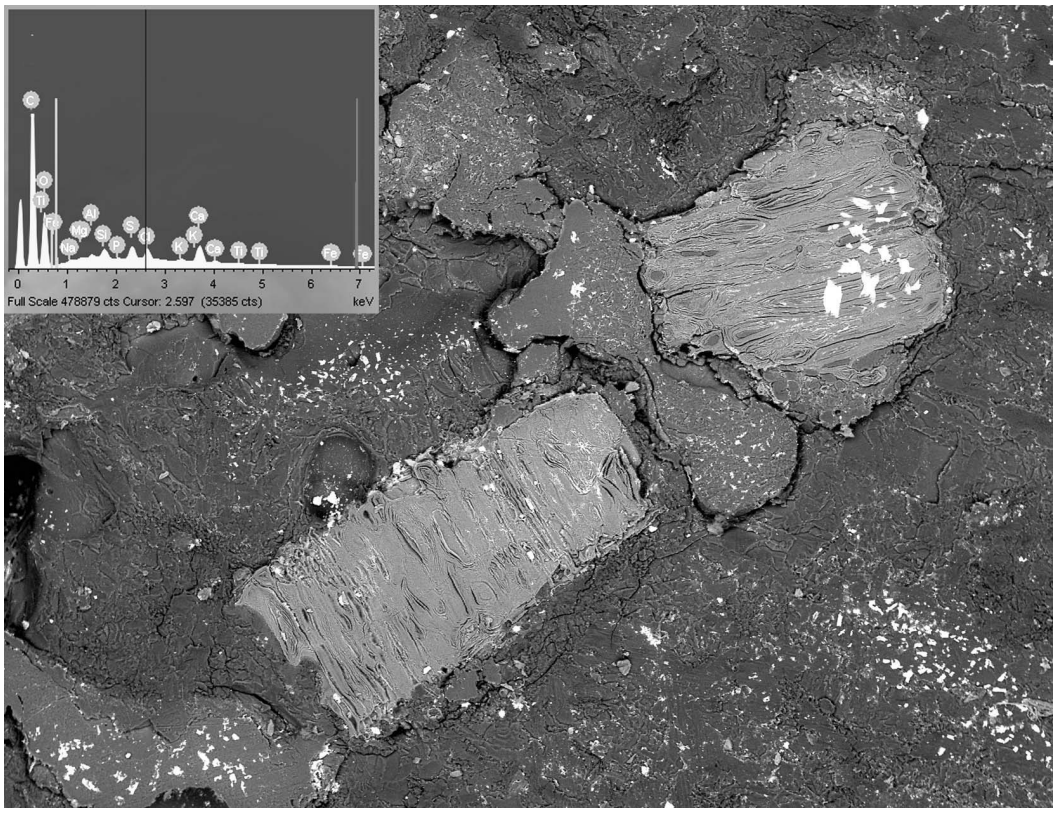

Figure 6. LVSEM image of sample YKPAL 2 taken in BSE mode. Shows the analysed area and the spectrum in the upper left-hand corner. The analysis shows a high presence of carbon in the analysed area. The instrumental magnification is 50 times.