

Polychromy and gilding in the Gandharan sculptures from Pakistan and Afghanistan: samplings from Museum Guimet in Paris, Civic Archaeological Museum of Milan and Museum of Oriental Art of Turin

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opposite page

Stucco Buddha head
from Milan Museum
(A 987.O3.1, sample 32):
the red colour is
clearly visible
(photo S.Pannuzi).

Keywords
polychromy, gilding,
stucco artworks,
stone artworks,
clay artworks,
chemical analyses,
Gandharan art.

Abstract

This paper will discuss the scientific results of a recent sampling of the polychrome and gilded stone, stucco and clay sculptures of Gandharan art not yet published. Four years ago, we had the opportunity to begin an articulated research project focused on the Gandharan polychrome stone and stucco sculptures, and in the last two years, thanks to a very limited grant, offered by the Italian Government to the Istituto Superiore per la Conservazione ed il Restauro (ISCR), we had the opportunity to develop a new research. This allowed us to investigate some important artefacts displayed in these Museums: the Archaeological Museum of Milan, the Museum of Oriental Art of Turin, the Museum Guimet in Paris. Moreover, we had the opportunity to take some archaeological samples from the new excavations of the Italian Archaeological Mission in Pakistan and the Italian Archaeological Mission in Afghanistan.

In this new research we analysed the artistic technique of painting and gilding on sculptures of Gandharan art made in different materials (stone, stucco and clay).

The results discussed in this paper comes from a notable number of chemical analyses (optical stereo-microscope, SEM-EDS, micro-FTIR, micro-XRD and micro-Raman).

Materials, polychromies and gildings of the Gandhara sculptures and the results of recent scientific investigations

This paper will discuss the scientific results of a recent sampling of the polychrome and gilded stone, stucco and clay sculptures of Gandharan art not yet published. Four years ago, we had the opportunity to begin an articulated research project focused on the Gandharan polychrome stone and stucco sculptures, in collaboration with the Museum of Oriental Art “Giuseppe Tucci” of Rome (ex MNAO, now merged into the *Museo delle Civiltà*) and the Italian Archaeological Mission in Pakistan (MAI), now led by Luca M. Olivieri. In the last two years, thanks to a very limited grant offered by the Italian Government to the Istituto Superiore per la Conservazione ed il Restauro (ISCR), we had the opportunity to develop this research. Our study aimed to clarify some issues, already highlighted in the preliminary



opposite page

Fig. 1a, 1b
Elephant schist
statue from Museum
Guimet. SEM image
of cross section of
sample 1 with a thick
ground layer on the
surface.

research. We had the chance to cooperate with several European Museums of Oriental Art: the Museum Guimet in Paris, the Civic Archaeological Museum of Milan (Oriental Art Collection) and the Museum of Oriental Art of Turin (MAO).

This new research allowed to investigate on some important artefacts displayed in these Museums: the Archaeological Museum of Milan has an interesting collection acquired on antique market and the Museum of Oriental Art of Turin exhibits a part of the artefacts discovered during the excavations by Domenico Faccenna, chief of the Italian Archaeological Mission in Pakistan from the Fifties to the Nineties.

Moreover, we had the opportunity to take some samples from the famous statues with polychromy and gilding from the Gandharan sites in Pakistan and Afghanistan preserved in Museum Guimet in Paris.

Thanks to this funding, we kept cooperating with the Italian Archaeological Mission in Pakistan and we increased the number of samples of different materials, including a series of plaster samples, some of which with polychromy, found in the recent archaeological excavations of the Italian Mission (2014-15)¹.

Recently, we have also begun to cooperate with Italian Archaeological Mission in Afghanistan, led by Anna Filigenzi, and we had the possibility to analyze some samples from Tapa Sardar, near Gazhni, and Tepe Narenj, near Kabul, two important Buddhist sites of the Gandharan culture.

In the frame of these studies, it has been fundamental to cooperate for the scientific investigations, especially about the binders, with Ilaria Bonaduce and Anna Lluveras Tenorio of Chemical Department team of Pisa University, led by M. Perla Colombini.

The first phase of our study (2014-2015) was focused on technological and conservative issues, concerning, in particular, the polychrome stone sculptures of the Rome Museum collection (ex MNAO)². Only a few petrographic studies were carried in the past on the Gandharan stone and stucco sculptures and on the composition of the stucco; the polychromy and the gilding layers on these artworks were not analysed³.

In the past geological studies on Gandharan metamorphic schists were scarcely supported by specialized geological mappings⁴. Lithological-petrographic studies were carried out in order to find out if the use of different stones was owed to the proximity of the caves or to political-economic reasons, that changed according to different periods, as in the site of Taxila in Pakistan⁵; but simply, the use of different stones could be depended on the different types and employment of the artefacts.

In our first research, carried out in ISCR in cooperation with Roma 3 University on the samples taken from Rome Museum (ex MNAO), information on the lithotypes on record was considered in the perspective of the local outcrops and the general archaeological and cultural contexts⁶.

Petrographic and mineralogical analyses of the samples [carried out with Scanning Electronic Microscope/Energy Dispersive X-Ray Analysis (SEM-EDS) and with X-rays diffraction (XRD)] verified that the main lithotype of

¹ The samples were allowed by MAI in Pakistan/ACT-Field School Project (Cooperazione Italiana allo Sviluppo, UTL Pakistan) with export licence of Directorate of Archaeology and Museums Government of Khyber Pakhtunkhwa/Department of Archaeology and Museums Government of Pakistan. We thank L.M.Olivieri for this.

² Pannuzi 2015; Talarico 2015; Pannuzi, Talarico 2018.

³ About bibliography on this theme, see: Pannuzi 2015, pp.10 and 14, footnotes 8-10). In the latter researches, little attention was given to the polychromy and the gilding of the artworks, although Alexander Cunningham and Alfred Foucher, famous explorers of the late nineteenth century, had already commented on the presence of gilded and polychrome sculptures (Foucher, 1918; Faccenna, 1980, pp. 719-720, note 6).

⁴ See for these themes: Rosa, Theye, Pannuzi in this issue.

⁵ A search for the schists caves and the technology of architectural stone carving was organized in 1990 by Domenico Faccenna, together with Peter Rockwell (Rockwell, 2006, pp.157-159) and the University of Bari (see e.g.: Di Florio et al., 1993, pp. 357-372; Faccenna et al., 1993, pp. 257-270; Olivieri, 2006, pp. 137-156).

As regards the use of lithotypes in different historical periods in Taxila site: Marshall, 1951, pp. 476-481 and 671-699.

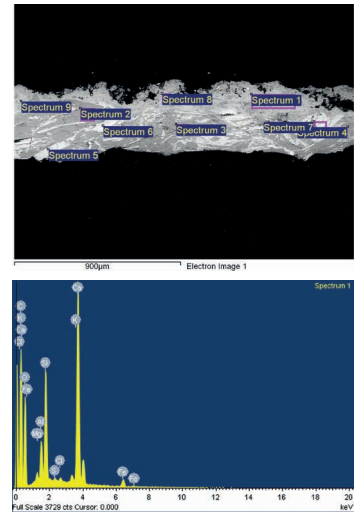
Swat is not a schist, as previously stated, but *serpentinite*. Other less common lithotypes were found such as *talcoschist* and *serpentinoshist*⁷. In the future we hope to implement geochemical studies: we will compare these samples with a stone sampling to be carried out in Swat schist mines. Our aim will be to identify — if possible — the provenance of the stone used for the sculptures in the Gandharan region of Pakistan and whether some stones were preferred because of the vicinity of the quarry to the religious sites or because of the different carving methods.

We are planning to carry on this research about the stone of the Gandharan artefacts, adding other samples taken from reliefs of the Milan Museum, that were acquired through the antique trade. In this latter case, the comparison with already acquired results, could help to establish a geological origin of these stones. Through this comparison we might also understand if an artefact is original or not.

During our new research we decided to extend our investigations also to stucco and clay polychrome and gilded artworks. The selection of samples, from Paris, Milan and Turin Museums⁸, was based on the characteristics of the raw materials (stone, stucco and clay) and the polychromy covering with gilding or pigments. In these phase, as well as in the past, micro samples were taken from the back of artefacts preserved in the museums, or in spots where the surface films were already detached.

Moreover, our interest was devoted to the stucco architectural decorations of the religious monuments of Buddhist sites in Swat (Amluk-dara, Barikot and Gumbat), discovered during the recent archaeological excavations⁹. These stucco samples come from the walls of some collapsed buildings, decorated with coloured patterns on the stucco coatings and on the polychrome stucco architectural and figurative elements; the coloured surfaces of the walls were damaged by weathering. These samples are very important for their precise dating elements, deriving from the stratigraphic contexts, even though they are not fine artefacts as the sculptures kept in the Museums. We developed a growing interest in detecting the precise composition of stucco artefacts from archaeological excavations and from Museums, the kind of pigments and the binders used on the stucco artefacts. Moreover, it was interesting to compare the various type of stucco used to made artworks, come from different sites of Gandhara. These new scientific data could be compared with the few others highlighted in the past about stucco in Gandharan art¹⁰.

By scientific investigations (optical microscope, FTIR, SEM-EDS analyses) on artworks kept in the Museums, we noted the presence of calcite, gypsum and clay in the plaster of Head of Salabhanjika from Hadda (near Jalalab) preserved in Museum Guimet (samples 6, 7)¹¹. Indeed, also in the plaster of an important artwork of Milan Museum, the painted monk statue (sample 22), we detected the high presence of the gypsum in the plaster, while another stucco Bodhisattva statue of Milan Museum reveals a calcium carbonate matrix with heterogeneous grains (iron, potassium, sodium, silicon-aluminate) (sample 23).



⁶ Petrographic studies followed the standards of stone identification of the International Union of Geological Sciences (IUGS): see Guida et al., 2015.

⁷ Guida G. et al. 2015.

⁸ About the Gandhara sculptures of these Museums see e.g.: Verardi, 1991; Provenzali, 2005 and in this periodical; Bartoux, 1933; Hackin, 1940; Cambon, 2004, 2010, 2013 and in this periodical.

⁹ About this theme see e.g.: Faccenna, 1980; Faccenna, 1995; Callieri et al., 1992; Callieri et al., 2000, pp. 191-226; Faccenna, 2002a; Faccenna, 2002b; Faccenna and Spagnesi, 2015; Olivieri, 2015; Olivieri and Filigenzi, 2018.

¹⁰ Barthoux, 1933, pp.45-47; Faccenna, 1980, pp.703-718; Varma, 1987, pp.13-16: the scholar precisely identified two type of stucco used in Gandhara art, a mixture of quick-lime and sand and a "gypsum compound"; Middleton and Gill, 1996; Ohlidalová et al., 2016, pp.124-131. About sculptures of North India see also: Kumar, 1984.

¹¹ Barthoux had already noted the presence of gypsum in the stucco statues discovered in his Hadda excavations: Barthoux, 1933, p. 46

opposite page

Fig. 2a, 2b
Schist statue of Maitreya
from Museum Guimet.
SEM image of cross
section of sample 5:
thick ground layer on the
surface.

By petrographic microscope, SEM-EDS, XRD analyses, the fragments of stucco architectonic decoration from the archaeological excavations in Swat show mostly a plaster with calcite, and sometimes fragments of quartzite, granite, gneiss, garnet, marble and mica flakes, produced from limestone with a certain fraction of clay added, in which the gypsum is always absent.

The use of stucco decoration in the Swat valley is certainly notable but the “kanjur” stone – the limestone probably used for realised stucco artefacts, considering that the petrographic analyses have shown a chemical compatibility, belongs to another geological areas of Pakistan. The area of Taxila, other important Gandharan site, is one of the nearest (others are e.g. Buner, Swabi). Based on this we suppose that the Swat sites imported limestone from an external area, in order to build and to create stucco architectonic decoration and sculptures¹². This import is a considerable change for the economy of Swat sites at the end of the 3th century A.D. In the future, the new historical and archaeological research about Gandharan culture will have to check why this stone was used in those times instead of the schist rock¹³.

Instead, the artefacts from Hadda in Afghanistan were surely made with a local conglomerate and sandstone rocks, that it can easily find in that region, as also gypsum that in some cases was used in the plaster.

Then, we compared the pigments and their possible ground layers on stucco artefacts, both from excavations and Museums, with the polychromy of stone sculpture already analysed in the past to verify if the same polychrome technique was used for different materials or if in the Gandharan area two different methods were used to produce painted stone and stucco objects.

White ground layer for painting polychrome decoration is clearly visible on the schist artworks and it is sometimes very evident and thick as a base for painting over the raw stone surface of statues and reliefs (1, 3, 5 samples from Museum Guimet and 25-26, 27-28-29, 30-31 samples from Milan Museum)¹⁴. By SEM-EDS and FTIR analyses on the schist samples, the composition of this white ground layer shows a high amount of calcium carbonate and aluminum-silicate; in some cases, we also observed inclusions of iron, titanium, zirconium and gypsum¹⁵.

Instead, this white ground layer is not usually visible on all stucco artefacts, probably because is not usually necessary for this material: on these artefacts we noted only a smoothing white surface and over the polychrome layer. We verified this lack of a real ground layer both on the stucco statues from different Museums¹⁶ and on the fragments of the painted architectural decorations. Instead, in a stucco cornice from Butkara I stored in Rome Museum (ex MNAO) (n.1240), by Scanning Electron Microscopy (SEM-EDS) we verified the presence of four different ground layers for overlapping red pigment, containing calcium: in this case we suppose that these ground layers were the trace of successive ancient restorations of polychromy¹⁷. Therefore, it is possible to hypothesize that for par-

¹² See Rosa, Theye, Pannuzi, in this issue.

¹³ This argument was examine by L.M.Olivieri during the last Conference at Courtauld Institute of Art in London (Spring 2016). Also see about it: Olivieri and Filigenzi, 2018, pp. 81-85.

¹⁴ This ground layer was preserved when the incorrect restorations or the times did not destroy it.

¹⁵ Moreover, we also noted the high presence of calcium, sometimes combined with coloured layers, on the surface of the limestone artefacts (e.g. sample 11 from Museum Guimet), a fair but permeable stone.

¹⁶ It was very interesting the analysis of the cross section of a stucco artwork from Milan Museum (sample 22): it showed the lack of the ground layer and the absorption of red colour into the surface of stucco, as still not solidified.

ticular purposes, e.g. for restorations, even the stucco artefacts could have had a background under the colour layers.

Recently, for an exhibition in National Museum of Prague, Czech équipe analysed Afghanistan stucco artworks with a clay core: they noted that on the artworks made in lime stucco the thick polychrome layers are directly applied on the plaster, as in the cases that we studied¹⁸.

Then, also on painted clay artworks we verified the possible presence of the ground layer.

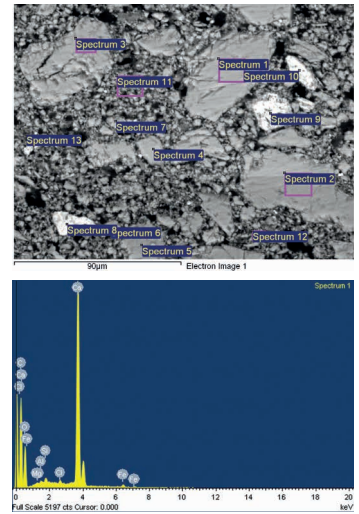
On some samples (15, 17 and 20, Two Naga Kings and Seated Buddha) from Museum Guimet, SEM-EDS analysis of the cross sections showed a lower red orange layer, characterised as red lead (minium) for the high presence of lead, under the blue (lapis lazuli), yellow (orpiment) and red (vermillion) pigments. Instead, on another artwork of the same Museum (samples 18 and 19, statue of Bodhisattva) under the blue ultramarine pigment we noted a red ground constituted by a red ochre mixed with calcite. On artwork from Milan Museum (sample 33, Brahma Head) yellow pigment (an ochre) was lied on a red layer achieved with a red ochre.

So, it would seem that also the clay artefacts had a kind of ground layer for the polychromy: above the red clay it was made with another coloured layer, always red, not white like that of stone artworks. Probably, we suppose that this red covering was laid on whole surface of clay artefacts also to make uniform those parts that should not have been painted later. We think that this is more a coloured surface finish than a real ground layer for the polychromy. It needs to verify this hypothesis in the future with other analyses.

Therefore, we always verified the need of a ground layer or a surface finish for painting on the Gandharan sculptures. The artists used these ground layers as a base with a uniform colour, on which they could then paint. Thus, these ground layers were made in different ways on different raw materials.

Moreover, we noted a various use of colours for painting the stone, stucco and clay artworks: red, with various hue, yellow, white, blue, with various hue, black. Thanks to scientific investigations we highlighted that the Gandharan artists used many pigments: ochre, red lead (minium), vermilion, orpiment, lead white, blue ultramarine, bone black. We also highlighted in some cases the particular techniques to stratify different pigments on the surface and to mix different chemical elements probably to obtain a colour with particular shades. Furthermore, it seems that red ochre from hematite (iron oxide) is the most used pigment for the polychrome decoration on stone and stucco artefacts, usually upon a white ground layer on the schist artworks¹⁹, as we highlighted in our previous sampling in Rome Museum (ex MNAO)²⁰.

On stucco artifacts more colours are used perhaps than on those in stone. Domenico Faccenna noted in Butkara site (Swat Valley, Pakistan) the use of various pigment to paint on stucco works, both ornamental and figured, and on schist sculptures²¹: red, with different shade (red ochre), yellow (yel-



¹⁷Talarico 2015, pp.55-5 and 59.

¹⁸ Ohlidalová et al., 2016, pp.127-128. This équipe studied a different type of stucco artefacts with inside a clay core: lime stucco (statues) and gypsum stucco artworks (heads of Buddha with a gilded covering of the whitish gypsum stucco, in the latter case). Some details of these heads, e.g. the eyes, are painted, but in the Czech work it is not explained the stratigraphic relationship between coloured layers, gilding and stucco surface.

In our research we didn't analysed stucco artefacts with inside a clay core, a more elaborated technical and decoration, that Varma well described (Varma, 1987, pp.41 and 63-75). Therefore, in the next future we would also examine in depth this type of artworks and compare the use of pigment and gilding with the stucco alone artefacts.

¹⁹ By new sampling only one a schist sample from Milan Museum (simple 30) preserved the traces of red polychromy (probably hematite) upon a white ground layer.

²⁰ Talarico, 2015, pp.55, 56, 59. The prevalence of the use of the red colour was also highlighted on coloured patterns of paintings from ancient sites of Central Asia (Lapierre, 1990, pp.33-34), in Indian sculptures and reliefs (Giuliano, 2015, p. 22, 24) and also in Greek and Roman wall paintings and coloured architectures and sculptures. Certainly, this colour, when made with red ochre, shows a great stability over time.

Fig. 3
Hadda's head from
Museum Guimet,
sample from
headgear: micro-
photography of
sample 6 (red layer
and stucco mixture)
(25x).

low ochre), blue (lapis lazuli) and black (ivory black), and also green, though these pigments were identified by microscopic preliminary analysis without more precise scientific investigations²².

In his important research about Gandhara stuccos K. M. Varma examined the mode of colouring stucco artworks and listed the colour used in order of frequency of employment: red, red-brown, black, grey black, crimson and blue. The scholar did not chemically analyse the pigment but only related the colour vision verified on many artefacts. Thus, he supposed the use of some pigments (e.g. vermilion, lac, lampblack), some of which we've not found in our analyses about Gandhara stucco artworks²³.

Successively, some studies were carry out on polychromy of stucco sculptures of British Museum but it seems without specific analyses, only using binocular microscope: they noted that "many of piece present very smooth, well-finished surfaces (...) achieved by the application of a thin layer of fine plaster, termed slip", with a similar composition of the body of the stucco²⁴. Sometimes this slip was pale bluff or yellow due to the presence of ochre. In this paper is not clear if we have to consider this slip as a finish of the stucco surface or a real polychromy.

However, the scholars noted that the "polychrome decoration" (generally with the use of black, red-brown, blue and also gilding) was limited only on some part of the sculptures examined (e.g. hairs, eyes, lips and dresses)²⁵. By some scientific investigations (optical microscopy, SEM-EDS, XRD, Raman spectroscopy, FTIR, XRF) Czech équipe highlighted on lime stucco artefacts the presence of hematite, sometimes perhaps in combination with gypsum and a red dye to achieve a pink colour; to made black they suppose a mixture of bone, carbon black, gypsum and plant fibres. They verified on the gypsum stucco artworks the use of lampblack and of orpiment in grains under the gilding²⁶; they also found cinnabar on the red painted lips of the Buddha head²⁷.

²¹ Faccenna, 1980, pp.719-721. During the restorations, by microscopic preliminary analysis the restorer Franca Callori di Vignale, verified the use of tempera and fresco techniques to paint in successive times the Buddhist buildings: Faccenna, 1980, pp.704, 707. They noted that the pigments were applied directly on the surface of the stone artefacts or "laid on a red bole" (for gildings), not better specified (Faccenna, 1980, p. 720).

²² It has already been highlighted that the green colour was rarely preserved, and probably used, in wall paintings found in ancient settlements of Central Asia (Bactria, Sogdiana and Parthia) and in Indian art. Probably its absence, or limited presence, was due to the discolouring of the green colour (also Varma noted that this colour was not employed in Indo-Afghan stuccos: Varma, 1987, pp.122-123); according to some scholars, this scarce use of the green colour was perhaps due to its lack in the palette of five main colours mentioned in some Sanskrit texts (Lapierre, 1990, pp.34, 37. Giuliano reports its presence in some of more ancient texts: Giuliano, 2012, pp. 58, 62; Giuliano, 2013, p.96). However, these texts were written in more recent time than the Gandharan period, but they show the ancient artistic tradition; about the relationship between these texts and the real artistic practise: Giuliano, 2013, pp. 108-113.

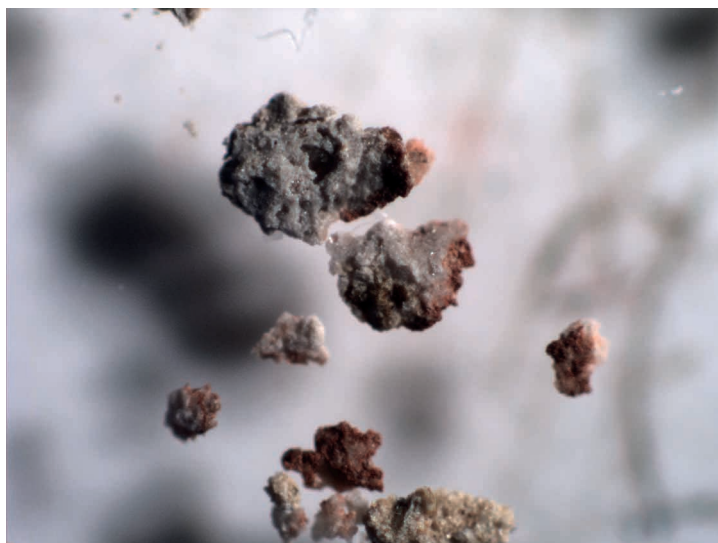




Fig. 4
Stucco Buddha
head with traces
of colour from the
Civic Archaeological
Museum of Milan
(A.987.03.1)
(photo S.Pannuzi).

About the palette of the colours used interesting comparisons can be verified with the ancient Central Asia and Indian paintings and sculptures²⁸.

By SEM-EDS analyses we examined the traces of red ochre, (samples 22, 23 and 32) and yellow ochre from samples of Milan Museum (samples 32, 33). The cross section of the sample from Hadda Head of Museum Guimet (sample 7) shows over the stucco a red layer of ochre and then another layer of red lead (minium): in this case we suppose that, perhaps, this overlapping was an ancient restoration of the polychromy or a refined way to achieve a pinkish colour. Moreover, we analysed another sample from a limestone Hadda relief with a particular polychrome covering: the blue ultramarine, made by lapis lazuli, was mixed to a few grains of red pigment (hematite) and lead white to get a pale blue colour (sample 10 from Museum Guimet). Certainly, this latter polychrome covering reveals a high artistic level and a great experience to use the different pigments.

We verified that the Gandharan artists usually spread the colours on the surface when the stucco plaster was solidified, but in one case (sample 22 from Milan Museum) our analyses showed that the red colour was

It needs to rectify that the colour visible on the stucco artifact of the ex MNAO (inv.1240) was not green but a blackish colour not identified in that research (Talarico, 2015, p. 53; Giuliano, 2015, p. 22).

²³ Varma 1987, pp. 113-126. Thus far, e.g., we never found lac, although this pigment was used in ancient Indian art: see e.g. Giuliano, 2012, p. 59.

²⁴ Middleton and Gill, 1996, p. 367. The research on the stucco sculptures of the British Museum highlighted a different composition and modelling tools and the use of polychromy and gilding (Middleton and Gill, 1996, pp. 363-368).

²⁵ Middleton and Gill, 1996, pp. 363-368.

²⁶ Yellow colour under the gilding was also noted on clay artworks from Nisa: Bollati 2008, p. 180.

²⁷ Ohlidalová et al., 2016, pp. 128-131.

²⁸ About these themes see e.g.: Varma, 1970, pp. 106-108; Kumar, 1984, pp. 199, 203; Lapiere, 1990; Bollati, 2008; Appolonia et al., 2008; Capanna et al., 2012; Giuliano, 2012 (in particular for the use of lead white and orpiment in Ajanṭā painting: pp. 61, 63); Capanna, 2013; Giuliano, 2013; Giovagnoli et al., 2013; Iole, Giovagnoli, Mariottini, 2013; Iole, Giovagnoli, Artioli, 2013.

Fig. 5
Hadda's head from
Museum Guimet,
sample from cheek:
micro-photography
of sample 7 (100x).

Fig. 6
Hadda's head from
Museum Guimet,
sample from cheek:
SEM image of
sample 7.

opposite page

Fig. 7
Sampling of Hadda's
relief from Museum
Guimet (sample 10)
(photo S.Pannuzi).

Fig. 8
Hadda's relief from
Museum Guimet:
micro-photography
of sample 10.

absorbed into the surface of stucco: we can suppose that the plaster was heterogeneous and the pigment was fluid or, most probably, that the stucco mixture was not still solidified. Thus, we can reasonably hypothesize not a hastily work to make this artefact, but on the contrary, the aim to achieve on purpose a better duration of the painted covering, through an integration between colour and stucco similar to a fresco technique.

On the surface of some samples from stucco architectural decorations from Swat, we noted a few traces of very pale, faint and dilute red colour: by preliminary investigations (Raman analysis) we verified the use of the red ochre (hematite)²⁹. We hope in next future to analyse thoroughly.

Concerning the clay artworks of Gandharan art, found in Afghan sites, their loamy composition and the type of pigments used for the polychromy we have little bibliographic informations³⁰. Unbaked polychrome clay sculptures, mostly Buddhas and Bodhisattvas, were recently found in Mes Aynak excavations: the colours preserved are red, black, blue, white and gilding on the Buddha heads³¹. In comparison with these our investigations we analysed the data about clay polychrome sculptures from Nisa excavations in Turkmenistan³². There it was used cinnabar and red ochre for red colour, red ochre with kaolin for pale pink, lac for pink, yellow ochre for yellow colour, blue Egyptian and lapis lazuli for blue colour, lampblack for black colour and kaolin and gypsum for white ground layer for painting³³. In that site it was noted a very developed processing techniques to make pigments.

The results obtained in our research on clay sculptures will need further analyses regarding the production of the clay mixture, always unbaked but in some cases baked at low temperatures, as we are checking with our analyses³⁴. On clay artworks we highlighted the presence of different pigment for polychromy, also with a stratification: by SEM-EDS analyses on the cross section of sample taken from Two Naga Kings statue of the Museum Guimet (from hair) we found on the clay surface a red orange layer with lead (minium) (sample 15) with overlapping lapis lazuli layer (blue ultramarine); in another sample taken from the same artworks (sample 17) (from ear) under the yellow colour (orpiment) the analysis showed a lower red orange layer (minium), already found in the first sample. Moreover, on the surface of clay statue of Bodhisattva from Fundukistan (from hair) we found a red layer with iron (red ochre) with an overlapping blue ultramarine layer, that visually turned to a black colour (sample 18); instead on

²⁹ See Rosa, Theye, Pannuzi in this issue.

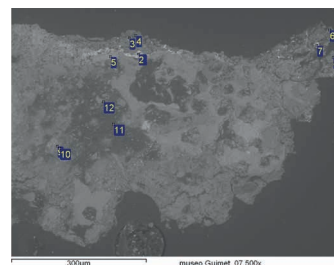
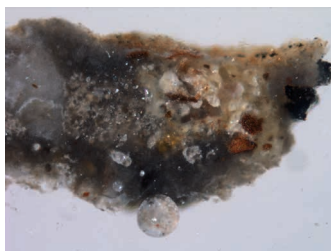
³⁰ A few hints about this theme in: Fussman, Le Berre, 1976, p.78; Verardi, 1983, pp.479-502; Tarzi, 1990, pp.57-93. About the Gandharan art in Afghanistan settlements see e.g.: Taddei and Verardi, 1978, pp.33-135; Taddei and Verardi, 1981, Taddei, 1993, pp.118-122; Filigenzi, 2008.

³¹ The clay sculptures were compared to the artworks from Kabul area (IV-IX century A.D.). In Mes Aynak excavations the archaeologists also found stone and plaster sculptures (AA.VV., 2011, p. 32).

³² Bollati, 2008, pp. 188-189; Appolonia et al., 2008, pp.197-209.

³³ As indicated before, on clay sculptures analysed from Paris and Milan Museum we found under the polychromy a red layer, not white as on Nisa clay sculptures.

³⁴ By polarized optical microscope, preliminary analysis on Tapa Sardar sample indicated that this clay mixture baked with low temperatures, because calcite, still well-formed, indicates surely temperatures below 600°C. I thank Anna Lluveras Tenorio for this important information. See also Rosa, Theye, Pannuzi in this issue.

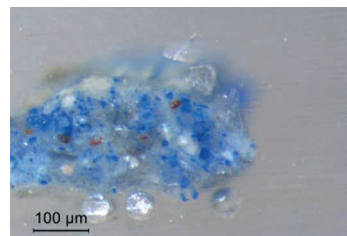


the garland of this same statue (sample 19) we found a complex stratification: a layer with lead compound mixed with calcium silicate and lapis lazuli covered a layer with lead white (cerussite/hydrocerussite) mixed with bone black (calcium phosphate) spread on red ochre layer visible on the clay surface. On clay seated Buddha from Museum Guimet (sample 20) we saw two different red layers overlapping: with lead the lower one and with cinnabar (vermillion pigment) the upper one. Then, a clay Brahma Head from Milan Museum (sample 33) showed the presence of two different coloured layers, red below and yellow above, together made with ochres.

By this overlapping of colour layers, always with the red below, we suppose that this is more a clay surface finish than a real ground layer for the polychromy (see above). We suppose that on the clay artworks this red layer, with red lead (minium) or red ochre, was used as a ground layer, spread on the artwork surface to paint over with other different colours (see above). Moreover, very interesting results are issued by analyses on schist sculptures with visible and now invisible traces of gilding. The investigated gildings were always constituted of a gold leaf made with a high percentage of gold and little copper and silver (indicatively by our analyses, the amount of gold is between 93.04% and 97.26%, copper between 1.27% and 5.14%, silver between 0.78% and 2.26%). In all cases the gildings were put on different ground layers: a bolus composed by hematite, gypsum and clay, similar to the typical technique for gildings in Mediterranean area (sample 13 from Museum Guimet and sample from Saidu Sharif excavation³⁵); a red layer composed by calcium and lead (probably minium) (sample 14 from Museum Guimet); a ground layer was composed by a whitish mixture of clay, red ochre and mainly with the presence of calcium (standing Buddha from Milan Museum, sample 21); a mixture of silicon, aluminum and calcium (samples 34,35 from Turin Museum).

On sample 12 from a very famous statue of Buddha from Paitava monastery in Afghanistan, kept in Museum Guimet, SEM-EDS analysis showed a different chemical composition in different fragments of the leaf: one of these had less gold and more copper percent, while the silver was a similar percentage to other fragments. We supposed that this part of the gilding could have been restored in ancient time, as we already noted for other Gandharan artworks³⁶. These data clarify the presence of continuous maintenances, carried out by artists to preserve the beauty of the sacred images.

Finally, by FTIR analysis, GC-MS and MS proteomics analysis³⁷ we thoroughly examined the type of binders used for stucco and clay polychrome artworks and the technique used to achieve gilded stone artworks. These investigations clearly showed different types of binders for polychromy and gildings, especially proteinaceous materials: only animal glue³⁸ [sample 21 (gilding), sample 22 (polychrome stucco) and sample 25 (polychrome clay) from Milan Museum]; animal glue, milk³⁹ and eggs together (samples 15-17 and 18-19 from Museum Guimet); a protein binder, probably eggs⁴⁰ (samples 12-13 from Museum Guimet)⁴¹. On one clay fragment from Tapa



³⁵ See the results discussed in Zaminga et al., in this issue.

In Butkara site Domenico Faccenna already highlighted the presence of typical bolus under the gildings; in other cases the gilding was laid directly on the surface of the stucco artefacts (Faccenna, 1980, p.720).

³⁶ Pannuzi, 2015, p.12; Talarico et al., 2015, p.59; Zaminga et al., in this issue.

³⁷ The proteomics analysis is one of the most promising analytical approaches to identify proteins, introduced in the field of cultural heritage about eleven years ago. See the results of GC-MS and proteomics analysis discussed in Bonaduce et al., in this issue.

³⁸ Animal glue is obtained by boiling bones, hide or other cartilaginous parts of animals; it is made of, collagen partially hydrolysed.

opposite page

Table 1

Sample 1, SEM-EDS spot analysis by the cross section. All results in weight %.

Table 2

Sample 5, SEM-EDS spot analysis by the cross section.

Table 3

Sample 9, SEM-EDS spot analysis by the cross section.

³⁹ Milk is a water emulsion of proteins and lipids.

⁴⁰ Eggs can be used whole, or using only one of its components: yolk or glair.

⁴¹ It is very interesting the presence of saccharidic and proteinaceous materials in subsequent painted layers of the lost Giant Buddhas of Bāmiyān, Afghanistan, (6th-7th century AD) (Lluveras Tenorio et al., 2017).

⁴² See the results about clay of sample 1 from Afghanistan: Rosa, Theye, Pannuzi, in this issue.

⁴³ Ohlídalová et al., 2016, pp. 128-130. Moreover, on gilded gypsum stucco artwork the Czech équipe noted the presence of a binder probably based on polysaccharides (p.131). The presence of this type of binder (polysaccharides) has also been identified on polychrome clay artefacts from Nisa excavations (Bollati, 2008, p.188, n.134).

⁴⁴ The tragacanth gum was found in the clay modelling of the sculptures and in the following restorations of the painted covering (with egg) (Lluveras Tenorio et al., 2017, pp.8, 12-13). Instead milk and egg were found as binder of original polychromy and of first historical restorations. On Central Asian paintings the binder with vegetable origin, probably a gum, was discovered (Lapierre, 1990, p.35). The use of gum was report by Sanskrit texts (Giuliano, 2012, pp.59-60; Giuliano, 2013, pp.101-104).

⁴⁵ Report of Pisa University (20-10-2015) to ISCR.

⁴⁶ See Bonaduce et al. in this issue.

⁴⁷ About lapis lazuli quarries see, e.g.: Varma, 1970, p.165 note 76.

⁴⁸ Chinese pilgrims reported that the Gandharan monasteries in Swat possessed mines of gold and iron (Tucci, 1958, pp.280-281).

Sardar in Afghanistan it is very interesting the identification of tragacanth gum as the polysaccharide binder used in the clay mixture and a proteinaceous binder in painted layer⁴². Vegetable gum was noted also by analyses recently achieved on stucco artworks by Czech équipe⁴³ and on painted layers of clay samples from the lost Giant Buddhas of Bāmiyān in Afghanistan (6th-7th century AD)⁴⁴.

By GC-MS analysis on samples of architectural decoration from Swat excavations (Amlukdara, Gumbat and Barikot) traces of proteinaceous material have been highlighted as binder in the red painted layers (not animal glue, perhaps egg)⁴⁵. Very interesting was the analyses on a sample collected from a polychrome decoration on plaster coming from Amlukdara in Pakistan (sample AKD14C): on ground layer of colour GC-MS analysis showed the presence of proteins, most likely milk or egg white. By proteomics analysis on the painted layer the identification of 26 peptides ascribable to collagen allows us to ascertain the presence of animal glue in the sample. Moreover, a comparison of the peptide sequences with the available databases allowed us also to identify the specific biological source of the collagen: bovine⁴⁶. In next future, we would understand if different binders have been purposely used on different raw materials or if the choice of the binder was connected to the costs and to the natural resources available to the artists in different sites.

In conclusion, in Gandharan sculptures we highlight the use of different ground layers, pigments and gildings with various, refined and expensive technology to paint and to gild the artworks. Indeed, although lapis lazuli⁴⁷, lead, iron, gold⁴⁸, silver and copper are present in large amount in the Afghan and in Pakistani regions, we have to consider the costs of the different productions of the pigments, the gildings and especially the binders with eggs and milks. Thus, in the future, we will try to understand if these different artistic modalities to work were due to different and not local traditions, come to the Gandharan sites through trades or invasions of foreign people, or if these various artistic technologies were specific creations of Gandhara artists in different times⁴⁹ and sites, linked with the local different resources.

(S. P.)

Gandharan artworks from Guimet Museum in Paris: chemical analyses on polychromies (see Sampling List)

Sample 1

By SEM-EDS spot analysis by the cross section of the sample, taken from an Elephant schist sculpture, the spectra 1, 8, 9 show the presence of a high amount of calcium carbonate (figg.1A and 1B, tab. 1), to be referred to a white substance applied over the schist stone and used for a polychrome decoration that is now lost. Considering the geo-archaeological origin of the land in the Ghandara area, there is no reason to presume that this layer has a natural origin due to the presence of water, rich in carbonates, in the earth where the objects were found.

Table 1

Spectrum	Na	Mg	Al	Si	S	Cl	K	Ca	Mn	Fe	Total
Spectrum 1	0,00	2,06	7,29	20,37	0,60	0,90	1,89	61,19	0,00	5,70	100
Spectrum 2	0,00	0,00	4,88	84,05	0,00	0,72	0,58	5,94	0,00	3,82	100
Spectrum 3	0,00	0,76	4,85	82,36	0,00	0,76	0,81	5,56	0,00	4,90	100
Spectrum 4	0,90	0,00	13,81	64,61	0,00	1,20	3,55	10,81	0,09	4,55	99,54
Spectrum 5	0,00	2,1	31,9	29,3	0,00	0,79	0,88	2,56	0,35	31,16	99,05
Spectrum 6	0,68	1,4	29,02	32,31	0,00	0,81	0,54	4,24	0,00	31,00	100
Spectrum 7	0,00	1,65	29,84	26,53	0,00	1,00	0,87	7,26	0,28	31,62	99,06
Spectrum 8	1,14	1,43	7,45	23,74	0,59	1,14	3,45	56,4	0,00	4,67	100
Spectrum 9	0,00	1,66	5,19	15,98	0,00	1,14	1,01	71,85	0,00	3,16	100

Table 2

Spectrum	Mg	Al	Si	Cl	K	Ca	Fe	Total
Spectrum 1	0,37	0,54	1,27	1,27	0,00	93,27	3,28	100,00
Spectrum 2	0,74	0,68	1,05	0,85	0,00	94,45	2,23	100,00
Spectrum 3	0,00	0,58	1,09	0,96	0,00	95,39	1,98	100,00
Spectrum 4	0,48	0,62	1,49	0,73	0,00	94,61	2,07	100,00
Spectrum 5	0,00	0,00	1,65	1,10	0,00	95,42	1,83	100,00
Spectrum 6	0,00	0,00	1,26	0,98	0,00	94,88	2,88	100,00
Spectrum 7	0,40	0,97	1,66	1,26	0,00	91,63	4,08	100,00
Spectrum 8	0,00	2,38	3,97	0,74	0,00	36,12	56,79	100,00
Spectrum 9	0,00	1,83	3,03	1,20	0,67	38,53	54,74	100,00
Spectrum 10	0,89	2,49	3,45	0,89	0,78	36,32	55,18	100,00
Spectrum 11	0,00	1,04	1,96	1,61	0,00	91,86	3,53	100,00
Spectrum 12	0,00	0,98	3,24	1,72	0,00	90,80	3,28	100,00
Spectrum 13	0,00	1,18	2,24	3,38	0,00	89,62	3,58	100,00

Table 3

Processing option: All elements analysed (Normalised)

Spectrum	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	As	Pb	Total
Spectrum 1	1,25	0,00	1,37	4,04	4,04	0,00	4,77	1,31	13,72	0,00	9,20	60,30	100
Spectrum 2	0,00	0,00	0,00	6,50	5,26	0,00	4,85	1,20	21,88	0,00	8,88	51,43	100
Spectrum 3	0,00	0,00	1,39	4,20	4,68	0,00	5,55	1,32	23,34	0,00	9,62	49,90	100
Spectrum 4	2,49	11,92	4,21	36,80	1,13	1,67	2,53	1,79	28,70	1,17	0,51	7,09	100
Spectrum 5	4,49	6,71	8,13	31,29	0,00	4,67	3,78	2,67	27,29	0,00	2,09	8,89	100
Spectrum 6	1,97	4,27	8,37	16,32	3,04	3,68	6,51	4,05	14,03	5,39	3,41	28,96	100
Spectrum 7	0,83	3,42	1,68	7,12	0,73	0,86	1,68	1,35	5,01	67,99	1,01	8,32	100

In the lower layer of the cross section, the presence of Ce, Nd, and Th (group of Lantanidi) is common in the schist stone, as well as the presence of Ti, often combined with iron.

Sample 2

This sample was taken to an Elephant schist sculpture (see sample 1). SEM EDS analysis is only referring to the schist stone. Zr is contained in the sam-

⁴⁹ We hope that it will be possible to clarify the chronology of the various Gandharan artefacts (see Ingholt, 1960), especially with the help of new historical and archaeological researches.

opposite page

Table 4

Sample 11, SEM-EDS spot analysis by the cross section.

Table 5

EDS analyses of gilding from sample 12. Elements are expressed as atomic percent.

Table 6

EDS analyses of gilding from sample 14. Elements are expressed as atomic percent. All results in weight%.

ple, as commonly in the schist stones. Inclusions of Ti combined with iron are observed.

Sample 3

By SEM EDS analysis the sample, taken from a white layer on the surface of Pakistani schist relief from Buner Valley, shows the presence of a high amount of calcium. Inclusions of iron and Ti are observed too. This layer has to be referred to a white substance applied over the stone and used for a polychrome decoration that is now lost. The analyses do not include the schist.

Sample 4

SEM EDS analyses achieved on sample from Pakistani relief see above (see sample 3) are only referring to the schist stone (with a silico-alluminate matrix). Inclusions of Ti combined with iron are observed too. Thanks to the thin section, despite the small amount of material, it is possible in next future to deepen the petrographic investigation aiming at the definition of the lithotype.

Sample 5

The sample was taken from a white surface, preserved on the right foot, of the schist statue of Bodhisattva Maitreya from Pakistan. SEM-EDS analyses of highlighted the presence in the spectra of an abundant amount of calcium, probably in combination with calcium carbonate, owed to a white preparation layer, put on the surface of the stone and used for a polychrome decoration that it has now been lost (figg. 2A and 2B, tab. 2). (G. G., C. R.)

Sample 6

This sample was taken from the headgear of stucco head of Salabhanjika from Hadda (Afghanistan). Micro-FTIR analyses on the powders identified calcite and gypsum in the plaster (fig. 3). As known FTIR technique is unable to detect oxides (e.g. hematite, a red oxide). Micro-XRD analysis detected quartz, calcite and albite ($\text{NaAlSi}_3\text{O}_8$ – plagioclase feldspar mineral) as main components of plaster.

Sample 7

This sample was taken from the pinkish cheek of Hadda's stucco head (see sample 6). Micro-FTIR analyses on the powders identified calcite and gypsum in the plaster (fig. 4). The result of the analyses about the pigments used on this artwork to achieve a pinkish colour is very difficult to understand. Optical microscope images of the cross-section matched with SEM-EDS analyses seems to show a very thin, discontinuous red layer of ochre; a second red orange layer, slightly more thick, is over imposed to the previous one. Its chemical composition reveals the presence of lead, probably minium. This evidence may be explained as an ancient inter-

Table 4

Processing option: All elements analysed (Normalised)

Spectrum	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	As	Pb	Total
Spectrum 1	1,25	0,00	1,37	4,04	4,04	0,00	4,77	1,31	13,72	0,00	9,20	60,30	100,00
Spectrum 2	0,00	0,00	0,00	6,50	5,26	0,00	4,85	1,20	21,88	0,00	8,88	51,43	100,00
Spectrum 3	0,00	0,00	1,39	4,20	4,68	0,00	5,55	1,32	23,34	0,00	9,62	49,90	100,00
Spectrum 4	2,49	11,92	4,21	36,80	1,13	1,67	2,53	1,79	28,70	1,17	0,51	7,09	100,00
Spectrum 5	4,49	6,71	8,13	31,29	0,00	4,67	3,78	2,67	27,29	0,00	2,09	8,89	100,00
Spectrum 6	1,97	4,27	8,37	16,32	3,04	3,68	6,51	4,05	14,03	5,39	3,41	28,96	100,00
Spectrum 7	0,83	3,42	1,68	7,12	0,73	0,86	1,68	1,35	5,01	67,99	1,01	8,32	100,00

Table 5

Spectrum Label	1	2	3	4	5	6	7	8	9	10
Cu	4.58	4.74	3.87	5.14	42.14	29.02	2.74	3.25	1.27	4.86
Ag	1.52	2.22	0.78	1.47	0	5.31	0	1.26	2.26	1.63
Au	93.9	93.04	95.36	93.39	57.86	65.67	97.26	95.5	96.47	93.51
Total	100	100	100	100	100	100	100	100	100	100

Table 6

Processing option: All elements analysed (Normalised)

Spectrum	Mg	Al	Si	P	S	Cl	K	Ca	Fe	As	Au	Pb	Total
Spectrum 1	0,00	2,45	9,93	8,48	2,74	5,32	1,58	14,67	13,92	0,00	0,00	40,90	100,00
Spectrum 2	0,00	1,47	5,99	9,88	0,00	5,55	1,36	19,98	2,79	0,00	0,00	52,99	100,00
Spectrum 3	1,44	3,75	8,62	6,92	0,00	4,84	1,73	14,16	5,03	0,00	0,00	53,52	100,00
Spectrum 4	0,00	0,85	2,43	5,78	0,00	5,44	0,00	11,61	1,53	3,50	0,00	68,85	100,00
Spectrum 5	1,03	3,38	9,87	7,78	0,00	5,66	2,01	15,57	6,19	0,00	0,00	48,52	100,00
Spectrum 6	0,00	0,00	0,00	0,00	0,00	0,00	0,75	5,94	2,63	0,00	90,68	0,00	100,00

vention on the artifact, required to regain the chromatic integrity, or as a device to obtain a pinkish colour (fig. 5, 6). The chemical composition of the greater part of the cross-section is mainly silicon, aluminium, calcium and potassium. The most of calcium is present as carbonate, only a little part is gypsum, thus confirming FTIR analyses. Silicon, aluminum and potassium confirm the presence of clays in the stucco mixture. Spare grains of silica were identified too. EDS map shows iron grains, to refer to red and yellow ochres.

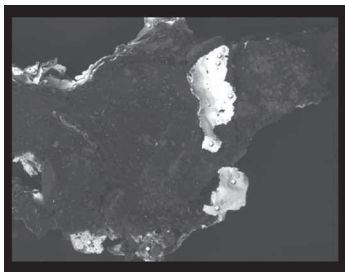
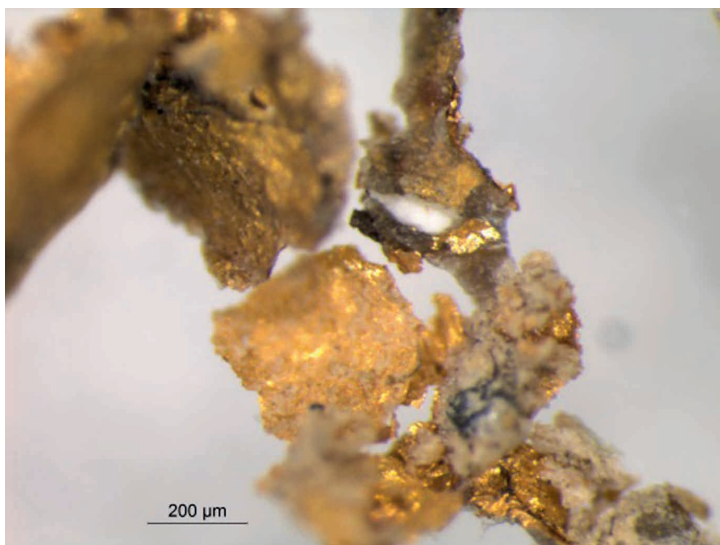
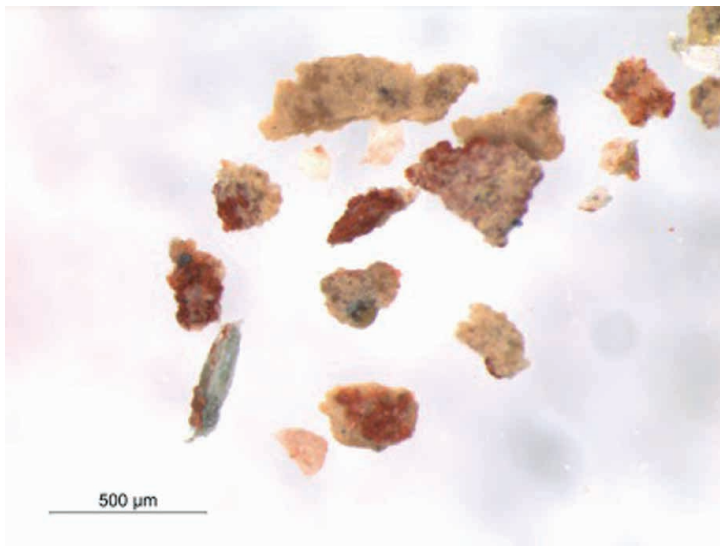
Sample 8 (n. 9 sampling)

This sample, taken from a figure of red painted limestone relief from Hadda, Tapa-i-Kafariha monastery (Afghanistan), was examined only by micro-FTIR. The main evidences of limestone are the presence of calcium carbonate and silicates. We noted also the presence of calcium oxalate: a

Fig. 9
Buddha statue
of Paitava from
Museum Guimet
(sample 13): micro-
photography. You
can see the bolus.

Fig. 10
Buddha statue
of Paitava from
Museum Guimet
(sample 12), gilding
micro-photography.
You can see the
gilding.

Fig. 11
Buddha statue of Pai-
tava from Museum
Guimet (sample
12): SEM image of
sample.



by-product of the deterioration of organic materials. As known, this technique is unable to detect oxide compounds, we cannot therefore say more about the red pigment. Micro-XRD analysis confirmed the presence of calcite and quartz raw material of the artefact.

(F. T.)

Sample 9 (n.10 sampling)

The SEM-EDS analyses are referring to the limestone of the same relief of Hadda (see sample 8). Spectra 1, 2, 3, carried out on the surface, highlight a high amount of Pb (probably minium) owed to a surface painting of the

artefact. The spectrum 7 indicates a high amount of iron (probably hematite): it must be referred to the composition of the raw material (with a silicon-aluminate matrix) of the relief (tab. 3).

(G.G., C.R.)

Sample 10 (n.11 sampling)

The sample was a greyish blue pigment taken from the same relief of Hadda see above (samples 8 and 9) (fig.7). We realized SEM-EDS analyses. Blue grains are made of lapis lazuli, characterized by a very good relation among the elemental maps of silicon, aluminum, sodium and sulphur, thus confirmed by spot analyses. A greyish component is associated to silicon-aluminates of magnesium; calcium carbonate is diffused on the whole sample, probably as a component of the raw material of the artefact. White grains contain mainly lead, probably as carbonate (lead white, i.e. cerussite / hydrocerussite). Note that arsenic is associated to lead, but at the moment a satisfying explanation for this cannot be given. Observing the micro-photo of this sample, we can suppose that lead white was mixed to the lapis lazuli, in order to obtain a pale blue colour (fig.8).

Phosphorus was detected in spot EDS analyses corresponding to lead. Some hypothesis may be proposed: it could be associated to the mineral composition or it could be a marker of a casein glue, but it is necessary to deepen this problem through specific analyses.

Few grains of red pigment are mixed to the ultramarine blue; EDS elemental maps and spot analyses report only iron, with no other chemical element, we can therefore suppose the presence of hematite (Fe_2O_3).

(F. T.)

Sample 11 (n.12 sampling)

The sample is only representative of the surface of the artefact, a limestone relief from Hadda, Chakhil-i-Ghoundi monastery, stairway of stupa C1 (Afghanistan). The SEM-EDS analysis shows a high amount of calcium, perhaps owed to the ground layer of a polychrome decoration or a raw material of the artefact (tab. 4). Other analyses will carry out to investigate this issue.

(G. G., C. R.)

Samples 12 and 13 [n.13 sampling (gilding and bolus on schist) and n.14 (bolus and schist)]

Some analyses were carried out on some samples of gilding and on an evident underlying bolus of a famous gilded statue in schist of *Buddha* in the *Miracle of Sravasti*, from Paitava monastery (Afghanistan). The results are very interesting, because micro-FTIR analyses detected a protein, probably egg, in the bolus. The red bolus, analysed by micro-Raman technique, is mainly composed by hematite (Fe_2O_3), with some gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) and clay as silicon-aluminate (fig.9). This result reminds the typical technique for gilding sculptures and paintings in the Mediterranean area.

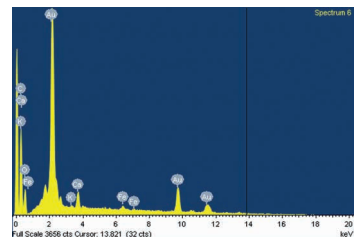
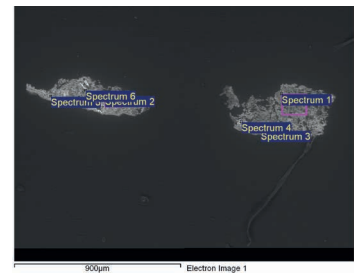
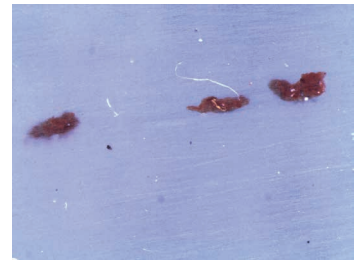


Fig. 12
Shotorak relief from Museum Guimet (sample 14): micro-photography of gilded sample.

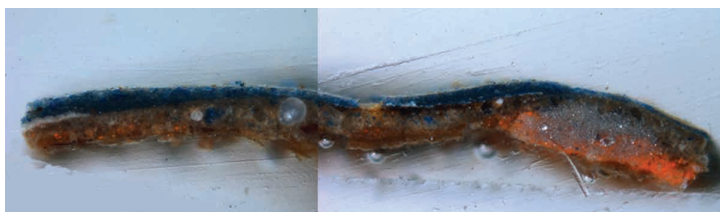
Fig. 13a
Shotorak relief from Museum Guimet (sample 14): SEM image of some fragments.

Fig. 13b
Shotorak relief from Museum Guimet (sample 14): EDS analysis of Spectrum 6 (see Fig.13a).

Fig. 14
Sampling of Statue
of two Naga Kings
(from hair) from
Museum Guimet
(sample 15) (photo
S.Pannuzi).



Fig. 15
Statue of two Naga
Kings statue (from
hair) from Museum
Guimet (sample 15):
micro-photography of
cross section (100x).



FTIR analyses carried out on several spots of the same sample shows the probable presence of egg glue as binder of the red colour. In some of the analyzed points we found a synthetic vinyl acetate based adhesive, certainly related to a recent intervention.

Analyses were performed after selecting one fragment of gilding, directly on the sample without any process to embed the sample in a cross section (fig.10). All analysed gildings are constituted of a gold leaf. SEM image clearly highlights the presence of three fragments of gilding on the *bolus* (fig.11). EDS analyses show a different chemical composition: two fragments have a very similar composition (see tab. 5, measurement nn. 1, 2, 3,

4, 7, 8, 9, 10): the amount of gold is between 93.04% and 97.26%, copper between 1.27% and 5.14%, silver between 0.78% and 2.26%. The third one, unlike the previous ones, has a very different chemical composition (measurements nn. 5 and 6): it was poor in gold (57.86% and 65.87%), rich in copper (29.2% and 42.14%); silver varied from 0% to 5.31%. The great difference in chemical composition in this part of gilding suggests a probable ancient restauration.

It is interesting to highlight the heterogeneous chemical composition in the same gold alloy; we suppose that this evidence could be related to the technique of purification and production of the gold leaf. Observing under microscope the gilded fragments we often note some roughness of the surface.

(F. T.)

Sample 14 (n.15 sampling)

The sample has been taken from a schist relief from Shotorak monastery (Afghanistan) with visible traces of a red colour. By optical microscope a golden gilding, not visible to the naked eye, has been detected (fig. 12). By SEM EDS analysis the presence of Pb might be referred to the red colour (minium?). The presence of calcium (in varying amounts) might be owed to a preparation layer of gilding (figg.13A and 13B, tab. 6).

(G. G., C. R.)

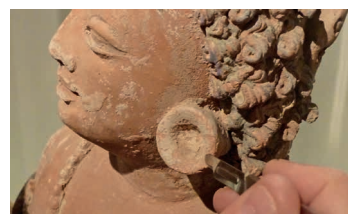
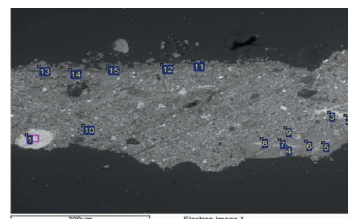
Sample 15 (n.16 sampling)

A sample of blue color was taken from the hair of one of two clay figures of the two Naga Kings sculptures from Fundukistan (Afghanistan) (fig.14). Observing under a microscope the cross-section obtained from the sample, a very interesting sequence of layers of paint appeared (fig.15). In the lower part of the cross-section an orange coloured heterogeneous layer, with various thickness, is characterized by the presence of lead; by SEM-

Fig. 16
Sampling of two Naga Kings statue (from arm) from Museum Guimet (sample 16) (photo S.Pannuzi).

Fig. 17
Statue of two Naga Kings statue (from arm) from Museum Guimet (sample 16): SEM image of cross section.

Fig. 18
Sampling of two Naga Kings statue (from hear) from Museum Guimet (sample 17) (photo S.Pannuzi).



EDS analysis we assume that it was minium. In the middle of the cross section elemental maps of silicon, aluminum and magnesium show a very good overlapping. A discontinuous white layer was observed on the left of the cross section, under the blue pigment. Blue ultramarine was used in the upper layer.

Sample 16 (n.17 sampling)

This sample was taken from the arm of one of two clay figures of the two Naga Kings sculptures from Fundukistan (Afghanistan) (fig.16). By SEM-EDS analysis the maps of elements of this cross-section show the overlapping of cobalt and tin (fig.17). The only possible explanation for this is the presence of stannous cobalt, a modern pigment synthesized in the second half of the 19th century. So its presence is due to a modern restoration. On the upper layer of the cross-section Cobalt is not related to tin, (point 12) so we suppose that the pigment cobalt blue has been used (CoAl_2O_4). Spot analyses on point 12 show a good connection between calcium and phosphorus, probably due to the presence of calcium phosphate, typical of bone black.

The lower part of the cross-section reveals the presence of silicon, aluminum and iron, related to the clay material of the statue.

Sample 17 (n.18 sampling)

The sample has been taken from one ear of one of Naga kings (see samples 15 and 16) (fig.18). The cross-section has a complex stratigraphy, at least four layers have been detected. The most interesting layers show, under visible light, a well-defined yellow pigment, applied on a red-orange layer (fig.19). The red-orange layer, indeed, when observed under UV light, is almost split into two layers not well defined (fig.20). Indeed, the lower red-orange layer of the cross-section appears heterogeneous and incoherent.

Fig. 19
Statue of two Naga Kings
(sample from hear) from
Museum Guimet: micro-
photography of cross section
of sample 18 (visible light).

Fig. 20
Statue of two Naga Kings
(sample from hear) from
Museum Guimet: micro-
photography of cross section
of sample 18 (UV light).

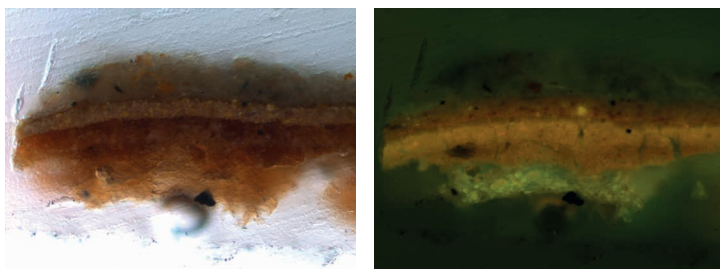
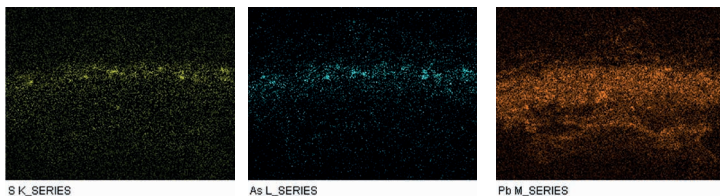


Fig. 21a, b, c
Statue of two Naga Kings
(sample from hear) from
Museum Guimet: EDS
elemental maps of Sulphur,
Arsenic and Lead on cross
section of sample 18.



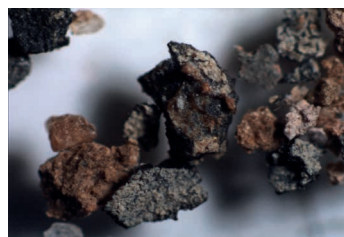


Fig. 22
Sampling of Statue of Bodhisattva (from hair) from Museum Guimet (sample 18) (photo S. Pannuzi).

Fig. 23
Statue of Bodhisattva (from hair) from Museum Guimet: micro-photography of sample 18 (25x).

Fig. 24
Sampling of Statue of Bodhisattva (from garland) from Museum Guimet (sampling 19) (photo S. Pannuzi).

Another superficial and incoherent layer, over the yellow layer, was chemically characterized by silicon, aluminum, calcium and potassium and may be explained as dirt or as a restoration ground layer.

A more complex description is necessary to describe the red-orange and the yellow layers. These layers, as seen above, are clearly visible under UV light. Both layers, however, do not have a different chemical composition: both maps and spot analyses reveal the presence of lead as main element. No silicon, nor aluminum or iron have been detected in these layers, we therefore exclude the presence of a clay and we can attribute them to two painted layers. Lead is the most plentiful chemical element, both in the red-orange layer than in the upper yellow layer.

The presence of lead may be owed to the presence of different pigments, according to their color: in the lower layer, the red-orange colour, may be related to the pigment minium.

SEM-EDS elemental maps and spot analyses of the upper yellow layer show a very good fit between arsenic and sulphur, related to the pigment orpiment (fig.21). Moreover, the presence of lead in this layer, may be inferred to the use of massicot/litharge pigment, mixed with the orpiment pigment.

Micro-FTIR analyses highlighted the presence of an animal glue as binder of the pigments.

Table 7
EDS analyses of gilding from sample 19. Elements are expressed as atomic percent.

Table 8
EDS analyses from sample 20. Elements are expressed as atomic percent.

opposite page

Fig. 25
Statue of Bodhisattva (from garland) from Museum Guimet: micro-photography of cross section of sample 19 (100X).

Fig. 26
Statue of Bodhisattva (from garland) from Museum Guimet: SEM image of cross section of sample 19.

Samples 18 (n.19 sampling)

This sample was taken from the hair of clay Bodhisattva statue from Fundukistan monastery (Afghanistan) (figg. 22, 23). It was constituted of a powder and it was analyzed by micro-FTIR. The FTIR spectrum of the black-blueish pigment well fits with the pigment ultramarine blue. The underlying red ground was constituted by red ochre mixed with calcite. At the moment we are not able to state if this red layer comes from to the clay material or it is a ground for the blue pigment; we are presently working on this issue and hope to be able to answer soon.

Sample 19 (n. 20 sampling)

This sample was got from the garland of the same clay Bodhisattva statue (see sample 18) (fig.24). The cross-section highlights two different layers made by a blue-greyish colour and a red colour. The cross-section was analyzed by SEM-EDS. Note that the photo is upside down, so the red color is the inner layer, while the blue-greyish is the upper one (fig.25).

The upper blue-greyish layer was obtained by mixing a blue pigment and a greyish one. Elemental maps highlight a lead compound mixed with calcium silicate (see maps of lead, silicon and calcium). Spot analyses on blue

Table 7

Spectrum	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Fe	Br	Pb	
1	3,07	5,14	10,79	45,06	0,00	0,00	2,59	2,28	28,34	0,00	0,00	0,00	2,72	100
2	0,00	7,89	4,82	48,93	0,00	0,00	0,00	1,35	35,46	0,00	0,00	0,00	1,55	100
3	6,32	1,43	21,22	43,82	0,00	0,00	3,62	3,65	16,14	0,00	0,00	0,00	3,81	100
4	0,00	0,77	0,95	92,36	0,00	0,00	0,00	1,16	2,84	0,00	0,00	0,00	1,92	100
5	0,00	14,32	9,70	43,36	0,00	0,00	1,41	22,64	4,23	1,97	0,00	0,00	2,38	100
6	0,00	1,69	21,04	46,57	0,00	0,00	2,34	14,56	4,74	1,23	5,51	0,00	2,31	100
7	0,00	0,00	4,33	15,79	0,00	0,00	0,00	1,55	2,65	0,00	74,19	0,00	1,49	100
8	0,00	0,00	0,00	24,30	0,00	0,00	1,32	1,02	4,12	0,00	59,50	8,04	1,70	100
9	0,00	1,63	8,18	29,78	0,00	0,00	2,60	1,34	5,00	0,00	49,91	0,00	1,57	100
10	0,00	1,74	14,87	47,94	0,00	0,00	3,03	4,92	10,00	0,00	13,84	0,00	3,66	100
11	0,00	3,09	3,28	14,63	0,00	0,00	0,00	1,12	4,77	0,00	73,11	0,00	0,00	100
12	0,00	3,63	5,02	27,93	0,00	0,00	0,00	2,75	20,57	0,00	0,00	0,00	40,11	100
13	0,00	3,58	3,96	17,71	0,00	0,00	0,00	0,00	11,01	0,00	0,00	0,00	63,74	100
14	0,00	8,30	3,79	47,11	0,00	0,00	0,00	0,83	38,14	0,00	0,00	0,00	1,84	100
15	0,00	3,24	0,00	31,27	5,46	0,00	7,91	5,25	18,18	0,00	3,61	4,86	20,23	100
16	0,00	2,55	6,85	24,70	8,69	0,00	10,00	5,07	19,40	0,00	3,03	0,00	19,71	100
17	0,00	0,00	3,69	22,53	9,27	0,00	9,74	0,00	22,60	0,00	3,06	0,00	29,11	100
18	0,00	2,02	4,45	18,35	11,12	0,00	9,63	0,00	25,17	0,00	4,14	0,00	25,11	100
19	0,00	2,23	3,55	14,17	0,00	0,00	1,20	1,53	4,25	12,39	59,07	0,00	1,61	100
20	0,00	8,62	1,86	47,15	0,00	1,51	0,00	1,03	38,46	0,00	0,00	0,00	1,38	100

grains (see fig. 26 and tab. 7, point 3: silicon, aluminum, sodium) and related elemental maps are congruent with ultramarine blue (fig.27). The greyish grains were analyzed by SEM-EDS too, in order to determine if the grey color was originated from the discoloration of the ultramarine blue pigment. As known, this pigment, in acidic conditions, may decay in a discoloured greyish pigment. This event was not confirmed, because the chemical composition of the greyish grains differs from the blue grains one. Lead could be formerly related to the lead white pigment; if this hypothesis is confirmed, we might suppose a chemical deterioration to lead oxide (plattnerite).

Under the blue-blackish layer, a white thin area in SEM image is related to the presence of lead. It is interesting to notice that in the thin white layer a good correspondence was among lead, calcium and phosphorous; we suppose that lead white (cerussite/hydrocerussite) was used, mixed with bone black (calcium phosphate), and applied directly on the red material.

The red material is characterized by a very good overlapping among the elemental maps of iron, silicon and aluminum, corresponding probably to a red ochre; some granules of silica were observed. It seems to be a “painted” red layer above the clay material of the statue.

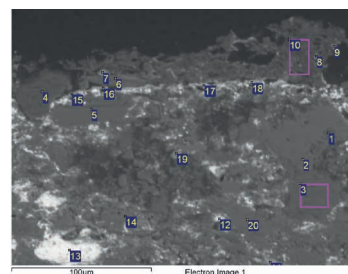
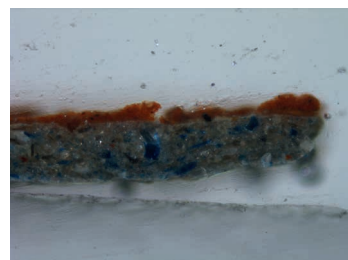
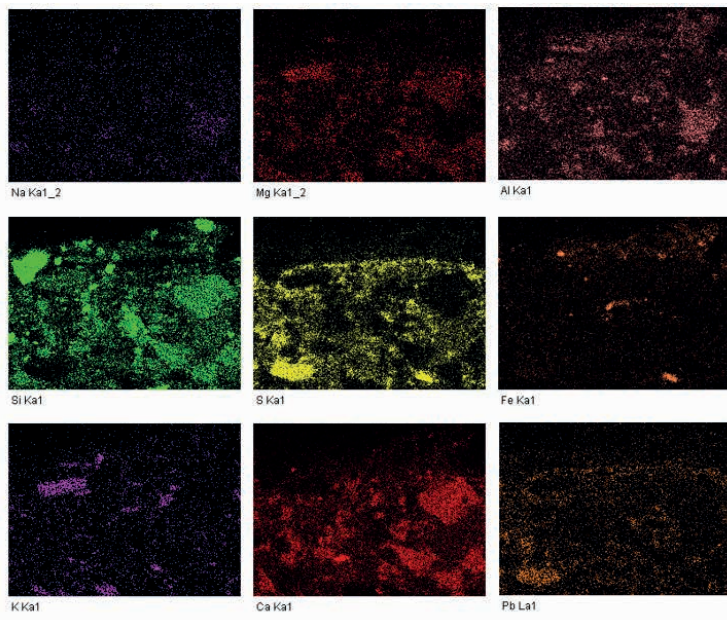


Table 8

Spectrum	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Fe	Br	Pb
1	3,07	5,14	10,79	45,06	0,00	0,00	2,59	2,28	28,34	0,00	0,00	0,00	2,72
2	0,00	7,9	4,83	48,98	0,00	0,00	0,00	1,35	35,5	0,00	0,00	0,00	1,55
3	6,32	1,43	21,22	43,82	0,00	0,00	3,62	3,65	16,14	0,00	0,00	0,00	3,81
4	0,00	0,77	0,95	92,36	0,00	0,00	0,00	1,16	2,84	0,00	0,00	0,00	1,92
5	0,00	14,37	9,73	43,5	0,00	0,00	1,41	22,71	4,24	1,98	0,00	0,00	2,39
6	0,00	1,69	21,04	46,57	0,00	0,00	2,34	14,56	4,74	1,23	5,51	0,00	2,31
7	0,00	0,00	4,33	15,79	0,00	0,00	0,00	1,55	2,65	0,00	74,19	0,00	1,49
8	0,00	0,00	0,00	24,3	0,00	0,00	1,32	1,02	4,12	0,00	59,5	8,04	1,7
9	0,00	1,63	8,18	29,78	0,00	0,00	2,6	1,34	5	0,00	49,91	0,00	1,57
10	0,00	1,74	14,88	47,97	0,00	0,00	3,03	4,92	10,01	0,00	13,85	0,00	3,66
11	0,00	3,09	3,28	14,63	0,00	0,00	0,00	1,12	4,77	0,00	73,11	0,00	0,00
12	0,00	3,63	5,02	27,93	0,00	0,00	0,00	2,75	20,57	0,00	0,00	0,00	40,11
13	0,00	3,58	3,96	17,71	0,00	0,00	0,00	0,00	11,01	0,00	0,00	0,00	63,74
14	0,00	8,3	3,79	47,11	0,00	0,00	0,00	0,83	38,14	0,00	0,00	0,00	1,84
15	0,00	3,24		31,27	5,46	0,00	7,91	5,25	18,18	0,00	3,61	4,86	20,23
16	0,00	2,55	6,85	24,7	8,69	0,00	10	5,07	19,4	0,00	3,03	0,00	19,71
17	0,00	0,00	3,69	22,53	9,27	0,00	9,74	0,00	22,6	0,00	3,06	0,00	29,11
18	0,00	2,02	4,45	18,35	11,12	0,00	9,63	0,00	25,17	0,00	4,14	0,00	25,11
19	0,00	2,23	3,55	14,17	0,00	0,00	1,2	1,53	4,25	12,39	59,06	0,00	1,61
20	0,00	8,62	1,86	47,15	0,00	1,51	0,00	1,03	38,46	0,00	0,00	0,00	1,38

Fig. 27
Statue of Bodhisattva
(from garland) from
Museum Guimet
(sample 19): EDS
elemental maps of
Sodium, Magnesium,
Aluminium, Silicon,
Sulphur, Iron,
Potassium, Calcium
and Lead.



opposite page

Table 9
EDS analyses of gilding
from sample 21.
Elements are expressed
as atomic percent.

Table 10
EDS analyses of gilding
from sample 21, *versus*:
ground layer under the
gilding. Elements are
expressed as atomic
percent.

Table 9

Spectrum Label	1	2	3	4	5	6	7	8
Cu	1,68	3,01	2,14	2,14	2,20	1,23	2,82	2,29
Ag	5,23	4,65	5,06	5,57	5,05	5,84	4,36	4,69
Au	93,09	92,34	92,80	92,29	92,75	92,93	92,81	93,03
Total	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

Table 10

Spectrum Label	18	19	20	21	22	24
Mg	0,77	0,74	0,00	0,00	0,00	0,00
Al	2,41	2,63	1,76	3,12	1,89	2,32
Si	2,90	3,28	2,22	4,47	1,51	2,95
S	0,93	1,16	1,54	1,58	0,00	1,00
K	0,00	0,00	0,00	0,69	0,00	0,00
Ca	87,05	85,37	90,79	85,21	88,60	88,59
Fe	0,00	0,96	0,00	1,20	0,82	0,59
Au	5,95	5,85	3,68	3,73	7,19	4,55
Total	100,00	100,00	100,00	100,00	100,00	100,00

Sample 20 (n. 21 sampling)

This sample was picked up from the clay statue of seated Buddha (fig. 28). The micro-photo of the powder shows a sequence of four different painted layers: a brown-greyish layer, two different red painted layers (figg.29A and

29B). The cross-section obtained from one of the fragments clearly shows the sequence of layers (fig.30). SEM-EDS analyses of red layers show in the lower layer mainly lead probably as minium, a lead oxide (Pb_3O_4), and a little of chlorine. In the upper red layer mercury and sulphur are related to cinnabar (or vermilion); vermilion is mixed in the upper layer to red lead (see Pb vs. Cl and Hg vs. S elemental maps (figg. 31 A and 31 B, tab. 8).

The lower brown layer is characterized by a very good overlapping of the elemental maps of silicon, aluminum and potassium. Minor elements detected are iron, calcium and magnesium, not directly related to the main elements (K, Si, Al), probably as oxide (i.e. Fe_2O_3 , hematite) or carbonates ($CaCO_3$, $MgCO_3$).

The chemical analyses may be explained as a clay (characterized by the main elements K, Al, Si) well mixed with iron oxides and calcium/magnesium carbonates, because the elemental maps of the main elements are not related to the minor elements (Fe, Ca, Mg).

Inside the clay ground some red-orange and black stripes on a red orange grain may be observed. The chemical spot analyses highlights iron, silicon, aluminum and potassium.

(F. T.)

Gandharan artworks from Civic Archaeological Museum in Milan: chemical analyses on polychromies

Sample 21 (n. 4 sampling)

This sample has been taken from a gilded stone statue representing Buddha, one of most important statues of the Milan Archaeological Museum (fig.32). The statue was made in shale and covered with a gilding; now only some spare traces of gold are preserved. This sample was representative of a gilding applied on its ground. The sample was analyzed by SEM-EDS on the *recto* (gilding) and *verso* (ground) (figg. 33, 34).

SEM-EDS analyses allowed us to understand the chemical composition of the gold leaf. Seven analyses were performed on the gold sample (see tab. 9). Gold (Au), Silver (Ag) and Copper (Cu) were found. The average (as atomic percentage) and the standard deviation (s.d.) were: Au 92.75% (s.d. = 0.3), Ag 5.06% (s.d. = 0.49), Cu 2.19% (s.d. = 2.19). The black material, partially covering the gilding, seems to be a superficial sediment, probably due to residues of excavation soil or atmospheric pollution. Its chemical composition (tab.: main elements, expressed as atomic percent) is Si (41.46%), Al (26.14%), Ca (16.58%), Fe (5.97%), K (5.78%).

The ground, *verso* side, representing the layers under the gilding the analyses revealed the presence mainly of calcium (Ca); minor elements were potassium (K), aluminium (Al), silicon (Si), iron (Fe), magnesium (Mg), sulphur (S) (tab. 10). The high content of calcium is due to calcium carbonate; gypsum, considering to the low amount of sulphur, is absent. Similar results were obtained on the EDS analyses, performed on *recto*. The high content of calcium highlights the absence of schist on this sample. Calcium carbonate has probably the function of the bolus: meant to make the gild-

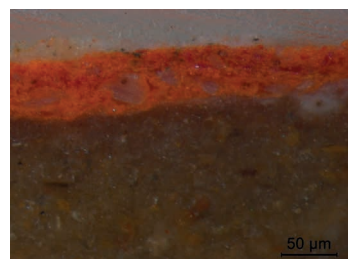


Fig. 28
Sampling of Statue of Seated Buddha from Museum Guimet: detail of the dress (sampling 20) (photo S.Pannuzi).

Fig. 29
Statue of Seated Buddha from Museum Guimet: micro-photography of sample 20 (12.5x).

Fig. 30
Statue of Seated Buddha from Museum Guimet: micro-photography of cross section of sample 20.

Table 12

Spectrum Label	1	2	3	4	5	6	7	8	9	
Na	1,76	1,52	1,42	1,18	1,56	2,65		1,44		
Mg	4,07	4,25	3,85	6,67	3,03	11,56	2,00	5,57	2,21	
Al	7,17	4,29	1,93	9,49	10,51	15,93	0,76	11,50	0,95	
Si	14,30	9,57	6,11	22,60	44,12	33,11	3,21	44,06	4,76	
P				0,37						
S	1,39	2,66	0,88	0,72	1,25	0,22		0,28		
Cl	2,29	3,08	1,64	1,55	2,48	0,40	0,47	1,26	0,64	
K	1,75	0,77	0,48	1,69	2,02	0,58		3,25		
Ca	62,40	69,72	82,47	50,85	32,61	15,32	93,30	28,41	91,04	
Ti	0,55	1,47			0,61	4,16		0,36		
Mn						0,22				
Fe	3,85	1,97	1,23	4,89	1,41	15,84	0,27	3,86	0,40	
Zn	0,46	0,72								
Mo										
Ba					0,40					
Total	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	
Spectrum Label	10	11	12	13	14	15	16	17	18	19
Na		1,70	1,88	2,18		1,80	1,04	1,35		1,44
Mg	2,00	5,28	4,96	3,97	3,52	6,65	4,28	5,26	4,29	3,55
Al	2,73	10,19	3,85	4,25	5,81	3,13	1,71	1,69	2,27	1,84
Si	12,36	40,40	16,38	13,63	58,34	11,25	12,65	8,41	8,56	7,02
P			0,44							
S		0,34	1,67	1,41	1,30	1,40	0,64	0,72	0,55	0,38
Cl	0,70	0,87	2,67	1,78	2,65	2,62	2,41	1,69	1,93	1,06
K	0,59	1,62	1,13	1,09	1,72	0,86	0,51	0,49		
Ca	80,72	34,33	58,93	68,35	24,07	71,43	75,86	78,90	81,59	84,23
Ti		0,75						0,78		
Mn										
Fe	0,67	4,51	7,54	3,35	2,22	0,87	0,91	0,72	0,81	0,49
Zn			0,53		0,37					
Mo	0,24									
Ba										
Total	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

is applied on a fresh layer of ground, so it diffused in the underlying stucco that is the raw material of this statue. The dough was obtained mainly by milled gypsum (more than 40%), mixed with silicates (figg. 37 A and 37 B, tab. 11). A large grain of dolomite $[(MgCaCO_3)_2]$, see Ca/Mg maps] was observed. Despite of the refined execution of the statue, a simple technique was revealed by the heterogeneity of the materials and the coarse dough employed on this artifact.

Table 12
EDS analyses from sample (23) (spectra 1-19). Elements are expressed as atomic percent.

Fig. 32
Sampling of
schist statue of
Buddha from
Milan Museum
(sample 21) (photo
S.Pannuzi).

Fig. 33
Schist statue of
Buddha from
Milan Museum
(sample 21): micro-
photography, *recto*
(10x).

Fig. 34
Schist statue of
Buddha from
Milan Museum
(sample 21): micro-
photography, *verso*
(10 x).



Sample 23 (n. 6 sampling)

This sample was taken from a stucco statue representing a Bodhisattva, discontinuous traces of red pigment are visible (Fig. 38). The cross-section of this sample reveals a thin red layer 10-20 μm ; its chemical composition shows the presence of red ochre for the presence of Fe, Si, Al in the upper layer of the cross-section (Fig. 39). Unlike sample 5, the red pigment has not been found in the underlying layer, it is therefore probable that the pigment was applied over the dried base.

The ground too differs from the sample 5. Observing its cross-section under visible light, we observe the presence of black and red grains that characterize the ground. Grains of iron, potassium and sodium silico-aluminate sprinkled in a calcium carbonate matrix (Fig. 40, 41; tab. 12).

Elemental maps of iron, aluminum and silica are often superimposed, denoting the presence of ochres (Fig.42). We noted a very good relation among silicon, aluminum, strontium and potassium. The diffuse presence of calcium carbonate was confirmed by micro-FTIR analyses on the powder of the sample. The cross-section highlights the presence of large grains of calcium carbonate, approx. 0,2-0,3 mm, mixed inside the stucco. Micro-XRD analyses were performed on a grounded sample: calcite, dolomite and quartz were detected; the same analysis on *tal quale* sample detected quartz, calcite and gold. This result is very interesting because gilding was not visible to the naked eye and on the cross section analyzed by SEM EDS. In next future other analyses will carry out to understand the presence of gold.

Sample 24 (n.7 sampling)

The sample was a powder picked up from a schist false corbel (*Nagadanta*) (fig.43). Micro FTIR analyses highlights the invasive presence of a synthetic adhesive, belonging to polyamides employed in a previous restoration. The strong signals of the adhesive hide the weak signals due to the original material. Only in a little fragment it was possible to observe weak signals, typical of the bands of silico-aluminate compounds.

Samples 25 and 26 (nn.8 and 9 sampling)

These samples were picked up from a relief in schist with Buddha life scenes, characterized by a superficial white layer (Fig.44). Observing the fragments under microscope and owing to the FTIR results we can assert that the upper white layer is not owed to the excavation soil or to the environment dust, it is something derived from human activity, most likely to be associated to a painting technique (Figg.45, 46).

Micro-FTIR analyses show the presence of Calcium carbonate and aluminum-silicate. Both samples were not suitable to get cross-sections.

Samples 27, 28 and 29 (nn. 10, 11 and 12 sampling)

These samples were taken from a stele, representing a Bodhisattva (Fig.47). The samples seem very similar to the samples 25 and 26, previously described: schist with a superficial white layer (fig.48). On sample 28 only the schist is visible, probably with some traces of the upper layer. Chemical analyses (FTIR) give similar results too: calcium carbonate and alumina-silicate.

(F. T.)



Fig. 35
Sampling of a stucco Monk statue from Milan Museum (sample 22) (photo S.Pannuzi).

Fig. 36
Statue of stucco Monk from Milan Museum: micro-photography of cross section sample 22 (50x).

Fig. 37
Statue of stucco Monk from Milan Museum (sample 22). SEM image of the sample and EDS elemental maps of Calcium and Sulphur.

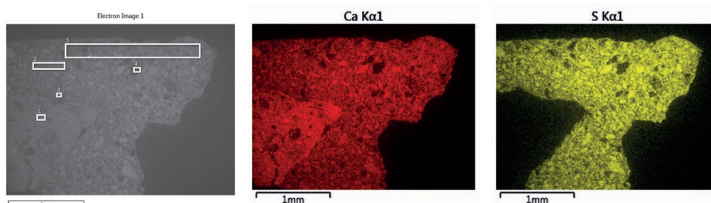


Fig. 38
Stucco statue,
Bodhisattva from Milan
Museum (sample 23):
image of the sample 6
tal quale (8x).



Fig. 39
Stucco statue,
Bodhisattva from Milan
Museum (sample 23):
micro-photography of
cross section (15x).



Fig. 40
Stucco statue,
Bodhisattva from Milan
Museum (sample 23):
SEM image of cross
section.

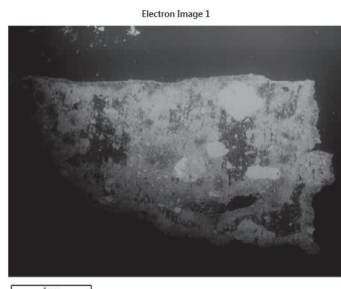
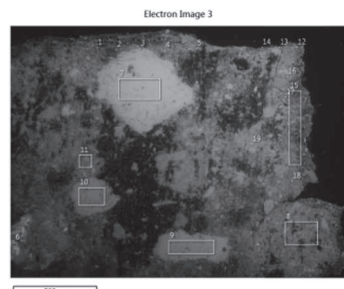


Fig. 41
Stucco statue,
Bodhisattva from Milan
Museum (sample 23):
SEM blow up image of
cross section.



Samples 30 and 31 (nn.14, 15 sampling)

These samples were taken from a schist capital of a lost pilaster (Fig.49). Grey schist and another whitish material are well shown in micro-photograph (fig. 50). The whitish material of sample 30 is analytically characterized by micro-FTIR analysis as calcite, gypsum and silicon-aluminate. By SEM EDS analysis, in spectrum 4, we noted a certain amount of calcium, probably matched to calcium carbonate, owed to a white superficial preparation layer, laid on the schist stone and used for a polychrome decoration that has now disappeared. A high amount of Fe, Ti and Zr were detected in the thin section.

Micro-Raman analyses on a red grain highlighted the presence of hematite, probably traces of ancient polychromy, not visible by naked eye.

(F. T., G. G., C. R.)

Sample 32 (n.17 sampling)

This sample was taken from the stucco Buddha's Head (Figg.51, 52). The cross-section obtained from this sample clearly shows on the right side the presence of a red layer, whereas on the left side the surface is quite orange (Fig. 53). Despite of this evidence, EDS analyses do not denote significant differences in chemical composition of the two colours: the presence of iron, aluminum, silicon as main chemical elements, in similar percent, are due to two chromatically different red colours, but chemically very similar ochres. According to FTIR and SEM-EDS analyses, the ground is mainly a mix of calcium (as carbonate) and silicon (as SiO_2). Note that magnesium was present mainly in red and orange ochres, as we can see in EDS maps of Ca and Mg.

Sample 33 (n.25 sampling)

This sample was taken from the hair of the clay head of Brahma (Fig.54). The cross section clearly highlights the sequences of the layers (Figg.55, 56). The clay plaster seems polished, in order to obtain a smooth surface covered by a thin layer of yellow paint.

Indeed, observing the cross-section at a greater magnification we notice in the upper part two layers of two very thin layers of different pigments over a rough clay plaster: a yellow pigment is applied on an underlying red pigment. EDS analyses show a good overlapping of the elemental maps of iron, magnesium and silicon, respectively due to two different ochres, a yellow and a red one.

The rough plaster was characterized by heterogeneous materials consisting in red, yellow, grey and black grains: a large red granule is observed on the right and greyish components characterize this sample. The chemical composition of the rough plaster was explained by SEM-EDS analyses: Silicon, Aluminium, Iron and Calcium and Magnesium are the main chemical elements found along the cross-section. The greyish component in the clay is composed by a calcium silicate.

(F. T)

Gandharan artworks from Museum of Oriental Art in Turin: chemical analyses on gildings

Samples 34 and 35 (nn.1 and 2 sampling)

Two samples of gilding were taken from two different sides of a schist corbel (MAO n. 4581), in order to analyse the chemical composition of gilding and its ground.

Looking at the micro-photos, the following superimposition of layers has been observed: 1) greenish grey of the schist; 2) a white ground; (3) partially browned in the upper; (4) gold leaf (Fig.57).

Sample 34 represents only the gilding and its underline layer (Fig.58).

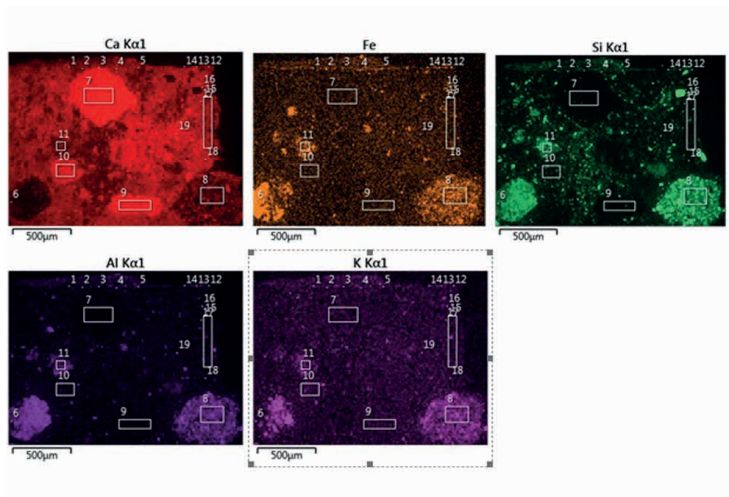


Fig. 42
Stucco statue,
Bodhisattva from Milan
Museum (sample 23):
EDS elemental maps of
Calcium, Iron, Silicon,
Aluminium, Potassium.

Fig. 43
Schist false corbel from
Milan Museum: micro-
photography of sample 24
(8x).

The samples were arranged without any preliminary treatment on the *stub* and analyzed by SEM-EDS (Figg.59, 60). In sample 1 gilding is characterized by gold leaf with a little amount of copper (Au = 97,64%; Cu = 2,36%) (tab. 13). Under the leaf the browned ground is a silicate compound, characterized by variable amounts of silicon, calcium, aluminum, magnesium and iron.

Micro-photo of sample 35 shows the golden leaf with browned ground, similar to the previous one (Fig.61). Micro-photography highlights some traces of manufacturing of the gold leaf, such as the curved lines on the left of the micro-photo. Its chemical composition is very similar to the sample 1 (Au = 96,85%; Cu = 3,15%) (Figg.62, 63, tab. 14).

The only important difference between these two samples of gilding is a not negligible presence of lead (its amount is few less than 10%), only found upon some gilded areas. This occurrence is hard to explain. Observing micro-photos we are led to exclude the presence of red minium or other lead oxides, such as the lead white. A hypothesis might be made: the lead comes from air pollution.

EDS analyses on brownish ground give a good overlapping among the elemental maps of silicon, aluminum, calcium, magnesium, iron. These results are very similar to that obtained for sample 34. (F. T)

Conclusive comment about the analyses

The results discussed in this new research comes from a notable number of chemical analyses. Micro-photos of sample were collected under opti-

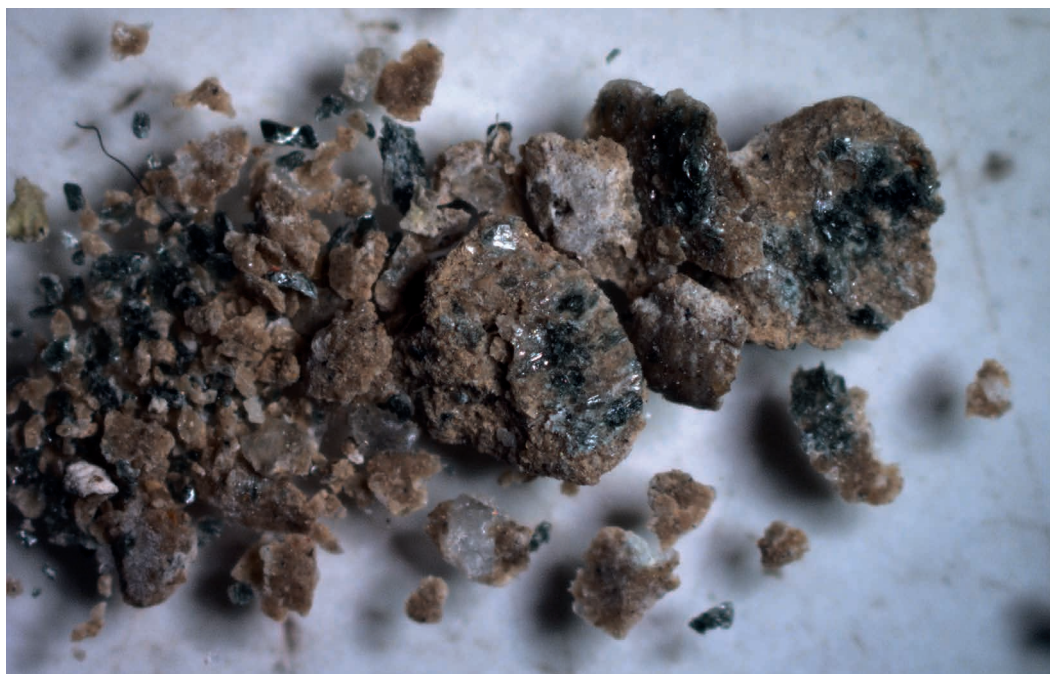


Table 13

Spectrum Label	1	2		3		4	5	
O	15,24	15,37		14,98		18,97	15,06	
Na		0,31						
Mg	0,59	0,56		0,58		0,95	0,59	
Al	1,23	1,42		1,27		2,76	1,27	
Si	2,48	2,52		2,38		5,36	2,50	
S								
Cl								
K	0,45	0,52		0,45		1,35	0,44	
Ca	2,55	2,29		1,86		2,49	2,26	
Ti								
Fe	0,87	0,87		0,80		1,32	0,77	
Cu	1,87	2,50	1,57	2,11	1,79	2,36	0,74	0,99
Au	74,73	97,5	74,58	97,89	75,91	97,64	66,80	76,37
Total	100,00	100,00		100,00		100,00	100,00	

Spectrum Label	6	7	8	9	10	11	12
O	25,82	42,55	34,01	40,65	40,42	16,15	37,98
Na	0,55				0,48		
Mg	0,94	3,06	2,74	11,39	1,72	0,77	6,47
Al	2,93	4,83	5,11	9,29	13,15	1,74	5,62
Si	12,49	23,72	9,78	15,21	17,81	3,00	12,10
S		2,18	1,63	1,23	1,18		3,43
Cl		0,42	0,54	0,31	0,22		0,52
K	0,76	1,45	1,37	1,02	5,55	0,63	1,01
Ca	2,63	8,71	27,60	7,32	4,40	3,26	17,55
Ti	0,15				0,38		
Fe	1,48	3,52	3,91	5,67	2,58	1,09	4,45
Cu	0,63		0,38				
Au	51,61	9,56	12,94	7,91	12,11	73,36	10,88
Total	100,00	100,00	100,00	100,00	100,00	100,00	100,00

Table 13
EDS analyses from sample 34 (spectra 1-12). Elements are expressed as atomic percent.

cal stereo-microscope (Leica M125). Cross-sections of greater samples were achieved embedding any sample in polyester resin and observed and photographed under optical microscope (Leica DM-RXP). Samples (as micro-fragment, powder or cross sections) were analysed by SEM-EDS (Evo 60 Zeiss), collecting data as chemical maps and spot chemical analyses. Micro-FTIR analyses were performed after a preliminary study under optical microscope. After this preliminary selection, the samples were housed on a diamond cell and then analysed under micro-FTIR spot by spot. In addition, some micro-XRD and micro-Raman analyses were carried out.

Fig. 44
Sampling of schist relief from Milan Museum (sample 25) (photo S.Pannuzi).

Fig. 45
Schist relief, micro-photography of sample 25 from Milan Museum (16x).

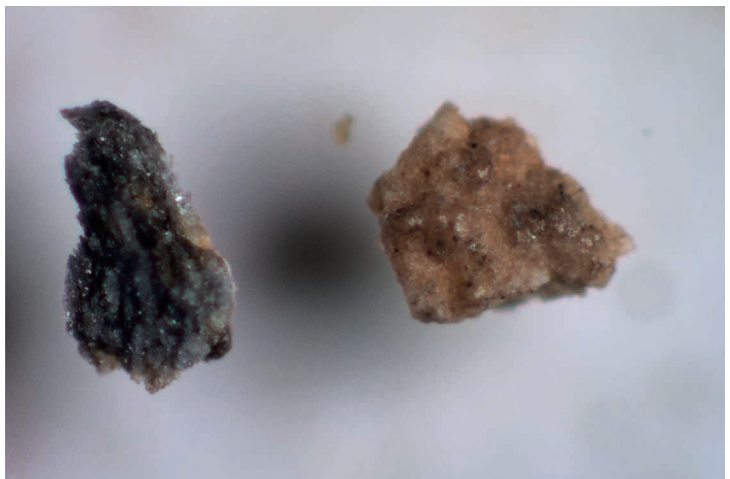


Table 14

Spectrum Label	1	2	3	4	5	6	7
Ca	0,00	1,38	1,34	2,38	2,84	0,55	0,67
Mg	0,00	0,65	0,77	0,59	0,67	0,00	0,33
Al	0,88	1,88	2,11	1,96	1,80	0,00	0,89
Si	1,10	2,83	3,36	2,98	2,85	0,98	1,33
Cl	0,00	0,00	0,00	0,00	0,00	0,00	0,00
K	0,00	0,48	0,58	0,59	0,57	0,16	0,25
Ti	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Fe	0,58	1,24	1,27	1,20	1,46	0,44	0,51
Cu	2,11	2,20	1,73	2,15	2,54	2,09	1,73
Au	85,34	81,36	88,84	81,39	80,50	85,01	85,52
Pb	9,99	7,98	0,00	6,76	6,77	10,77	8,76

Spectrum Label	8	9	10	11	12	13	14
Ca	12,35	6,31	8,39	3,29	13,79	17,71	3,29
Mg	2,01	2,19	3,71	2,08	2,23	4,61	1,66
Al	5,42	6,03	12,72	17,27	13,11	8,49	4,57
Si	8,98	9,08	27,46	23,30	18,07	17,47	7,59
Cl	0,00	0,00	0,00	0,00	0,64	6,80	0,00
K	2,81	2,24	5,52	7,67	5,06	2,65	1,29
Ti	0,52	0,52	0,00	0,46	0,00	0,00	0,00
Fe	14,85	17,52	6,55	3,90	3,39	5,48	2,70
Cu	1,95	2,31	1,25	1,07	0,00	0,00	2,02
Au	51,11	53,79	34,41	40,97	43,72	36,78	76,89
Pb	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Table 14
EDS analyses from sample 35 (spectra 1-14). Elements are expressed as atomic percent.

In this research we analysed the artistic technique of painting on sculptures of Gandharan art made in different materials (stone, stucco and clay). A white layer was observed under the pigment in a lot of the artifacts analyzed, often in little amounts, as a residue of the lacked painting used to decorate the surface of the artworks. This layer in painting plays the role of “ground” for the pigments. Often in the past it was accidentally removed with the soil during the cleaning operations performed in the excavation operations.

As regarding the red pigments studied in this work, we found that ochre was the most frequently employed pigments. Ochre are characterized by the presence of iron oxides and aluminum-silicates; their colour may differ one to the other mainly by the chemical composition, the oxidation number of iron, and different amounts of crystallized water. In red ochre a strict relation among silicon, iron and magnesium was noted. More, a lead red-orange pigment was employed. As only EDS chemical analyses were carried out without mineralogical insights, we believe that minium, a red

Fig. 46
Schist relief, micro-photography of sample 26 (16x).

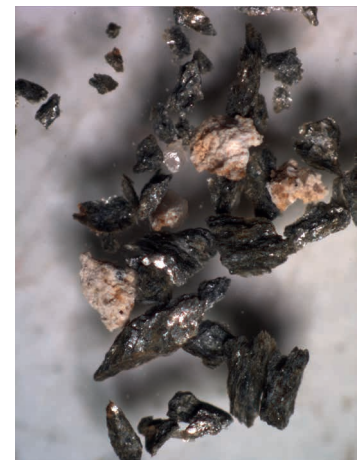


Fig. 47
Sampling of schist
Bodhisattva (sample 27)
from Milan Museum (photo
S.Pannuzi).



Fig. 48
Schist Bodhisattva: micro-
photography of sample 29.

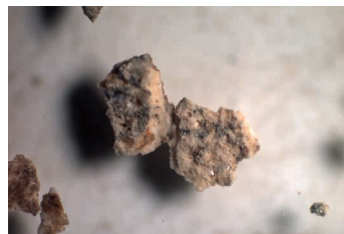


Fig. 49
Sampling of schist capital
from Milan Museum
(samples 30, 31) (photo
S.Pannuzi).

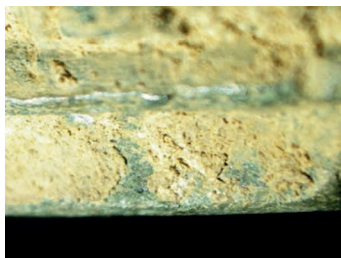
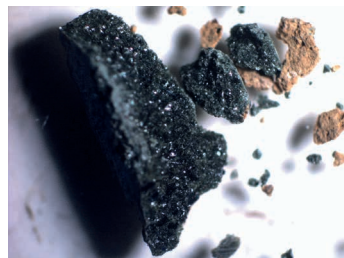


Fig. 50
Schist capital from
Milan Museum: micro-
photography of sample 30
(16x)



oxide, was used; however, we cannot be completely excluded other lead oxides, such as litharge and massicot.

In next future we will examine this issue. In a few cases, vermilion pigment, a mercury sulfide, was also found.

The technique of applying colours shows some differences in the artifacts studied. An interesting feature was observed on the head of Salabhanjika from Hadda, kept in Museum Guimet (samples 6 and 7), having a high level of manufacturing. Indeed, the cross-section of sample 7 shows red ochre mixed with yellow ochre. In the surface a very thick layer of lead oxide minium was superimposed to the ochre layer, that are not undamaged. This suggests that the head was re-painted with a different pigment, having a red-orange hue.

Ochre pigments were frequently employed in yellow hue too. Lead oxide pigments (massicot/litharge) and orpiment, an arsenic sulphide, were found.

Some blue hue was obtained with ultramarine blue (lapis lazuli). No copper pigments, as azurite and chrysocola, were found. Some modern synthetic blue pigments containing cobalt and tin were found on an important sculpture (sample 18 from Museum Guimet). We can suppose that this is a trace of a modern restoration⁵⁰.

Black pigments were obtained from bone calcinations.

By micro-XRD we analysed the stucco sample form Bodhisattva statue kept in Milan Museum (sample 23): calcite, dolomite and quartz were identified. As calcite is the binder of the stucco, dolomite and quartz are the inert components of the plaster. It is very interesting the presence of dolomite in this stucco sample, that could be used as a marker to identify the source of the stone materials used into the stucco. This information is very important because the origin of this artwork is uncertain as it comes from antique market.

⁵⁰ See Cambon in this issue.

Some gildings and their different ground layers were studied. Gold was applied as a leaf. Its purity is around 98%, the remaining was copper, and very little silver.

In the case of the sample from the corbel of the Turin Museum micro-photos well describe the sequence of the overlapped layers: over the schist we observe a whitish layer of ground, partially browned in the upper. Its chemical composition is similar to a clay material: silicon, aluminum, calcium, magnesium, iron characterize this ground. Gold leaf was applied on this ground. The origin of the brownish layer is not clear. Probably it is due to a chemical decay of an organic binder, because we observe this colour even under the leaf gold. We exclude that the browning was originated by air pollution. We would examine this sample by other analyses about the binder (GC-MS and Proteomics analyses).

In the next future, we intend to carry on with other analyses on some of these samples to verify important issue showed by the investigations *supra* highlighted. Furthermore, we also hope to increase the sampling of the Gandharan artworks to verify some hypotheses suggested in this our research.

(F. T., S. P.)

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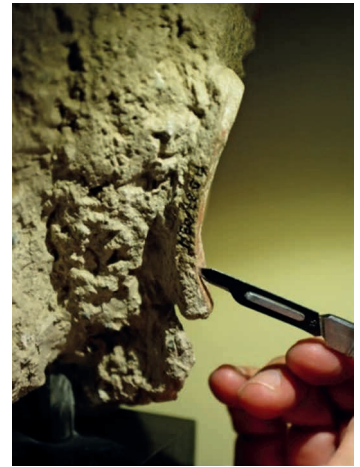
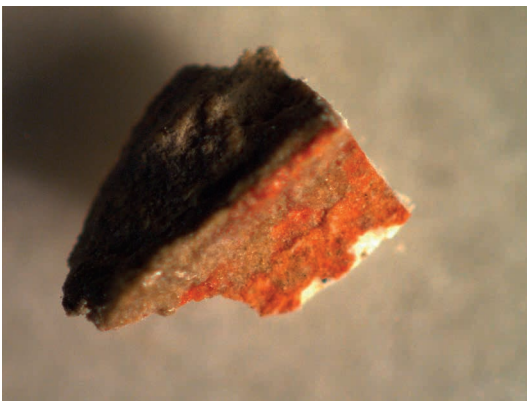


Fig. 51
Sampling of Stucco Buddha head from Milan Museum (sample 32) (photo S.Pannuzi).

Fig. 52
Stucco Buddha head from Milan Museum: micro-photography of sample 32 (16x).

Fig. 53
Stucco Buddha head from Milan Museum (sample 32): micro-photography of cross section (25x).



Sampling list 2015-2016

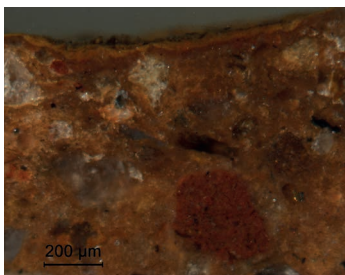
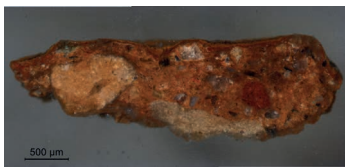
N.	N. sampling	Museum Inv.	Artwork	Sampling description
Museum Guimet, Paris				
1	1	MA 6295	Elephant schist statue (M.G.Fremont gift 1996)	White ground layer from back
2	2	MA 6295	Elephant schist statue (M.G.Fremont gift 1996)	Schist from back
3	3	AO 2956	Schist relief from Buner Valley (Pakistan)	Pale yellow ground layer from base
4	4	AO 2956	Schist relief from Buner Valley (Pakistan)	Schist from the left side
5	5	AO 2908	Schist statue of Bodhisattva Maitreya from Pakistan, III-IV century A.D.	White ground layer from foot
6	6	MG 17203	Stucco head of Salabhanjika from Hadda, Tapa- i- Kafariha monastery (Afghanistan), III century A.D.	Red layer from headgear
7	7	MG 17203	Stucco head of Salabhanjika from Hadda, Tapa- i- Kafariha monastery (Afghanistan), III century A.D.	Pinkish layer from cheek
8	9	Barthoux mission (1928) no number	Limestone relief from Hadda, Tapa- i- Kafariha monastery (Afghanistan), II-III century A.D.	Red layer from a figure
9	10	Barthoux mission (1928) no number	Limestone relief from Hadda, Tapa- i- Kafariha monastery (Afghanistan), II-III century A.D.	Red layer from a figure
10	11	Barthoux mission (1928) no number	Limestone relief from Hadda, Tapa- i- Kafariha monastery (Afghanistan), II-III century A.D.	Blue-greyish layer from a hair of a figure
11	12	MG 17191	Limestone relief from Hadda, Chakhil- i- Ghoundi monastery- stairway of stupa C1 (Afghanistan), II-III century A.D.	White ground layer from a figure
12	13	MG 17478	Schist statue of Buddha from Paitava monastery (Afghanistan, Kapiça region), III century A.D.	Gilding with red ground (bolus) from arm
13	14	MG 17478	Schist statue of Buddha from Paitava monastery (Afghanistan, Kapiça region), III century A.D.	Red ground (bolus) from the left side
14	15	MG 22148	Schist relief from Shotorak monastery (Afghanistan), II-III century A.D.	Red ground (bolus) with traces of gilding from base
15	16	MG 18957	Clay statue of two Naga Kings from Fundukistan monastery Ghorband Valley (Afghanistan), VII century A.D.	Blue colour layer from hair
16	17	MG 18597	Clay statue of two Naga Kings from Fundukistan monastery Ghorband Valley (Afghanistan), VII century A.D.	Blue colour layer from arm
17	18	MG 18597	Clay statue of two Naga Kings from Fundukistan monastery Ghorband Valley (Afghanistan), VII century A.D.	Pale yellow layer from ear

N.	N. sampling	Museum Inv.	Artwork	Sampling description
18	19	MG 18959	Clay statue of Bodhisattva from Fundukistan monastery Ghorband Valley (Afghanistan), VII century A.D.	Blue-blackish colour layer from hair
19	20	MG 18959	Clay statue of Bodhisattva from Fundukistan monastery Ghorband Valley (Afghanistan), VII century A.D.	Blackish colour layer from garland
20	21	MG 18970	Clay statue of seated Buddha from Fundukistan monastery Ghorband Valley (Afghanistan), VII century A.D.	Orange layer with ground layer from drapery dress
Civic Archaeological Museum of Milan				
21	4	A.09.10692	Schist standing Buddha, II-III century A.D.	Gilding with ground layer from drapery dress
22	5	A.988.02.1	Painted stucco Monk, IV-V century A.D.	Red layer and stucco from the right side
23	6	A.990.04.1	Painted stucco Bodhisattva, IV century A.D.	Red layer with ground layer from arm
24	7	A.996.01.3	Figurative schist false corbel (Nagadanta)	Whitish layer from drapery dress
25	8	A.09.21700	Schist relief with Buddha life scenes, I-II century A.D.	Whitish ground layer from architectural motif
26	9	A.09.21700	Schist relief with Buddha life scenes, I-II century A.D.	Whitish ground layer from figure
27	10	A.09.2921	Schist Bodhisattva stele, II-IV century A.D.	White ground layer from drapery dress
28	11	A.09.2921	Schist Bodhisattva stele, II-IV century A.D.	Schist with traces of ground layer from the top
29	12	A.09.2921	Schist Bodhisattva stele, II-IV century A.D.	White ground layer from drapery dress
30	14	A.990.05.1	Figured schist capital of a pillar, I-II century A.D.	Schist with whitish ground layer from base
31	15	A.990.05.1	Figured schist capital of a pillar, I-II century A.D.	Schist with whitish ground layer from base
32	17	A.987.03.1	Stucco Buddha head	Red layer from ear
33	25	A.09.9421	Clay Brahma head	Yellow layer from hair
Oriental Art Museum of Turin				
34	1	4581	Schist corbel, probably I-II century A.D.	Gilding from bottom
35	2	4581	Schist corbel, probably I-II century A.D.	Gilding from the top

Fig. 54
Sampling of clay
Brahma head from
Milan Museum
(sample 33) (photo
S.Pannuzi).

Fig. 55
Clay Brahma head
from Milan Museum
(sample 33): micro-
photography of cross
section of the sample.

Fig. 56
Clay Brahma head
from Milan Museum,
micro-photography:
blow up of cross
section of the sample.



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Fig.57
Schist gilded corbel from
MAO of Turin, detail of
the sampling
(photo S.Pannuzi).

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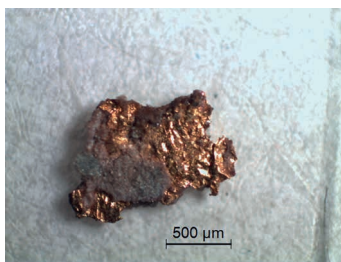
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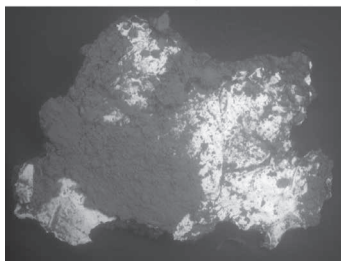
Fig. 58
Schist gilded corbel from
MAO of Turin: micro-
photography of sample 34.

Fig. 59
Schist gilded corbel from
MAO of Turin: SEM image of
sample 34.

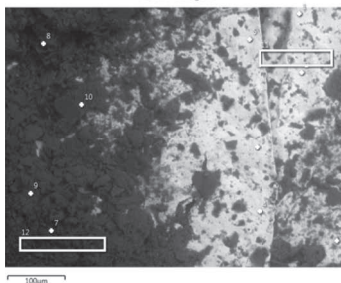
Fig. 60
Schist gilded corbel from
MAO of Turin: SEM blow up
image of sample 34.



Electron Image 1



Electron Image 2



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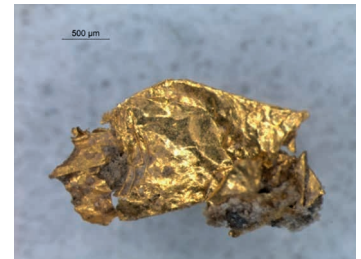
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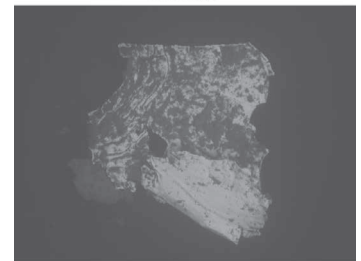
Fig. 61
Schist gilded corbel from MAO of Turin: micro-photography of sample 35.

Fig. 62
Schist gilded corbel from MAO of Turin: SEM image of sample 35.

Fig. 63
Schist gilded corbel from MAO of Turin: SEM blow up image of sample 35.



Electron Image 1



Electron image 2

