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The mineralogical characteristics of plasters of various ages used for restoration of walls of the Chapel of Amun, Temple of Hatshepsut –Upper Egypt.

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Abstract

Various types of plasters representing various ages used for the restoration of walls and sculptures at the chapel of Amun, Temple of the Hatshepsut were examined using mineralogical techniques. Samples represent at small destroyed fragments of the plasters removed during the conservation of the chapel.

The investigation showed various mineral compositions of the plasters and the evolution of the method of preparation of the plasters used for restoration of the walls of the monument. Plasters were prepared with the use of gypsum as the binding material.

Introduction

The Chapel of Amun constitutes one part of the temple of queen Hatshepsut. The restoration of the monument conducted by a Polish mission in 2004 helped preserve elements of that objects. The plasters were examined by mineralogical methods for better conservation as well as for the determination of the formula for the preparation of plasters at various times during the restoration of objects. Additionally, data obtained may help in the reconstruction and well done preservation of the monument.

Because of this plasters representing various ages were collected for analyses using the system of axes o, x, y and o', x', y' (Fig. 1). The locations of sampling were documented with photos.

Material for investigation

The coordinates of tested samples (See Fig. 1) and general description of localization were as follows:

sample AN1 - x = 8,83 m, y = 3.77 m (Photo 1, A) - pinkish plaster at the crown of Amun

sample AN2 - x = 8.62 m, y = 2.80 m (Photo 1, B) - two layers of plaster under the eye of Amun
sample AN3 - x = 6.18 m, y = 3.56 m (Photo 1, C) - flowers behind Hatshepsut coarse grained plaster composed of two layers from the second restoration

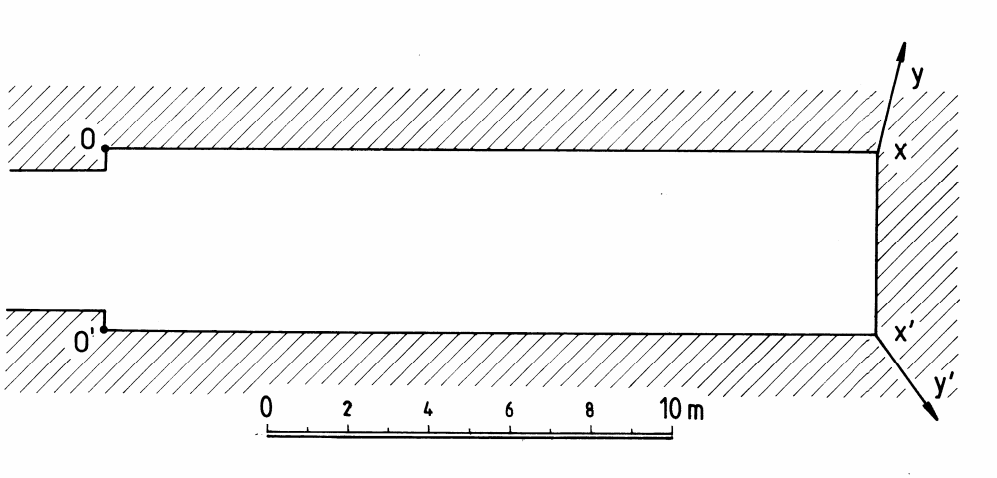

Fig. 1 The coordinates (x, y, z) of samples tested

sample AN4 - x' = 8.83 m, y' = 3.85 m (Photo 1, D) - nose of Amun, painted plaster after the first restoration + plaster made of Nile silt.
sample AN5 - x' = 9.45 m, y' = 3.85 m (Photo 1, E) - left arm of Amun, original plaster used for primary reconstruction of a poorly prepared limestone block

A small fragment of stone from the Chapel of Amun (near the roof of the chapel –photo 3F, 4F) was collected for a description of the mineral composition as well as for the determination of the character of a substance coating the surface of the block. These data are important because of sample AN6 - x = 8.13 m, y = 5.63 m. The limestone was coated with a grey organic substance which was very difficult to clean.

Photo 1A. Location of sample AN1

Photo 1B. Location of sample AN2

Photo 1C. Location of sample AN3

Photo 1D. Location of sample AN4

Photo 1E. Location of sample AN5

Methods of investigation

All plasters were tested using digital and polarizing light microscopy.

Microscopic investigations were performed on specially prepared thin sections. Small fragments of plasters were fixed using polymers cut with a diamond cuter and polished using special polishing powders. After polishing, 0.02 mm thin sections were covered with a covering glass and examined with polarized light. Analyses of mineral compositions were determined with the use of an automatic counter (jumping point analyses). The results of these measurements were recalculated into percents and presented in the form of a diagram. The bserved phenomenon were documented with photos.

Results

Examination using a digital microscope

Observations of the morphology of the samples showed that they are diversified structurally. This phenomenon was confirmed by an examination of the external – surface (Photo 3) as well as the internal structure of the plasters (Photo 3).

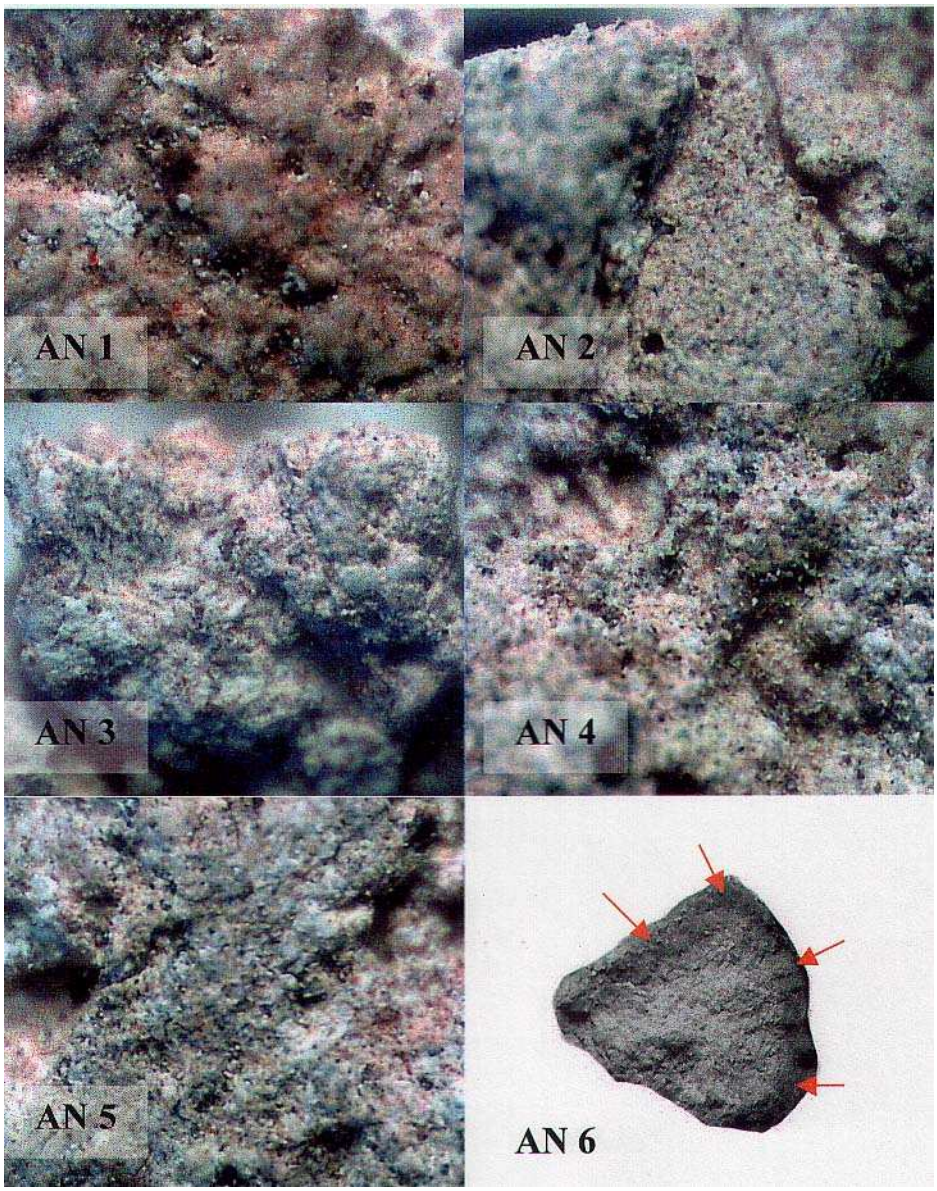

Photo. 2. Morphology of tested plasters AN1-5. Sample AN6 – rocks polluted with excrements of bats. Digital microscope, magnification 10 x.

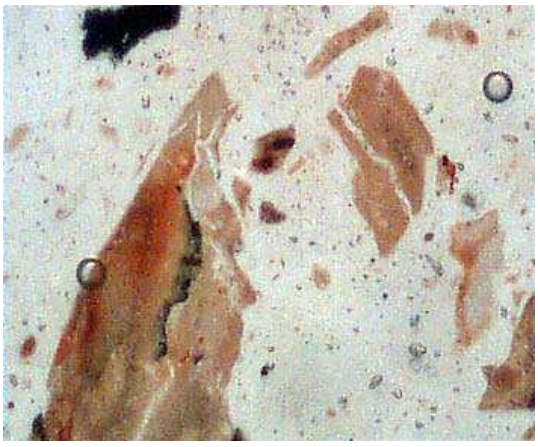

Photo. 3A

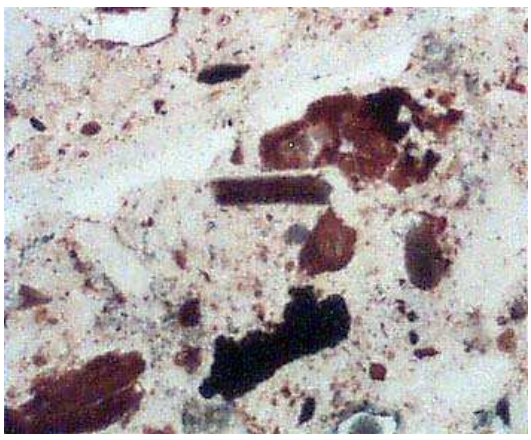

Photo 3B

Examination with a digital microscope showed that the internal structure of plasters (Photo 3 A-E) was represented by a fine crystallized mass containing an admixture of various, generally sharp fragments, of Esna shells as well as inclusions of organic substances. Observations conducted did not give an answer as to what this fine mass was. Due to this the next tests of samples were performed with the use of a polarizing light microscope.

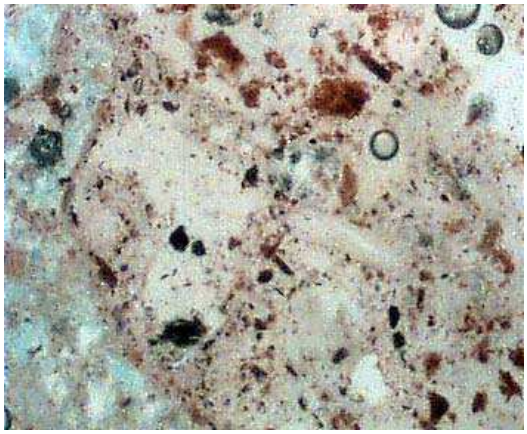

Photo 3C

Photo 3D

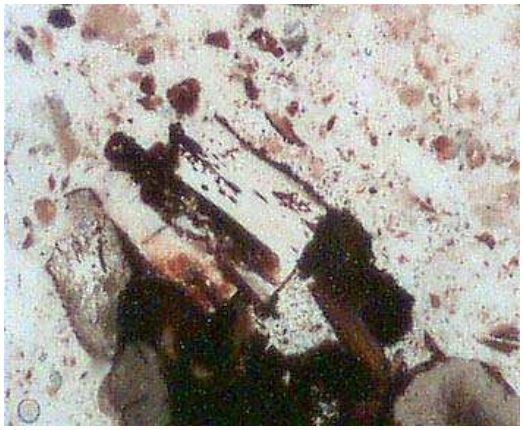

Photo 3E

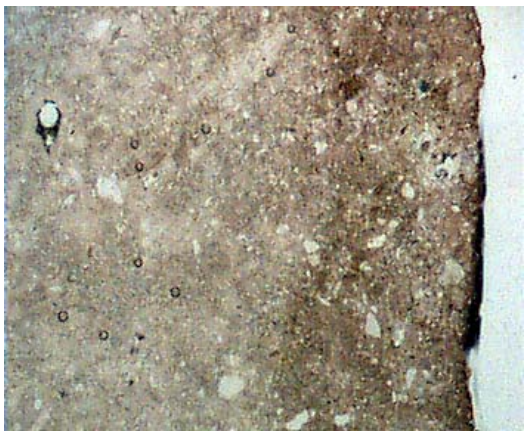

Photo 3F

Photo 3 A-E. The internal structures of tested plasters. Fine crystallized background containing disseminated fragments of esna shells as well as inclusions of organic substances. Photo 3F - A grey colour fragment of stone from the chapel. Digital microscope, magnification 40 x.

Characteristic of a tested plaster using a polarizing light microscope

Sample AN1

The picture observed under a digital microscope (Photo 3A) confirms the complex composition of plaster. Features observed using a polarizing light microscope showed the presence of fragments of limestone

disseminated in a background composed of fine gypsum containing fragments of fibrous gypsum (Photo 4A). Together with these components, one can see black grains of an organic substance of unknown origin (Photo 4A'). Data concerning the mineral composition of this plaster are shown in table no 1.

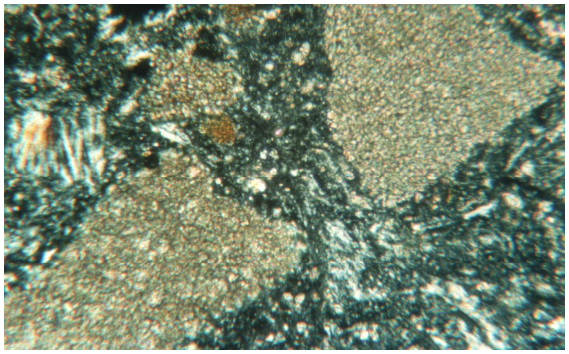

Photo 4A Fragments of Theban limstones in a gypsum background. Polarizing light microscope, polaroides X, magnify. 60 x.

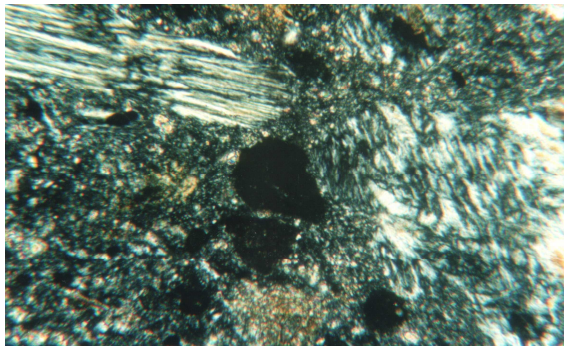

Photo 4A' Black concentrations of organic substances in gypsum cement. Polarizing light microscope, polaroides X, magnify. 60 x.

Sample AN 2

The plaster under a digital microscope shows a slightly different structure. Photo 4B. Small grains of material cemented with a fine mass can be seen. They are easily seen in polarizing light where one can observe light grains of gypsum and Theban limestones as well as fine calcite mixed with organic compounds and cemented with very fine gypsum (Photo 4 B, B').

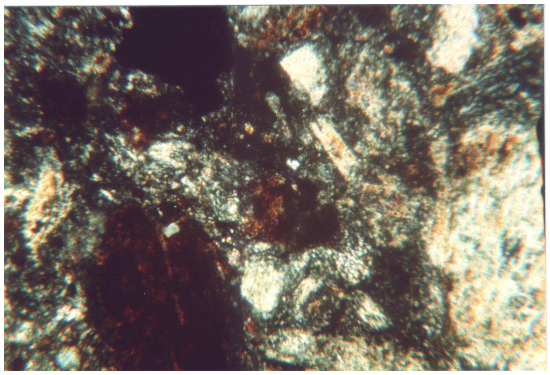

Photo 4 B General microscopic picture of plaster. Polarizing light microscope, polaroides X, magnify. 60 x.

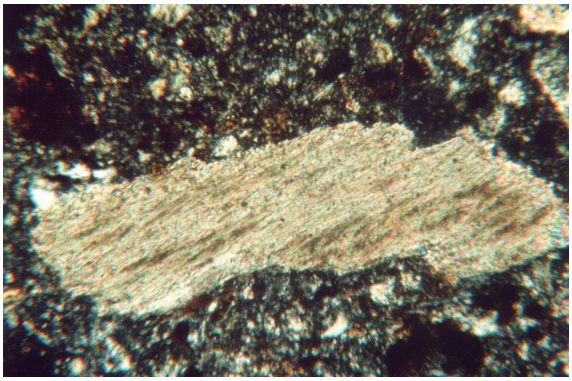

Photo 4b' Light fragment of Esna shale Polarizing light microscope, polaroides X, magnify. 60 x.

Sample AN 3

Microscopic observations performed with the use of a digital microscope showed that, morphologically, this plaster is similar to sample

AN 1 (Photo 2C). Similar pictures, using a polarizing light microscope shows where fragments of fibrous gypsum, organic matter and small grains of fine crystalline gypsum are disseminated in a cementing fine mass composed mostly of very fine gypsum (Photo 4C). But, at some places, gypsum is dehydrated and altered into anhydrite (Photo 4C'). The mineral composition of this plaster is slightly different than that of sample AN-1 and AN 2 (Table 1).

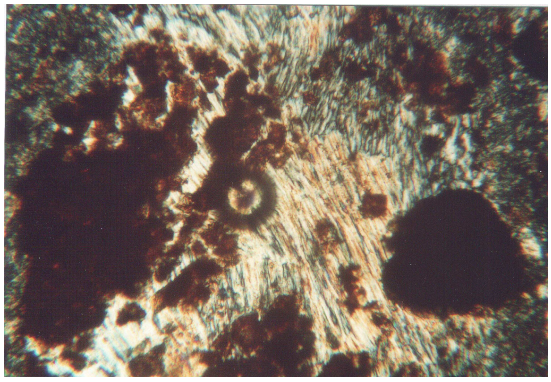

Photo 4C. Organic inclusion of gypsum Plaster. Polarizing microscope, polaroides X, magnify. 60 x.

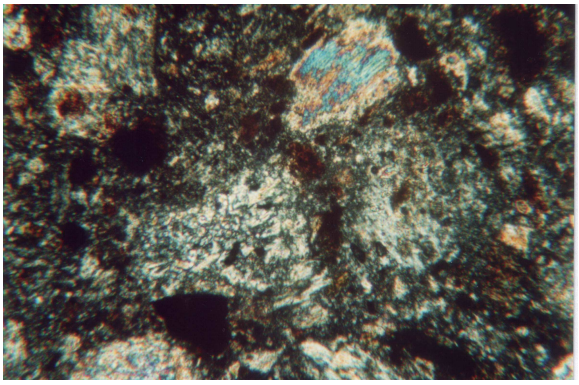

Photo 4C'. Grains of gypsum in a fine gypsum background. Poarizing microscope, polaroides X, magnify. 50 x.

Sample AN 4

A morphological picture of this plaster is similar to that described before in Photo 2D, but observations conducted with polarized light and a special counting of minerals showed the proportions between component are slightly different (Tab. 1). This plaster contains fragments of fibrous gypsum, grains of fine calcite and organic matter. Together with these components, one can see rare grains of light-grey quartz (Photo 4D). In contrast to samples described before, grains of these components are relatively large but the cementing gypsum is as fine as that observed in samples 1-3 (Photo 4D').

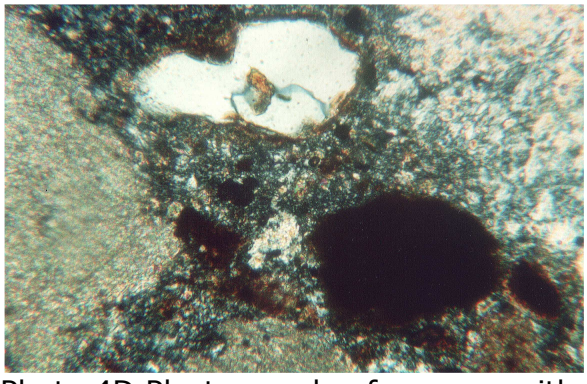

Photo 4D Plaster made of gypsum with grains of quartz (light) and black orga-Nic substance and gypsum fragments. Polarizing light microscope, polaroides X, magnify. 60 x.

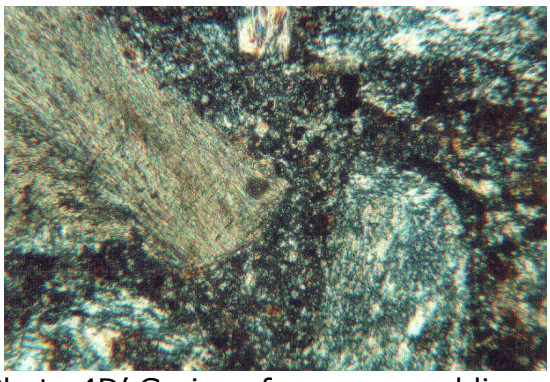

Photo 4D' Grains of gypsum and li-mestones at fine gypsum background. Polarizing light microscope, polaroi-des X, magnify. 60 x.

Sample AN 5

Observation of morphology of plaster shoved that material used for preparation of this plaster is of various granulation (Photo 2E). There are parts where material is finer but at other places one can see slightly coarser grains. This means that material for preparation of plaster was not well mixed. Observation of internal mineral structure conducted using polarizing light microscope shoved the presence of coarser grains of fibrous gypsum and limestone mixed together with organic matter and relatively coarse grains of quartz (Photo 4E and 4E'). All mentioned components are fixed with fine gypsum.

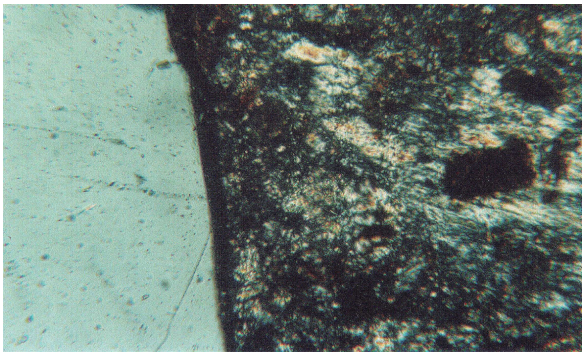

Photo 4E Light, big grain of quartz at fine gypsum background (dark). Polarizing microscope, polaroides X magnify. 60 x.

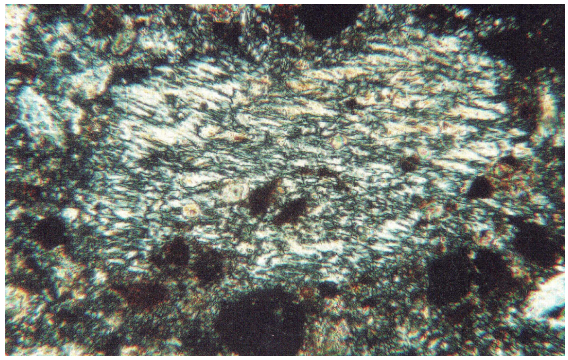

Photo 4E' Not grinded grain of Gypsum at fine gypsum mass. Polarizing microscope, polaroides X, magnify. 60 x.

Sample AN 6

Observation of a cross section of the sample (stone from a wall of the temple –photo 2F) showed the presence of dark rings just under the surface of the sample. Analyses of these ring structures under a polarizing light microscope showed that the dark tinted substance is of organic character and is the result of chemical activity and penetration of bat excrements. This is concentrated on the surface or just under it but at some places the thickness of the penetrated zone is up to several mm (Photo 4F).

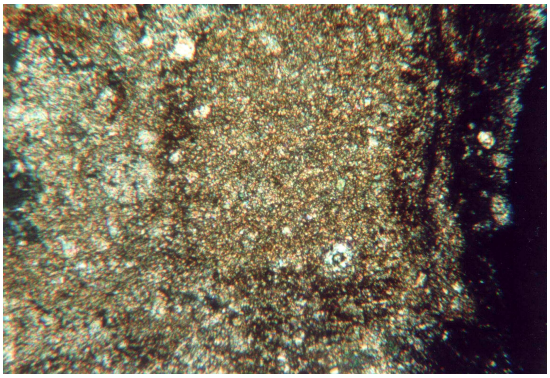

Photo 4F Dark organic concentration on and under the surface of the stone- right side of picture. Polarizing microscope, polaroides X, magnific. 60 x.

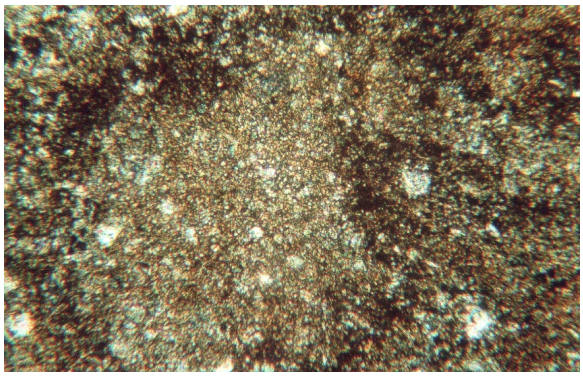

Photo 4F' Dark irregular organic spots in the stone. Polarizing microscope, Polaroides X, magnify. 60x.

The dark, colored substance is also present at deeper levels, but its appearance is different. Using a microscope, one can see dark irregular spots and veins (Photo 4F').

The investigation confirmed that the kinds of substances and deep penetration are the reasons for difficulties in the restoration and cleaning of the surface of the stone i.e. the walls of the chapel of Amun.

Conclusions

The investigation conducted showed that the tested plasters are prepared without the use of fired limestone (burned calcium) but are done on a base of gypsum. The data obtained confirmed the variability and evolution of the method of preparation of plasters used during the long history for the restoration of the walls and sculptures at the chapel of Amun. This phenomenon is very interesting technologically because of the use of gypsum as the binding material for the preparation of plasters. The presence of this mineral suggests that ancient Egyptians knew for a very long time the technology of the preparation of gypsum and its use as a binding material for plaster preparation. It is necessary to confirm if the Egyptians used burned gypsum or used ground (powdered) material for the preparation of plasters for other objects.

The results obtained from the investigation of stones from the walls of the chapel (sample AN6) suggest the infiltration of organic compounds into the structure of the stone. This phenomenon is the reason for the difficulties concerning cleaning and conservation of walls. The organic matter suggests that the use of oxidants such as H_2O_2 helped clean walls of the monument.

Investigation was supported by grant AGH no 11.11.140.158

Table 1. Mineral composition of tested plasters

COMPONENT	SAMPLE				
	AN1	**AN2**	**AN3**	**AN4**	**AN5**
Gypsum background	36,7	42,1	40,5	33,4	32,2
Fine calcite	20,1	15,7	7,2	22,4	18,2
Fibre gypsum	30,2	20,2	26,1	19,9	20,4
Limstone fragments	8,0	3,2			17,2
Grains of quarz		4,2	2,7		

Literature

Gazda R.W., Zagadnienia konserwacji i rekonstrukcji dekoracji świątyni królowej Hatszepsut w Deir el-Bahari, w: Materiały konferencji z okazji Pięćdziesięciolecia Wydziału Konserwacji i Restauracji Dzieł Sztuki ASP w Warszawie, Warszawa 1997, s. 101-108, il. 2.

Gazda R.W., Technologiczne problemy konserwacji dekorowanego kamienia świątyni królowej Hatszepsut w Deir el-Bahari (Technologische Probleme der Konservierung der dekorierten Steine des Tempels von Hatschepsut in Deir el-Bahari, Ägypten), w: IBB Forum auf der Denkmal '98, Löninger Schriften zur Baudenkmalpfege I (1998), s. 11-16, 17-23.

Gazda R.W., Esthetical and technical problems of conservation at the Hatshepsut Temple in Deir el-Bahari, w: Z. Hawass and A.M. Jones (red.), Eighth International Congress of Egyptologists: Abstracts of Papers, Cairo 2000, s. 69-70.

Gazda R.W., Deir el-Bahari. Conservation work and studies, PAM XI (2000), s. 167-171.

Gazda R.W., Conservation Work at the Temple of Hatshepsut, 1999/2000, PAM XII (2001), s. 206-214.

Gazda R.W., Protection of archaeological sites namely the Hatshepsut Temple at Deir el-Bahari in Egypt- the project of the Polish Center of Mediterranean Archaeology of the Warsaw University. 5 th European Commission Conference on Researche for Protection, Conservation and Enhancement of Cultural Heritage in Kraków, V, 2002, materiały konferencji w druku .

Gazda R.W., Konserwacja kamiennego wystroju dekoracji świątyni Hatszepsut w Deir el-Bahari- przywracanie starożytnego przekazu." Konferencja Naukowa „Nowoczesne Metody Konserwacji Zabytków Kamiennych", Uniwersytet Mikołaja Kopernika w Toruniu, 06.2002, materiały konferencji w druku

Grimm A., Schoske S., Hatschepsut KönigIN Ägyptens, München 1999.

James T.G.H., British activity on the Hatshepsut Temple, w: Z. Szafrański (red.), Queen Hatshepsut and her Temple 3500 Years Later, Warszawa 2001, s. 39-55.

Kwaśnica A., Reconstructing the Archtectural Layout of the Upper Courtyard, w: Z. Szafrański (red.), Queen Hatshepsut and her Temple 3500 Years Later, Warszawa 2001, s. 81-97.

Markiewicz T., New Fragmentary Coptic Texts from Deir el-Bahri, The Journal of Juristic Papyrology XXX (2000), s. 67-70, pl. I-II.

Markiewicz T., Five Coptic Ostraca from Deir el-Bahri, The Journal of Juristic Papyrology XXIX (1999), s. 81-82.

Pawlicki F., Deir el-Bahari. The Temple of Queen Hatshepsut, 1998/1999, PAM XI (2000), s. 153-166.

Pawlicki F., Hatshepsut Temple, Conservation and Preservation Project 1996/97, PAM IX (1998), s. 51-60.

Pawlicki F., Skarby architektury starożytnego Egiptu. Królewskie świątynie w Deir el-Bahari, Warszawa 2000, s. 60-173.
Said R., The geology of Egypt. 1960, Elsevier 377 p.
Szafrański Z.E., Upper Terrace of the Temple of Hatshepsut at Deir el-Bahari: Recent Results of Restoration Work, w: Z. Hawass and A.M. Jones (red.), Eighth International Congress of Egyptologists: Abstracts of Papers, Cairo 2000, s. 177.
Szafrański Z.E., Deir el-Bahari. The Temple of Queen Hatshepsut, season 1999/2000, PAM XII (2001), s. 185-205.
Szafrański Z. (red.), Queen Hatshepsut and her Temple 3500 Years Later, Warszawa 2001.
Szafrański Z., Exceptional Queen, Unique Temple: Polish Activity in the Temple of Hatshepsut, w: Z. Szafrański (red.), Queen Hatshepsut and her Temple 3500 Years Later, Warszawa 2001, s. 57-79.

Explanation for

Phot. 1, A - sample AN1 - pinkish plaster at the crown of Amun (x = 8,83 m, y = 3.77 m)
Phot. 1, B - sample AN2 - two layers of plaster under the eye of Amun (x = 8.62 m, y = 2.80 m)
Phot. 1, C - sample AN3 - flowers behind Hatshepsut -coarse grained plaster composed of two layers; second restoration (x = 6.18 m, y = 3.56m)
Phot. 1, D - sample AN4 - nose of Amun, painted plaster after first restoration + plaster made of Nile silt (x' = 8.83 m, y' = 3.85 m)
Phot. 1, E - sample AN5 - - left arm of Amun, original plaster used for primary reconstruction of a poorly prepared limestone block (x' = 9.45 m, y' = 3.85 m)
Photo 3-1. Sample AN 1. Grains of fine calcite cemented with gray grains of fine gypsum. Polarizing light microscope, polaroides X, magnification 80x.
Photo 3-2. Sample AN 1. Grains of fibrous gypsum mixed with black organic substance and cemented with gray grains of fine gypsum. Polarizing light microscope, polaroides X, magnification 80 x.
Photo 3-3. Sample AN 2. Dark brown organic inclusions mixed with light altered grains of gypsum. All component cemented with fine gypsum. Polarizing light microscope, polaroides X, magnification 80 x.
Photo 3-4. Sample AN 2. Grain of fibrous calcite with a fine gypsum bakground. Polarizing light microscope, polaroides X, magnification 80 x.
Photo 3-5. Sample AN 3. Dark brown traces of bats' excrements penetrating into structure of plaster. Polarizing light microscope, polaroides X, magnification 80 x.
Photo 3-6. Sample AN 3. Bluish dehydrated grains of fibrous gypsum (anhydrite) together with gray grains of fibrous gypsum and organic compounds cemented with fine gypsum. Polarizing light microscope, polaroides X, magnification 80 x.
Photo 3-7. Sample AN 4. Dark brown traces of bats' excrements together with light grain of quartz and fine calcite. All components fixed with fine gypsum. Polarizing light microscope, polaroides X, magnification 80 x.
Photo 3-8. Sample AN 4. Beige grain of calcite and gray grains of gypsum cemented with fine gypsum. Polarizing light microscope, polaroides X, magnification 80 x.
Photo 3-9. Sample AN 5. Large light grains of quartz (left part of photo) at the cone of contact with gypsum background of plaster. Polarizing light microscope, polaroides X, magnification 80 x.
Photo 3-10. Sample AN 5. Grains of fibrous gypsum present as fine gypsum polluted with brown concentrations of fragments of bats' excrements. Polarizing light microscope, polaroides X, magnification 80 x.
Photo 3-11. Sample AN 6. The picture of a cross section of the stone from the wall of chapel. One can see dark organic laminas coating the surface

of the stone and penetrating into the structure. Polarizing light microscope, polaroides X, magnification 80 x.
Photo 3-12. Sample AN 6. Irregular brownish spots (traces of bats' excrements) present deep in the structure of limestone. Polarizing light microscope, polaroides X, magnification 80 x.

Explanation for figures

Fig. 1 Schemate of sampling of plaster at chapel of Amun, Hatschepsut Temple – Deir el Bahari- Upper Egypt. 0, X, Y and 0', X', Y' Axes for location of tested samples.
Fig. 2 Mineral composition of mineral plasters used for restoration of walls at Chapel of Amun, Hatschepsut Temple – Deir el Bahari- Upper Egypt.