

Report

**Non-destructive analysis of the portrait of Katerina
Cornaro by combined Digital microscopy, IR
photography and XRF spectroscopy**

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The Cyprus Institute**

Aims of analysis

1. Confirmation of partial overpainting of the portrait
2. Delineation of the overpainted areas
3. Identification of authentic pigments and the ones of overpainting

Experimental conditions

Dates of analysis:

June 8, 2016: Multispectral imaging (The Leventis Museum)

June 9, 2016: Microscopy (The Leventis Museum)

June 10, 2016: XRF (The Cyprus Institute)

XRF conditions:

- Artax-200 µXRF
- Voltage: 50 kV
- Current: 700 µA
- Time: 60 s
- Filter: Molybdenum 12.5 µm
- Atmosphere: Air

Microscopy parameters:

- Hirox KH-8700
- Magnification 35x-2500x according to the target
- Dual illumination revolver zoom lenses; Low-magnification contact lens
- Ricoh WG-30 digital camera

Multispectral conditions:

- Musis multispectral camera
- Spectral range: 420-1000 nm, 20 nm step
- Light source: Halogen lamp
- IR images are taken at 1000 nm

Delineation of overpainted areas:

The delineation of overpainted areas has been performed by (1) analysing the IR images which are to reveal original painting and (2) comparison of the craquelure texture. The latter is based on the assumption that the older areas (original) have a more developed system of cracks than the ones added later (overpainting) which have to appear more smooth.

Summary of results

IR images revealed that the left side of the portrait (right shoulder and dress, [Figure 51](#)) was partly overpainted. IR images also revealed the old crown which was entirely overpainted with the new one ([Figure 38, 39, 43, 44](#)).

White

The original white paint mainly contains Lead white ($2\text{PbCO}_3 \cdot \text{Pb(OH)}_2$), whereas for the white areas of overpainting, a mixture of Lead white with Lithopone ($\text{BaSO}_4 \cdot \text{ZnS}$) was used. Using the composition of the white paint as a marker to distinguish between the original and the overpainting, the following white areas could be detected:

Original: white ovals of the dress (K.Cornaro's right shoulder, visible only on IR image [Figure 51](#) and microscopy image [Figure 36](#)), veil, dark white laces of the dress (area of chest), dark white pearls, thin white cover on the chest ([Figure 37](#)).

Overpainting: white ovals of the dress (K.Cornaro's right shoulder, [Figure 51, 35](#)), highlights of pearls, highlights of laces of the dress (area of chest). It is noteworthy that the white highlights of the new crown (spot 45) are painted with Lead white, but not Lithopone.

Carnation

The original paint used for skin has the same composition as the one used for presumed overpainting. In both cases, it represents a mixture of Lead white, Vermilion (HgS), Ochre (iron yellow, brown) and Copper green.

Yellow

The original yellow paint mainly contains Orpiment (As_2S_3). Small intensity of Sn lines might be related to small additions of a yellow tin pigment, such as Lead-tin yellow (Pb_2SnO_4). Small intensity of Ag lines might be related to admixtures of silver in natural orpiment. It is suggested that the yellow pigment of overpainting mainly contains Lead yellow (Litharge PbO). Using the composition of the yellow paint as a marker to distinguish between the original and the overpainting, the following yellow areas could be detected:

Original: spikes of the crown (visible only on IR image, [Figure 30, 38, 39, 43, 44,](#))

Overpainting: crown, decorative chain of the crown ([Figure 31](#))

Red

The red paint was used for gemstones of the crown (overpainting). Close observations reveal two hues of red (spots 42, 43, 44). Vermilion was used for the lighter and paler red, whereas Vermilion with an antimony pigment such as Antimony red ($2\text{Sb}_2\text{S}_3 \cdot \text{Sb}_2\text{O}_3$, superposition or mixture) was used to highlight the borders of the gemstones which appear brighter and darker. The red paint of both compositions is related to overpainting, since it appears not on the original, but on the new crown.

Red pigment Vermilion was also used as a component of a complex mixture for original carnation (see above).

Summary of results

Green

Copper green was used for green gemstones of the new crown (spot 41).

Black

All black areas of the painting have the same mixed pigment composition which contains Iron-Manganese black (Umber) and Copper (green) pigments. The similarity of the original black pigment and the one used for overpainting does not allow to use them as markers for detecting the overpainted areas. The XRF analysis showed no difference in the qualitative composition of the original black areas and the ones attributed to overpainting.

Background

The composition of the dark background of the portrait represents a mixture of Iron-Manganese black (Umber), small admixture of Copper (green) pigment.

Retouching

Apart from the large areas of the portrait that were presumably overpainted in the XIX century, the analysis revealed small areas of later retouching. A crack in the pictorial layer on the neck (spot 23) was retouched with a flesh colour obtained by mixture of Titanium white (TiO_2) and Zinc white (ZnO), Ochre and Vermilion. For small retouching of the area of chest (spot 19), a mixture of Titanium white, Ochre and a cobalt pigment such as Cobalt blue ($CoAl_2O_4$) was used.

Conclusions

Clearly overpainted areas, such as crown, shoulder and white ovals of the dress demonstrate the use of pigments whose composition differs from the original ones. The areas that were assumed to be overpainted (chest, background) based on the difference in craquelure texture, did not demonstrate the use of different pigments. The latter suggests that the possible overpainting of these areas was performed with authentic pigments.

XRF analysis

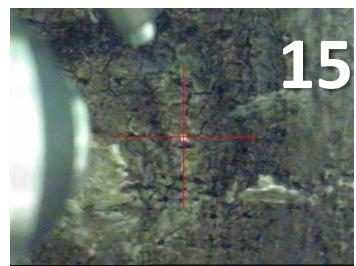
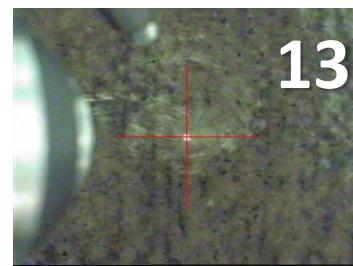
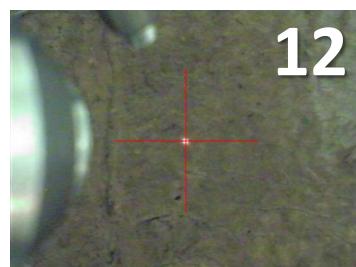
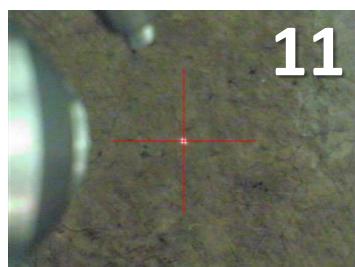
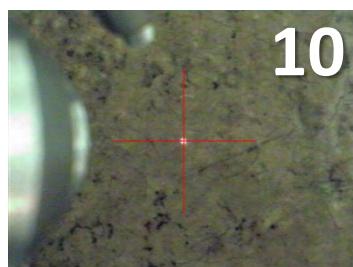
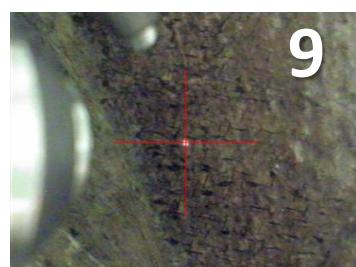
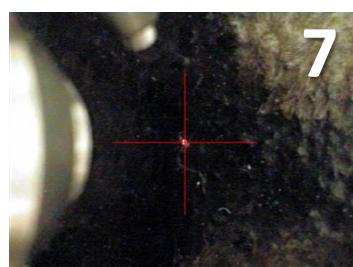
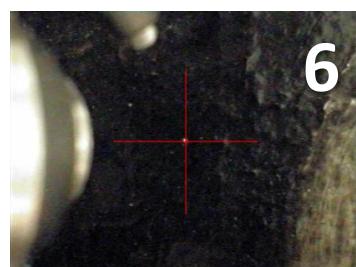
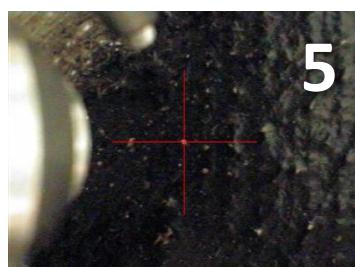
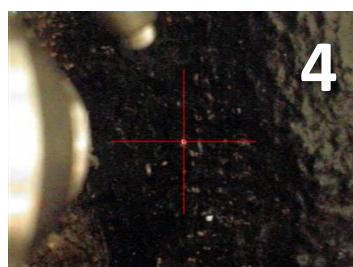
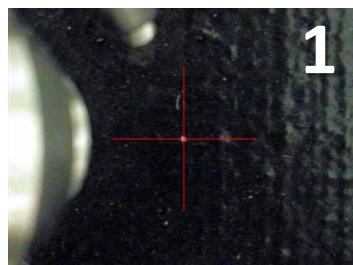
XRF analysis: Map of analysed spots

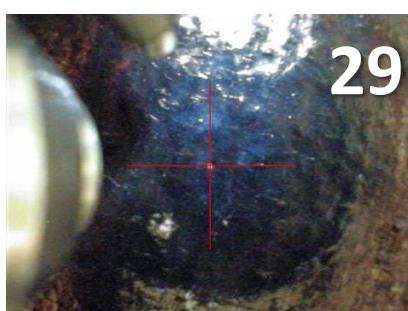
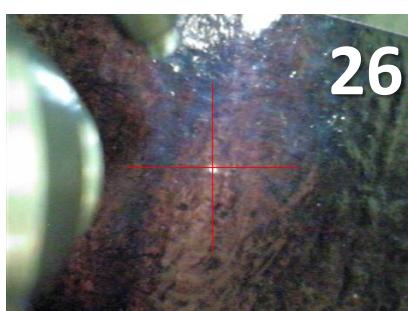
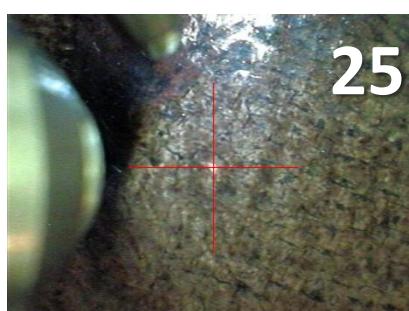
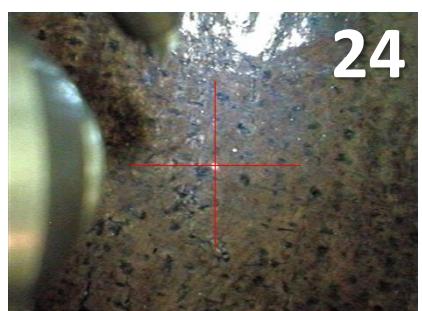
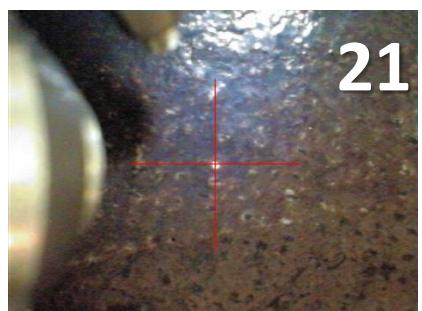
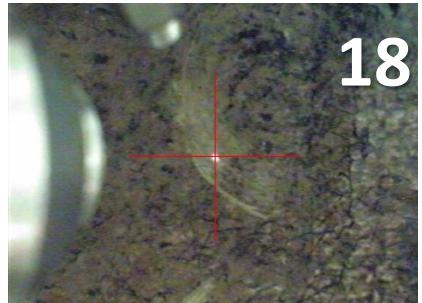
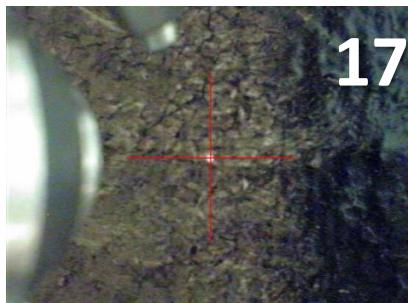
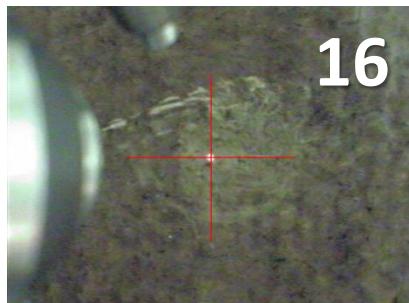


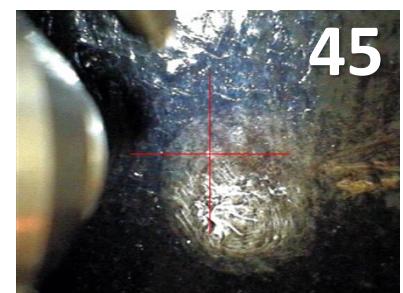
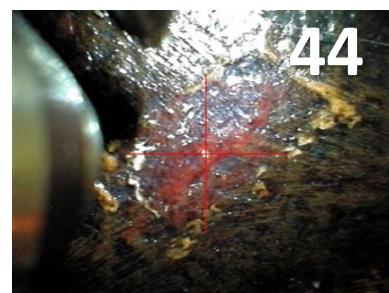
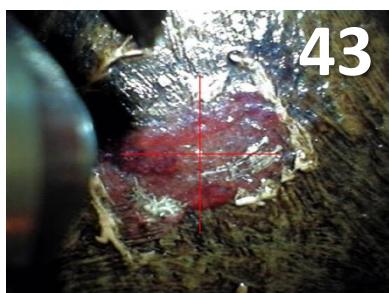
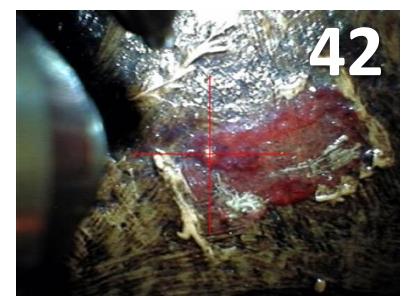
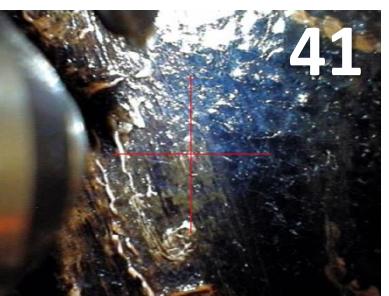
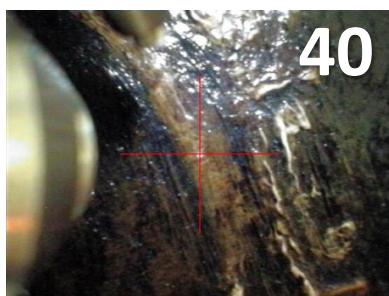
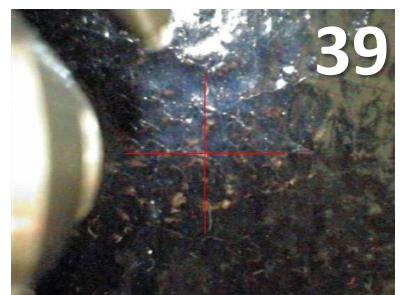
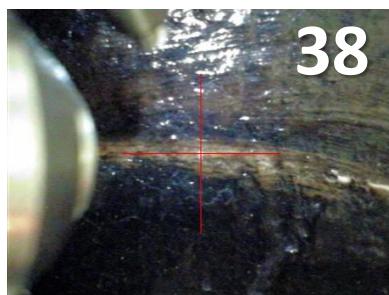
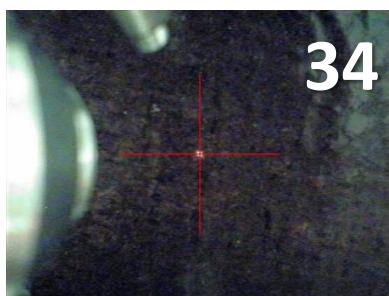
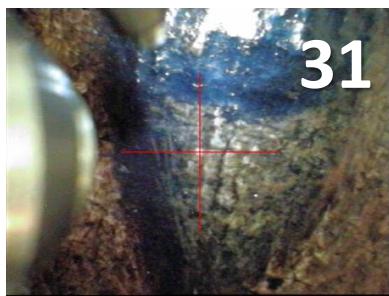
XRF analysis: Description of analysed spots

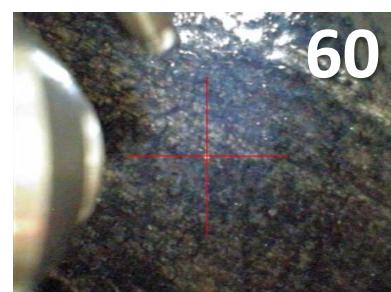
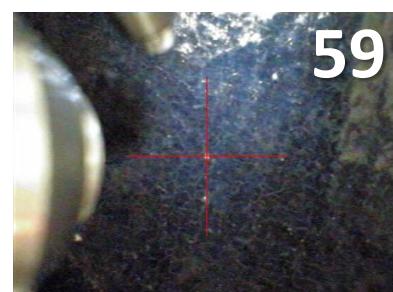
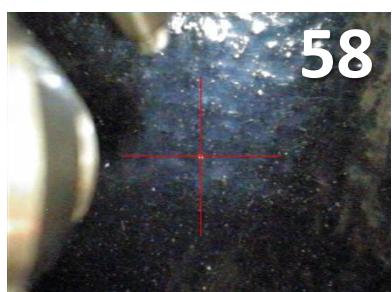
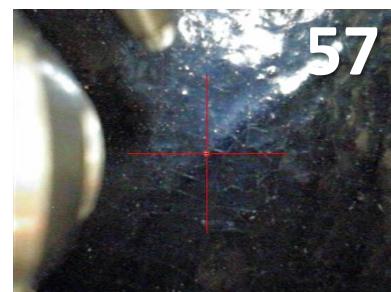
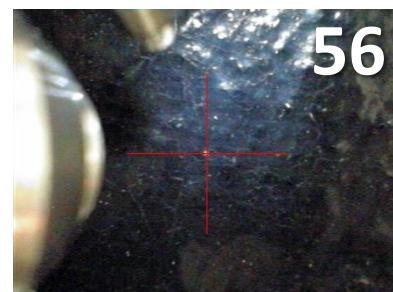
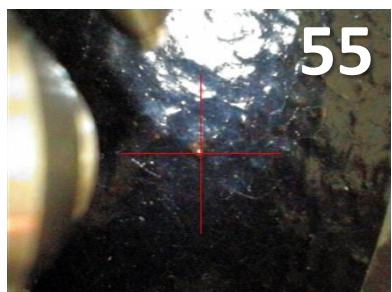
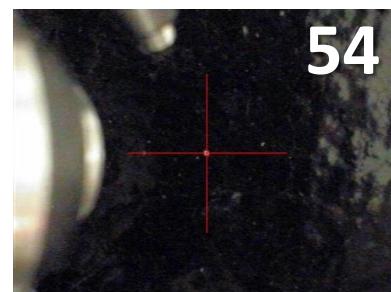
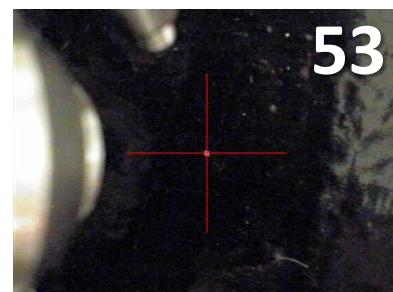
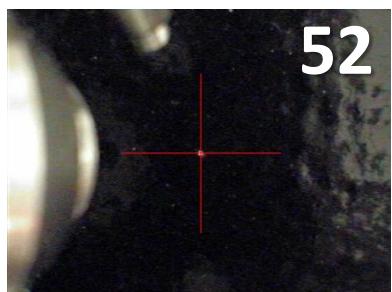
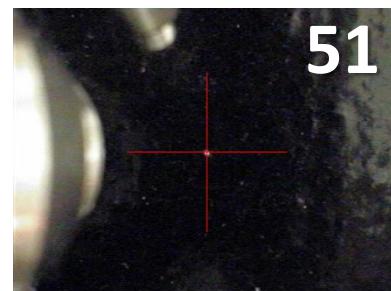
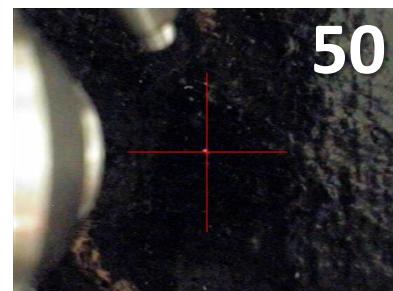
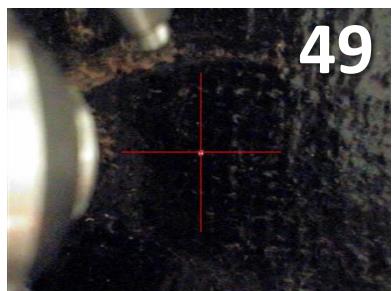
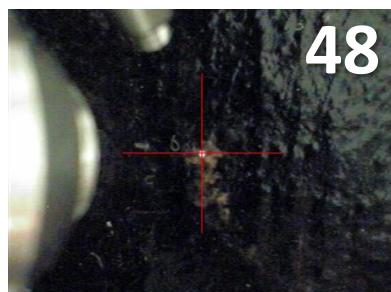
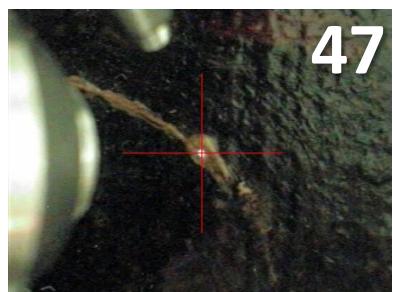
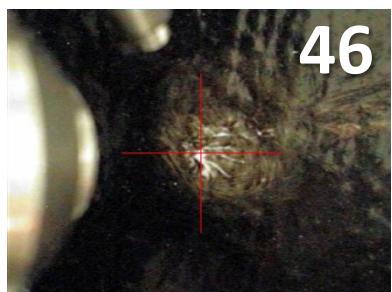
- 1 – dress, overpainting
2 – white oval, new
3 – white oval, new
4 – white oval, old, overpainted
5 – white oval, old
6 – background of the dress, close to old oval, overpainted
7 – background of the dress, close to new oval, more black
8 – white veil
9 – skin, close to the veil, old
10 – skin, far from the veil, new?
11 – skin, far from the veil, chest center, new?
12 – skin, far from the veil, chest center, new?
13 – left pearl
14 – upper pearl
15 – upper pearl, close to white, thicker, old?
16 – right pearl
17 – white laces, darker, old?
18 – white laces, lighter, new?
19 – pink retouch on the chest
20 – white on the chest, overpainted
21 – white on the chest, close to the shoulder
22 – neck
23 – crack on the neck, overpainted
24 – under the chin
25 – under the lip
26 – lip
27 – cheek
28 – nose
29 – eye
30 – red on the eye
31 – white of the eye
32 – white spot on the eye pupil
33 – eye corner
34 – dark cheek
35 – forehead, retouch
36 – forehead, retouch
37 – old crown, overpainted, yellow
38 – new crown, yellow
39 – old crown, yellow
40 – new crown, yellow
- 41 – green of the crown
42 – red of the crown, new?
43 – red of the crown, old?
44 – red of the crown
45 – white of the crown
46 – white of the crown
47 – yellow of the new crown
48 – chain, yellow
49 – inside chain
50 – outside chain
51 – old black of the crown, overpainted, new background
52 – background
53 – old crown, overpainted
54 – background outside the old crown
55 – old crown, yellow
56 – overpainted coat
57 – overpainted coat, edge
58 – background outside overpainted coat
59 – overpainted coat and the veil
60 – the veil with no coat on the background
61 – light on the background, right upper
62 – light on the background, right upper
63 – dark background new 61
64 – dark background new 62
65 – white preparation
66 – light spot on background, similar to 61, 62
67 – dark background near 66
68 – green dot
69 – green dot
70 – background near green dot

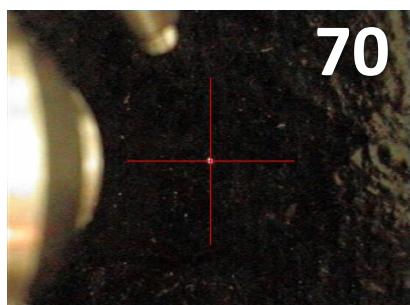
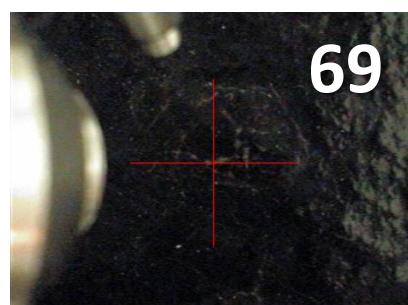
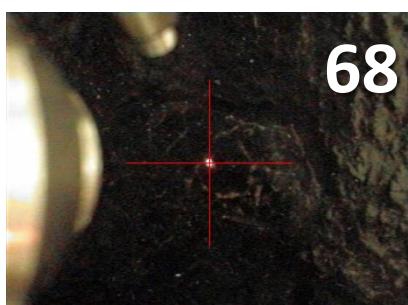
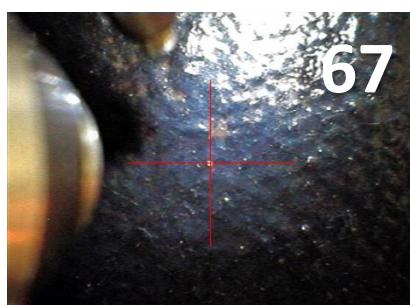
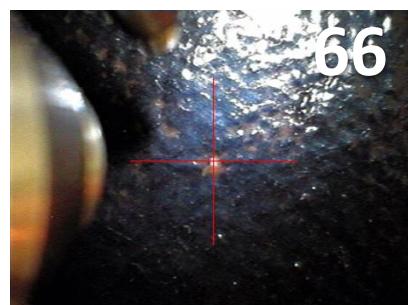
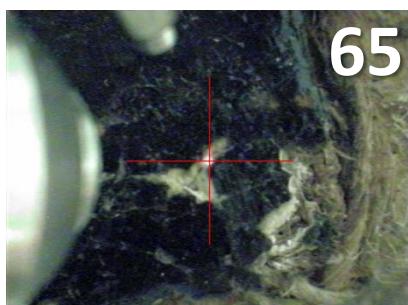
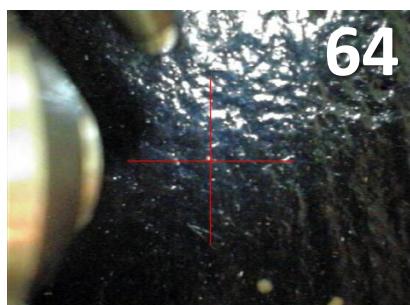
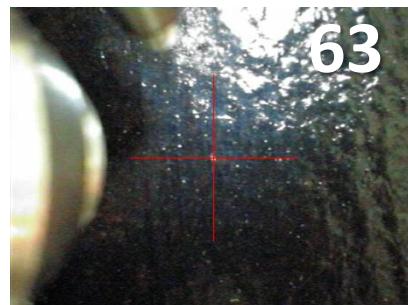
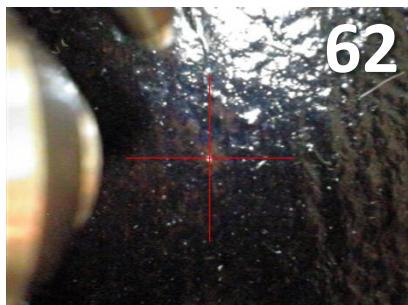
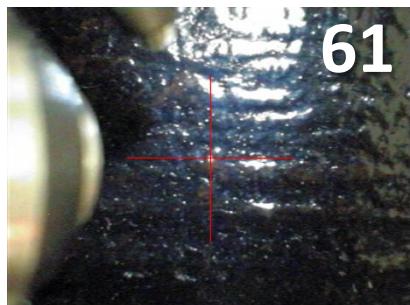
XRF analysis: Images of analysed spots











XRF analysis: Spectra

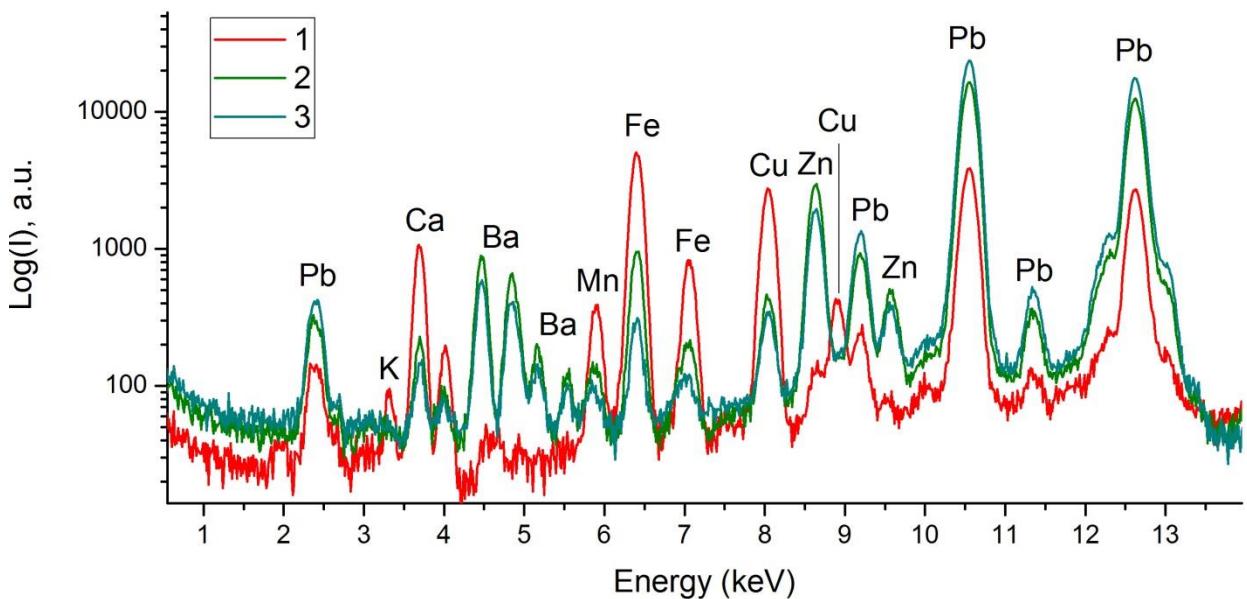


Figure 1

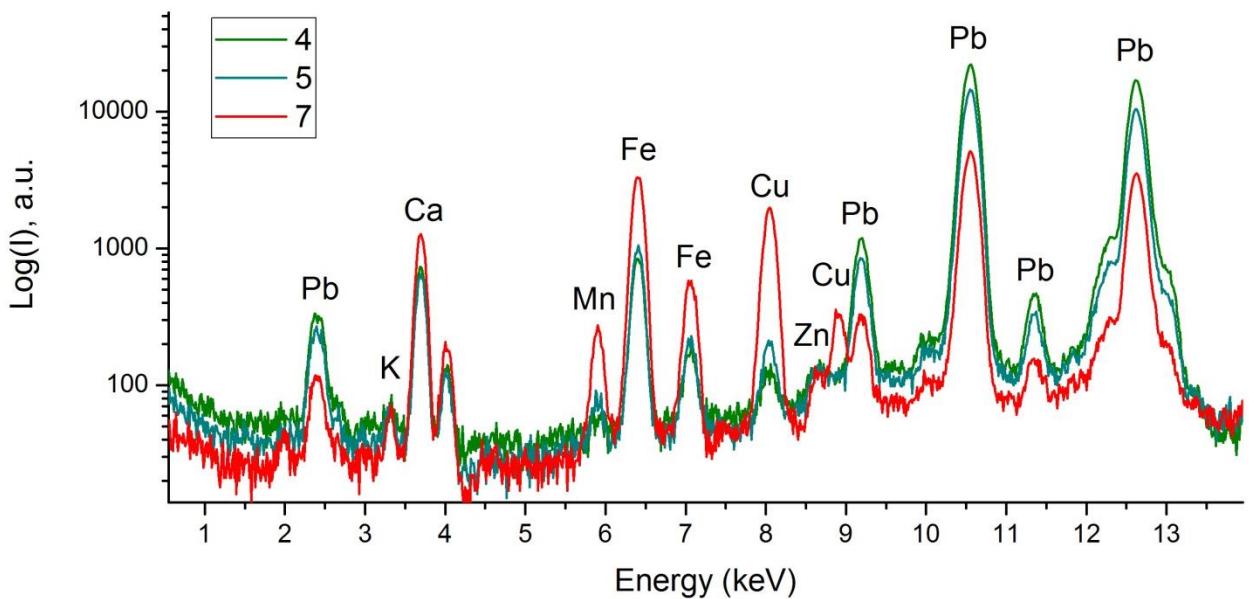


Figure 2

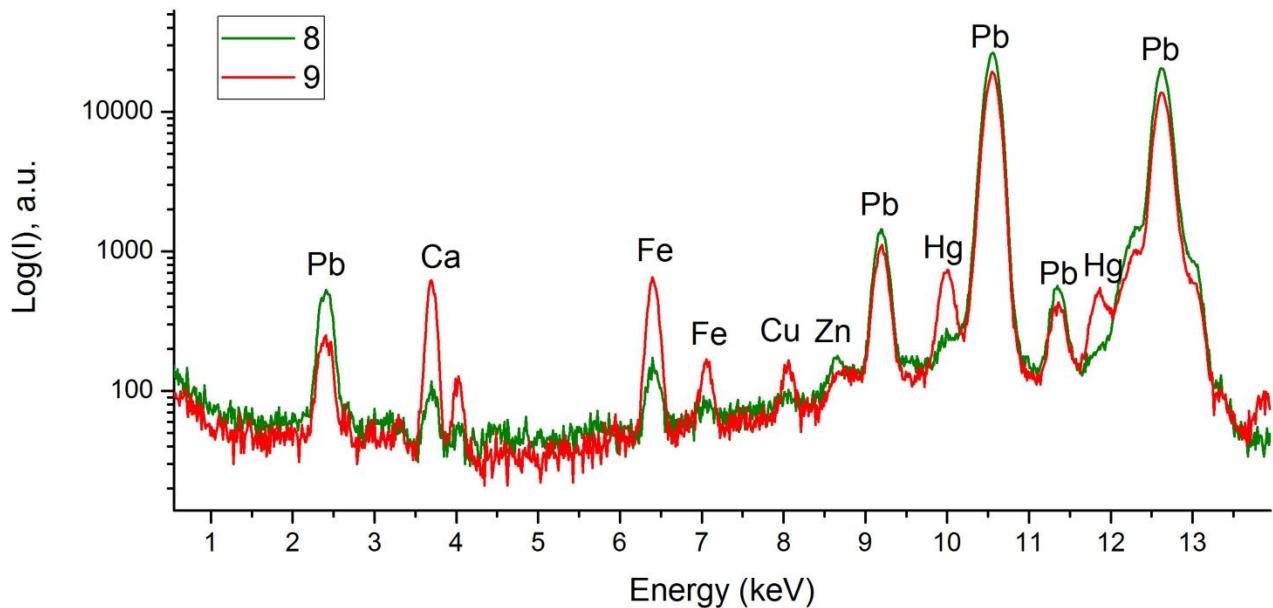


Figure 3

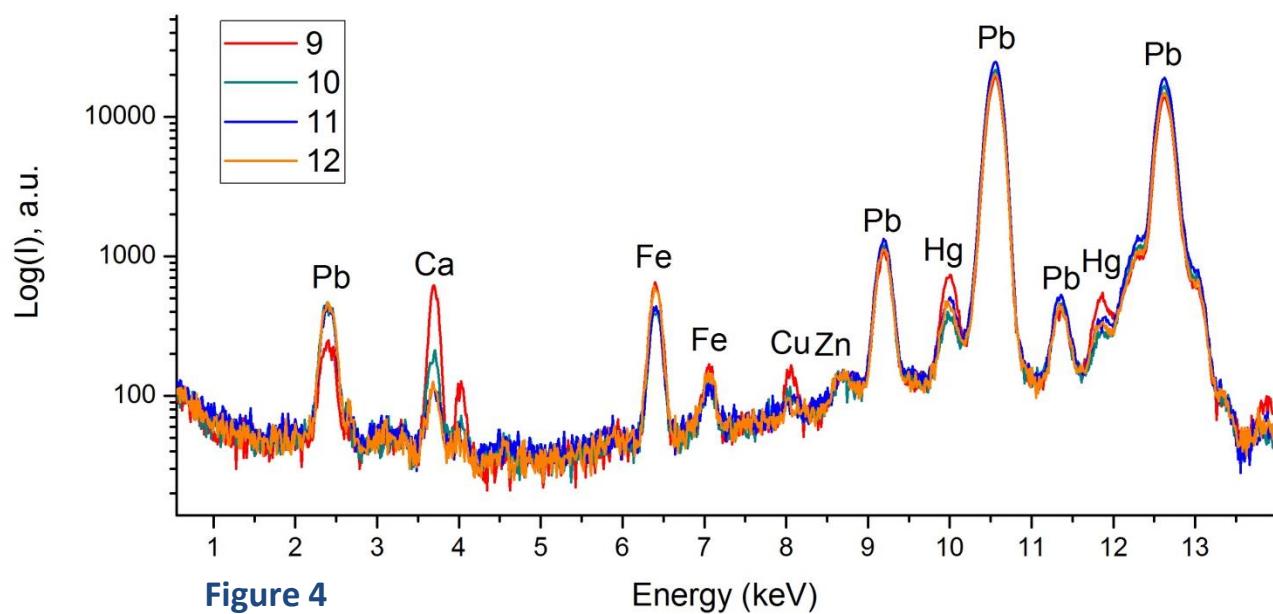


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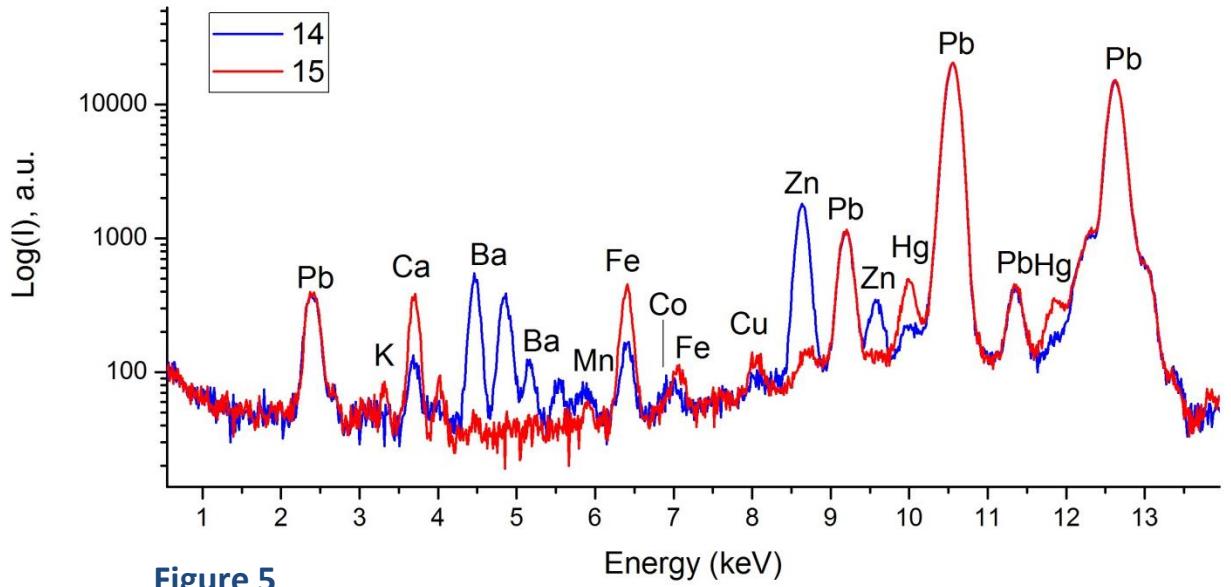


Figure 5

Energy (keV)

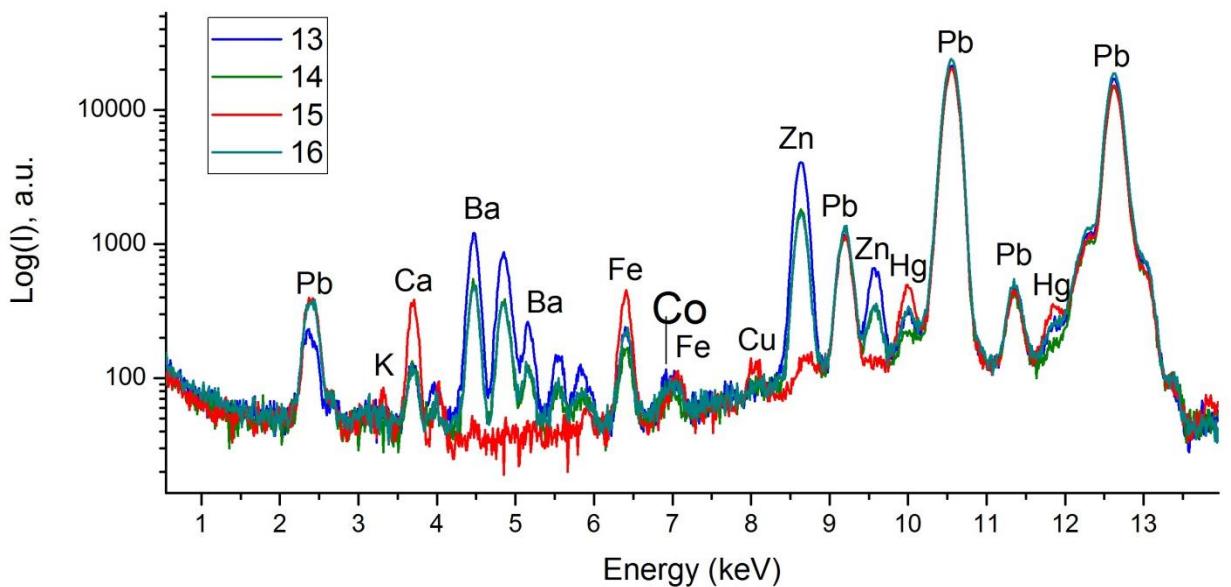


Figure 6

Energy (keV)

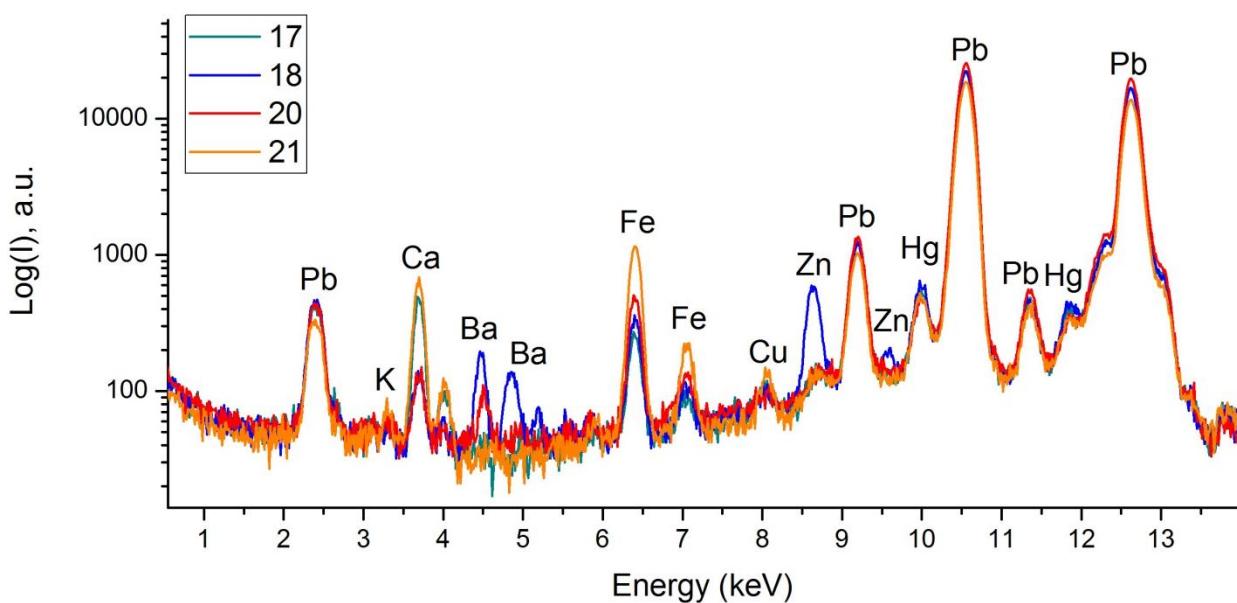


Figure 7

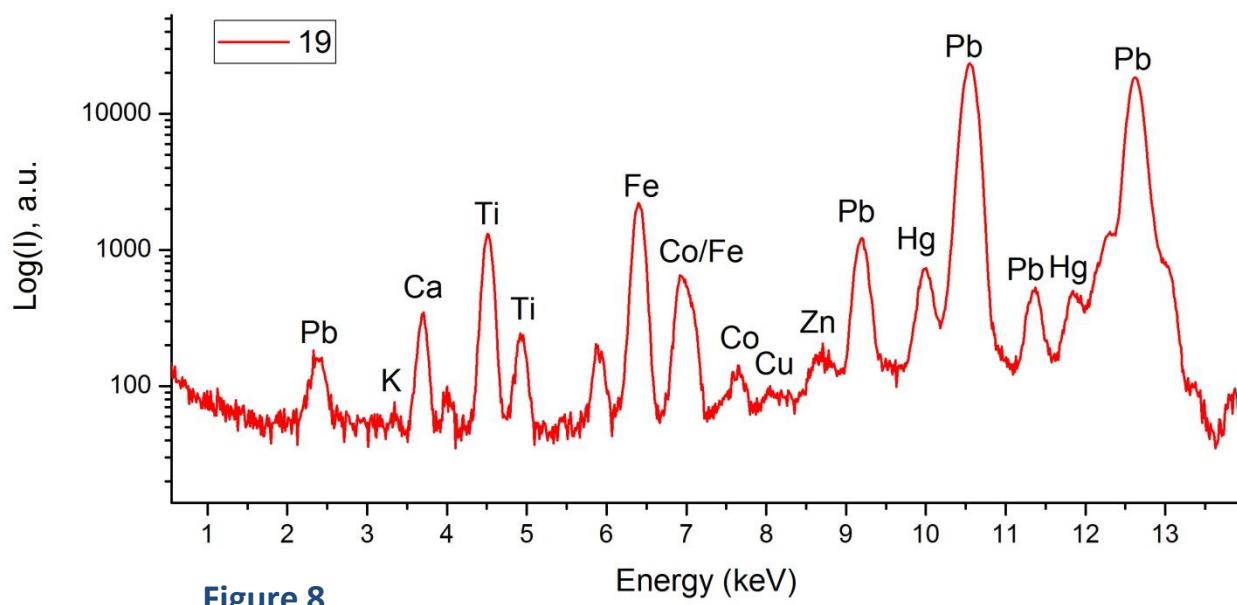


Figure 8

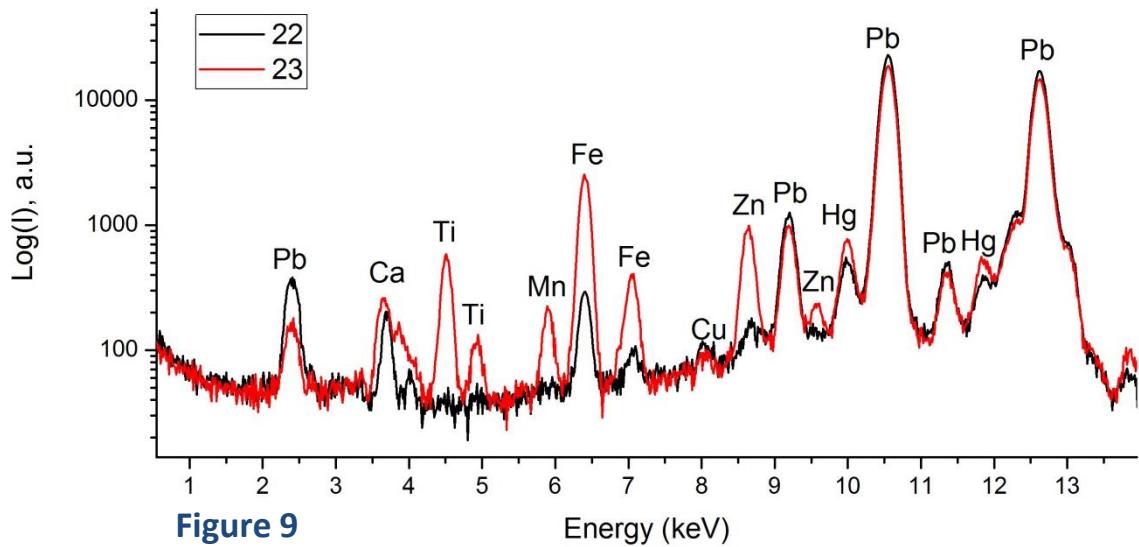


Figure 9

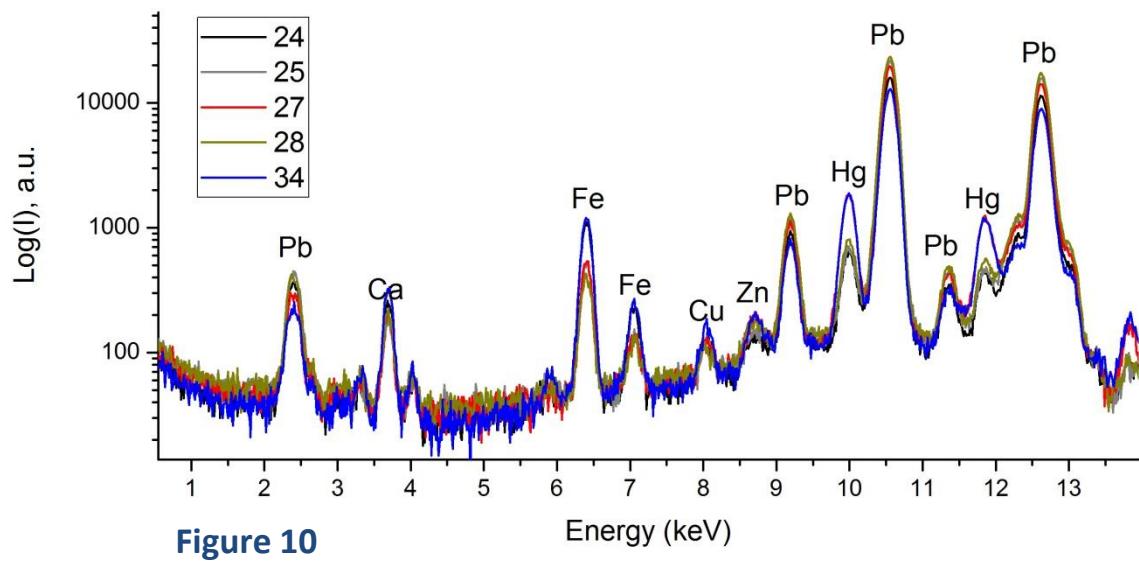


Figure 10

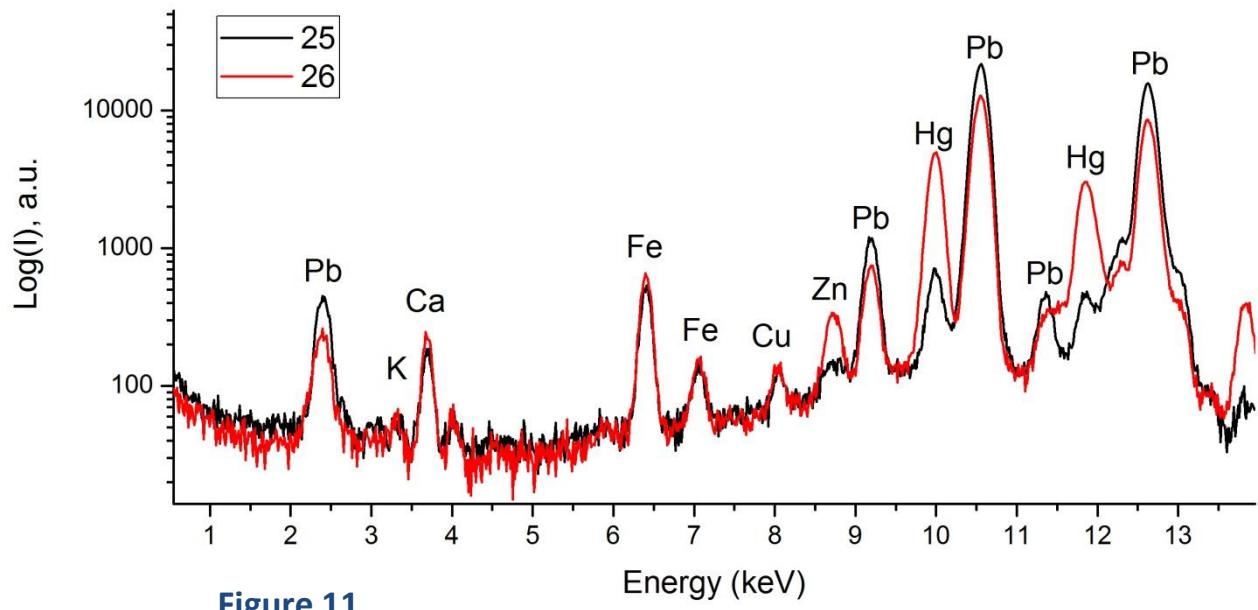


Figure 11

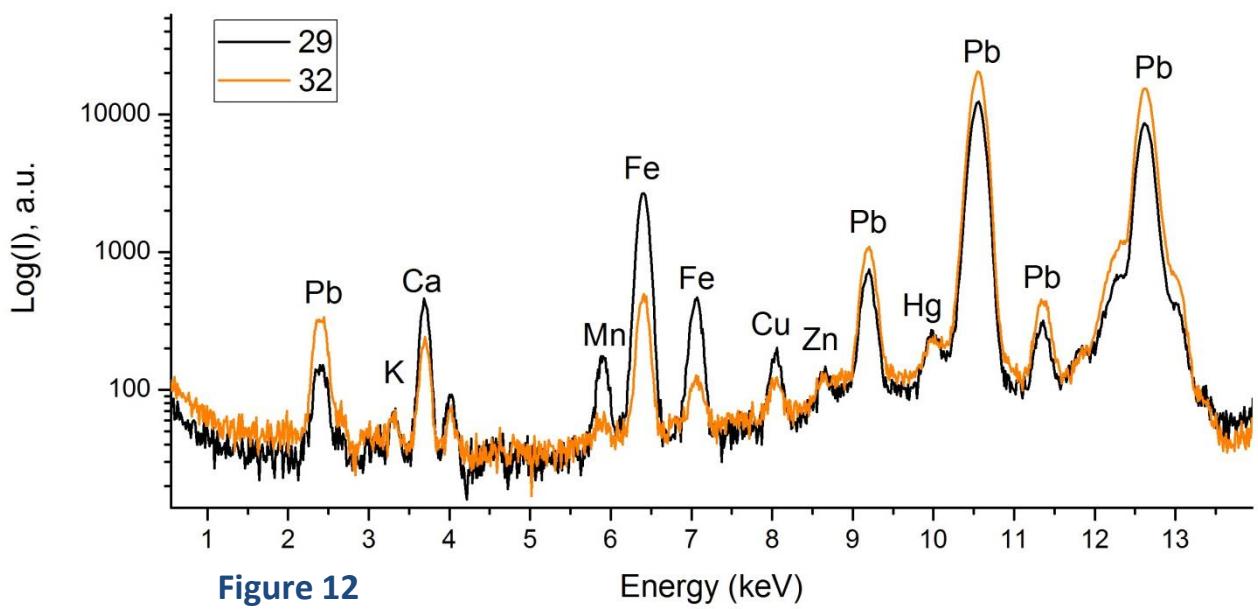


Figure 12

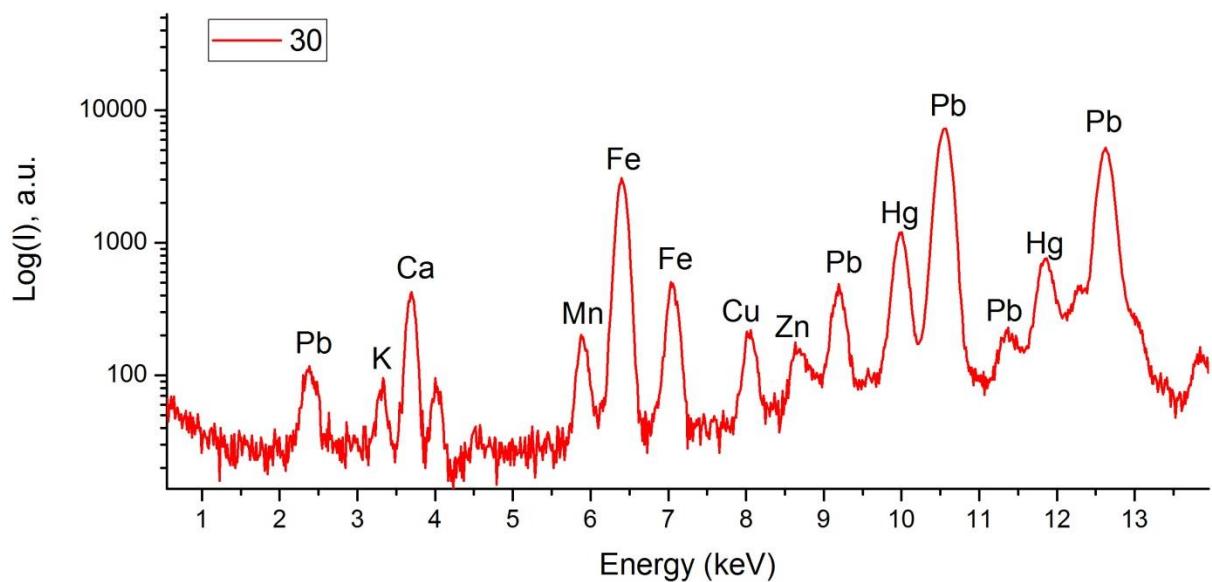


Figure 13

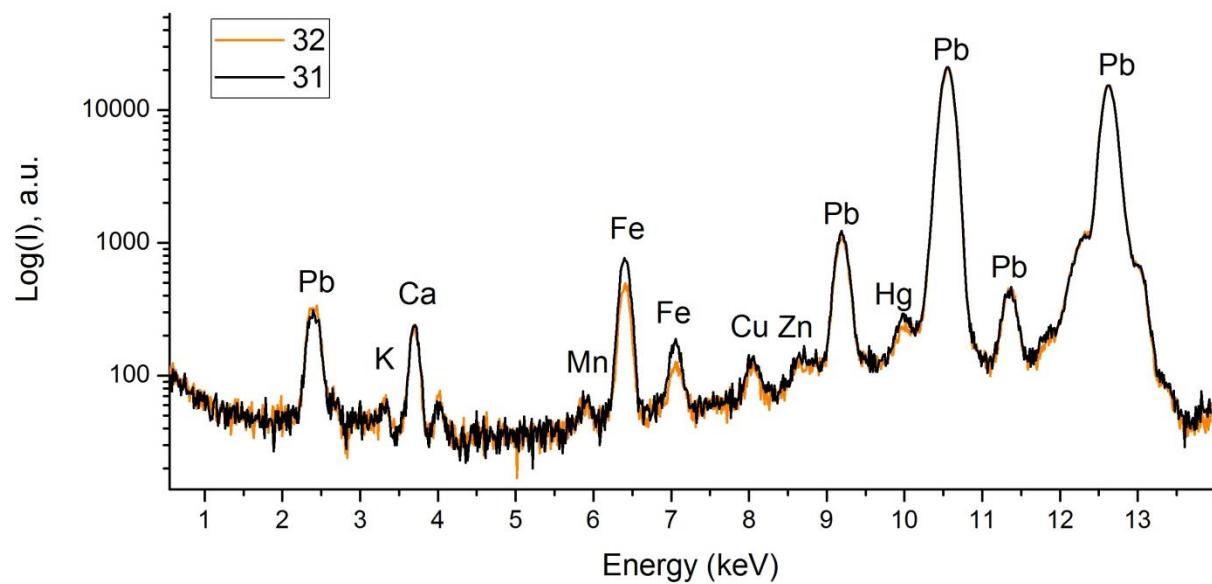


Figure 14

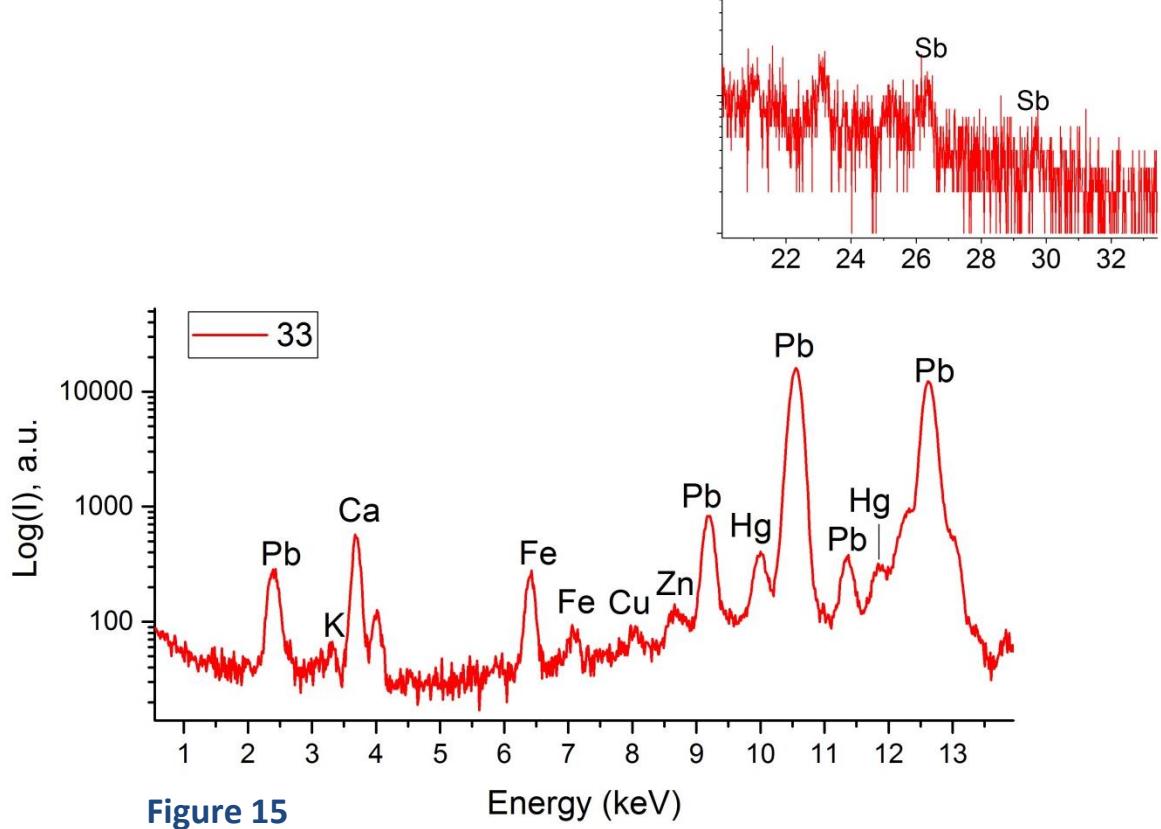


Figure 15

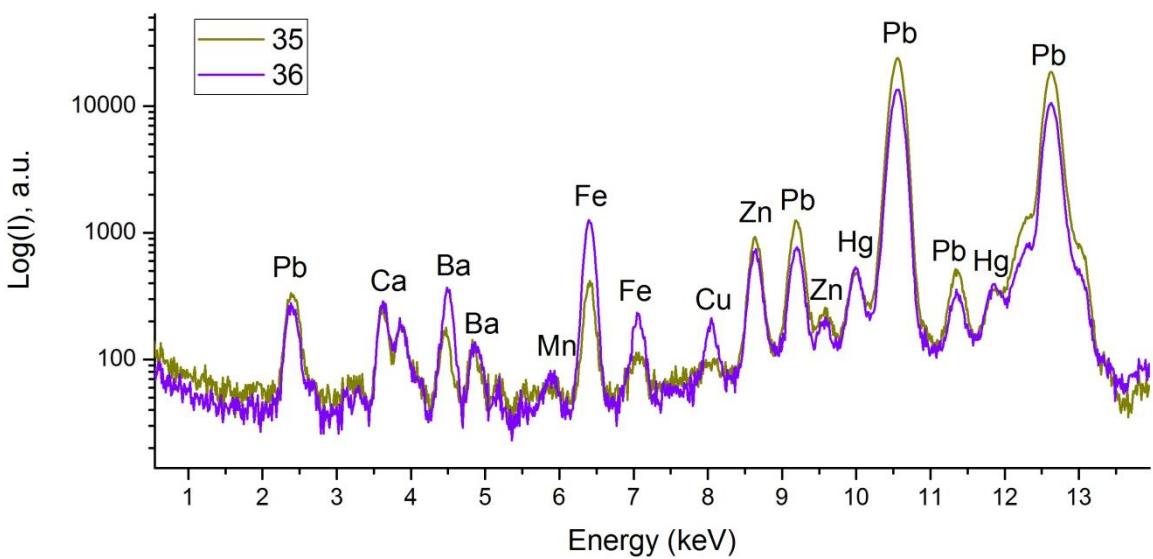


Figure 16

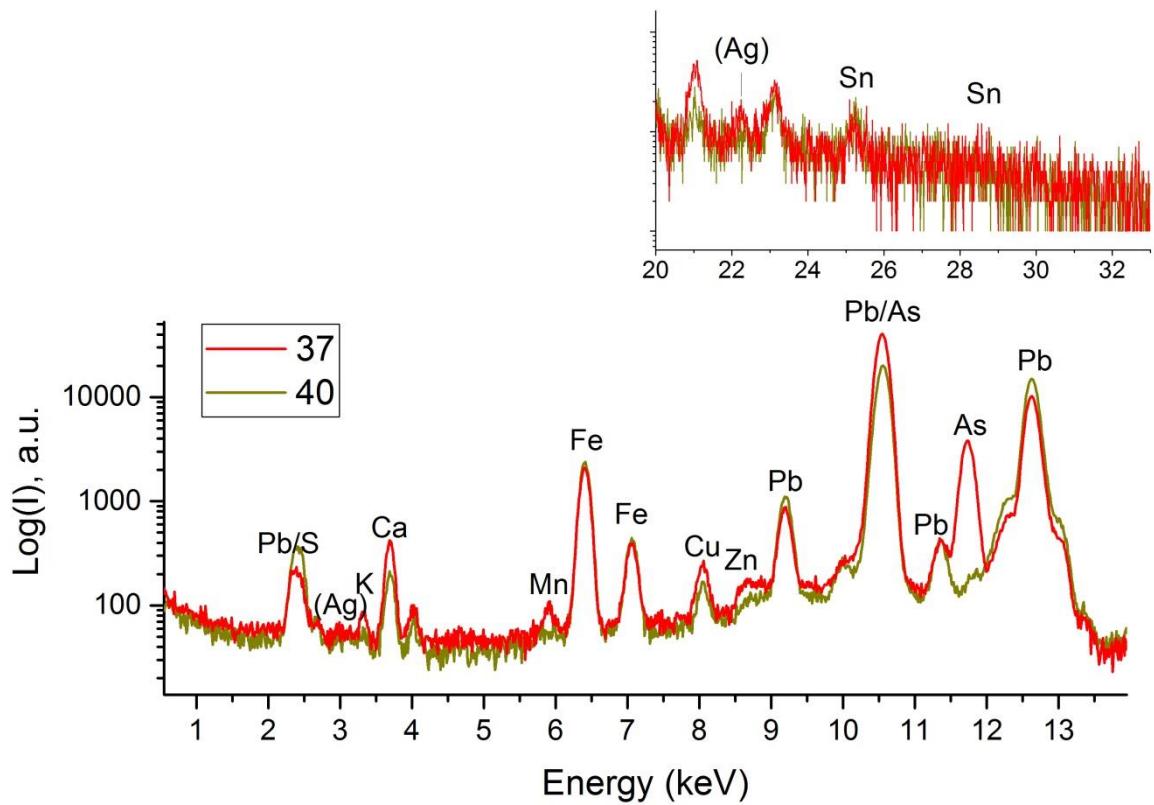


Figure 17

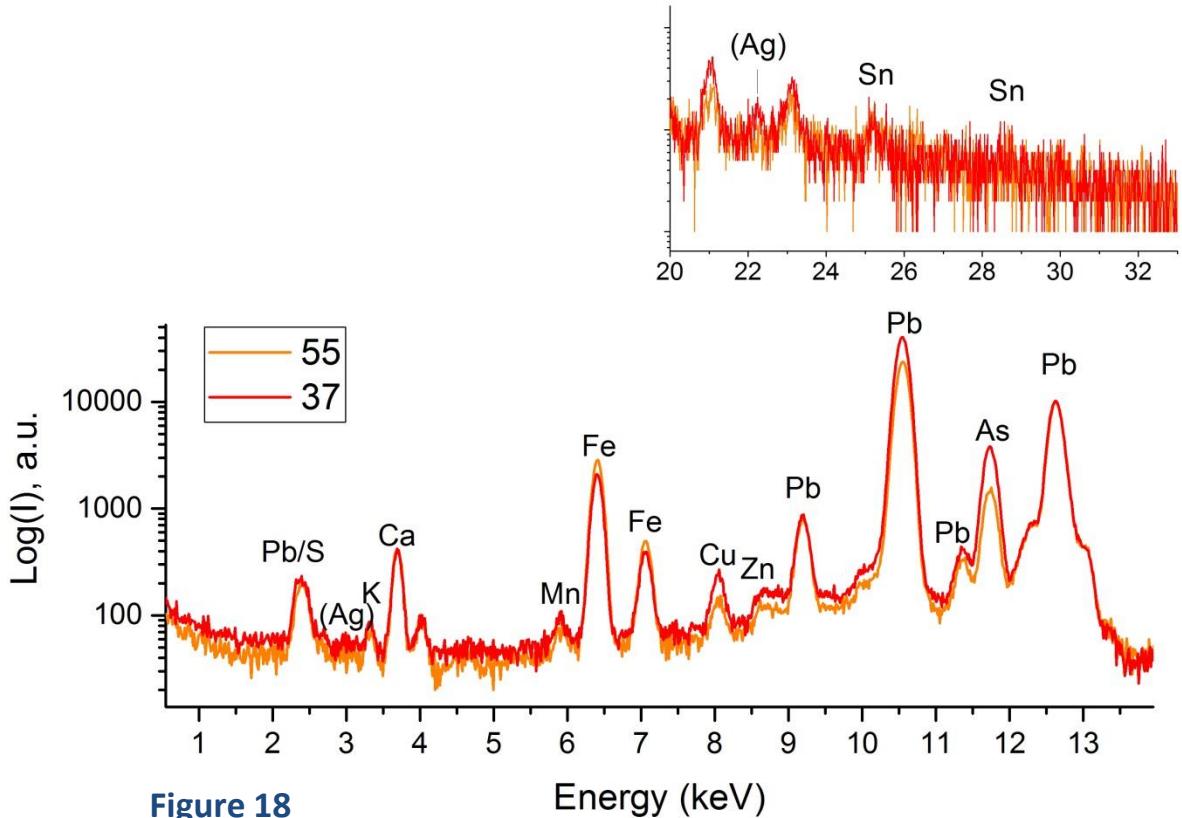


Figure 18

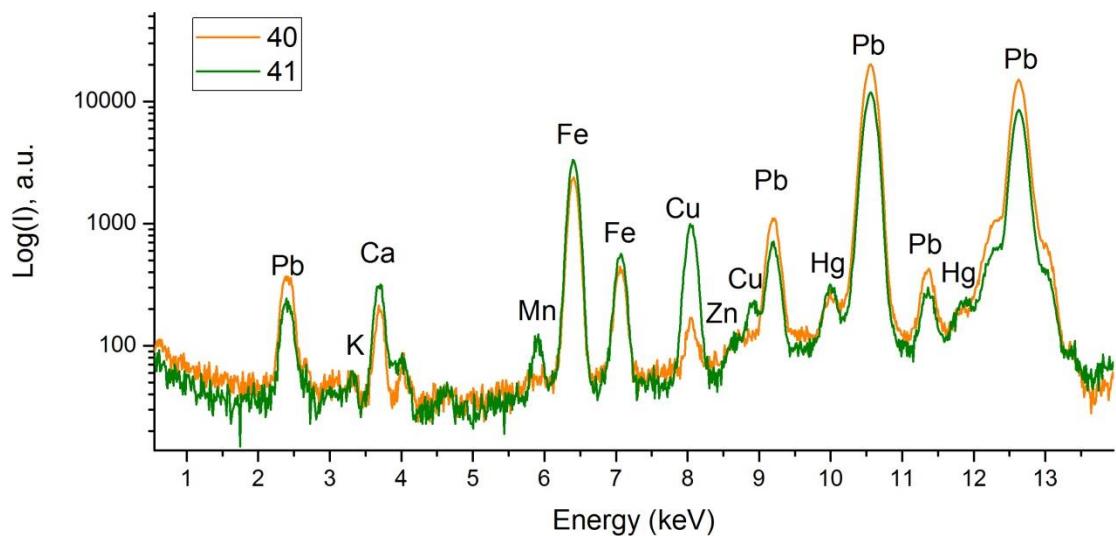


Figure 19

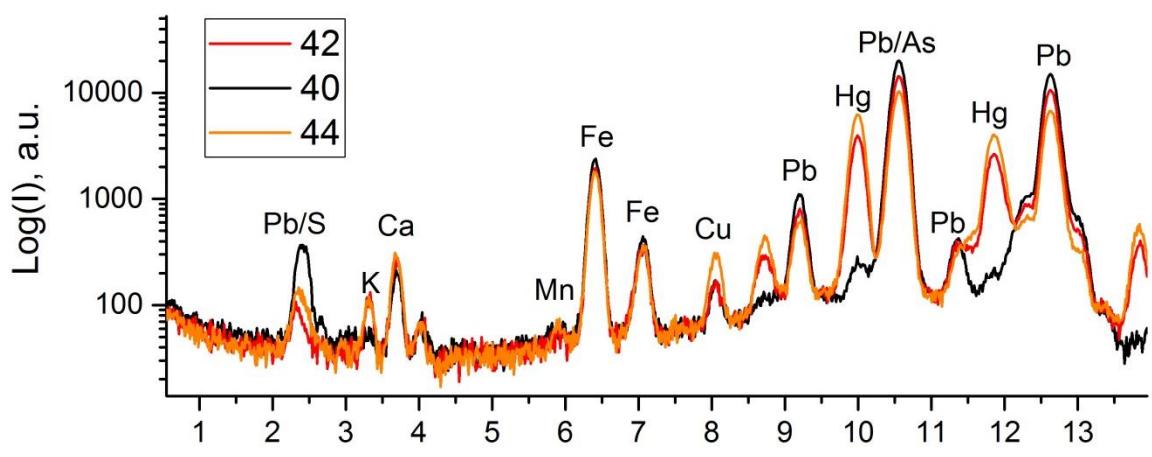
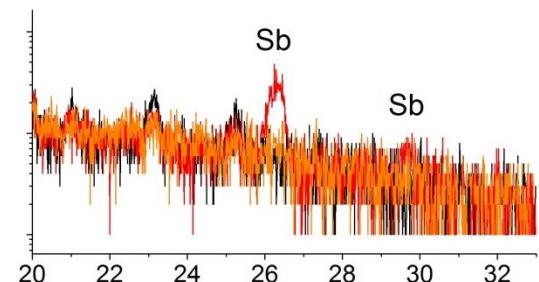


Figure 20

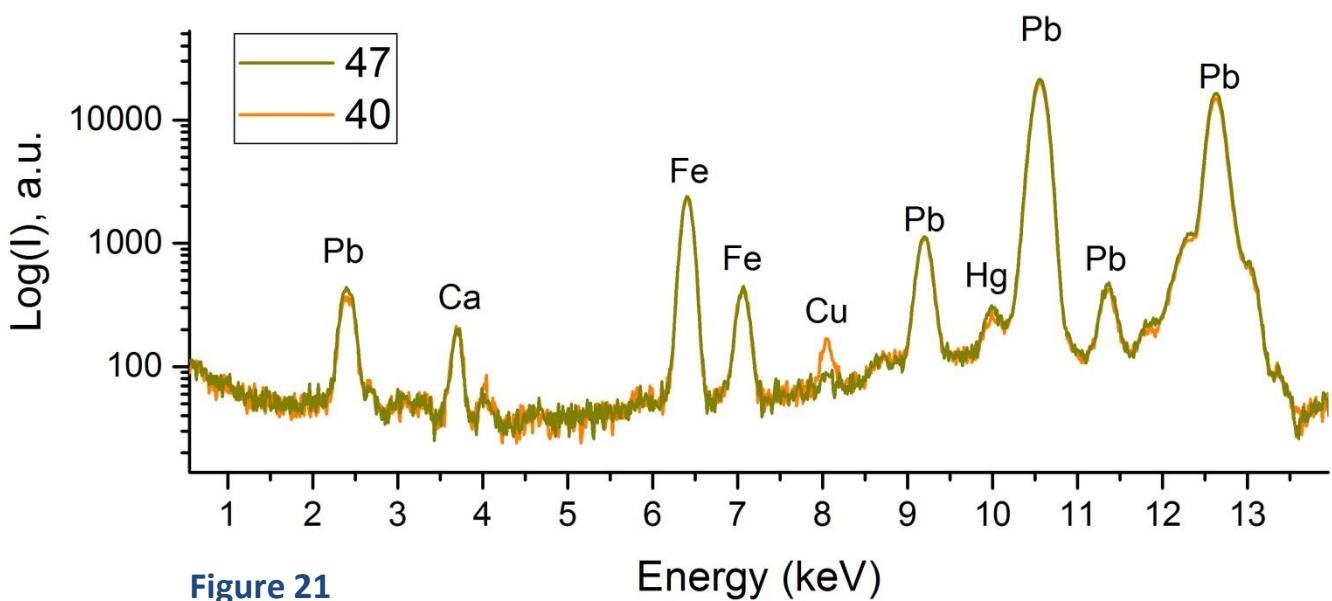


Figure 21

Energy (keV)

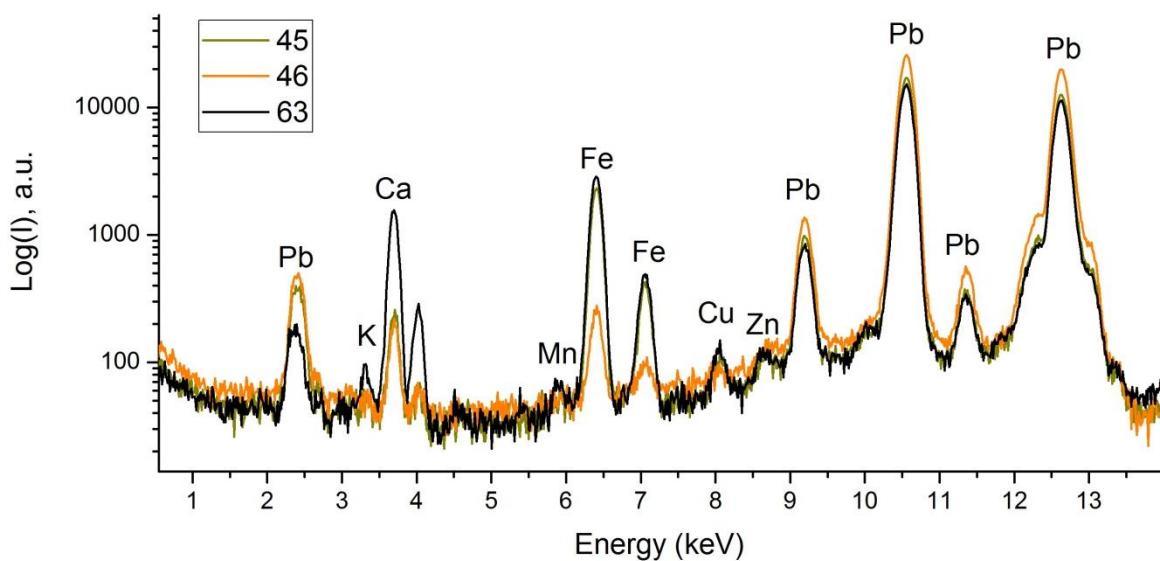


Figure 22

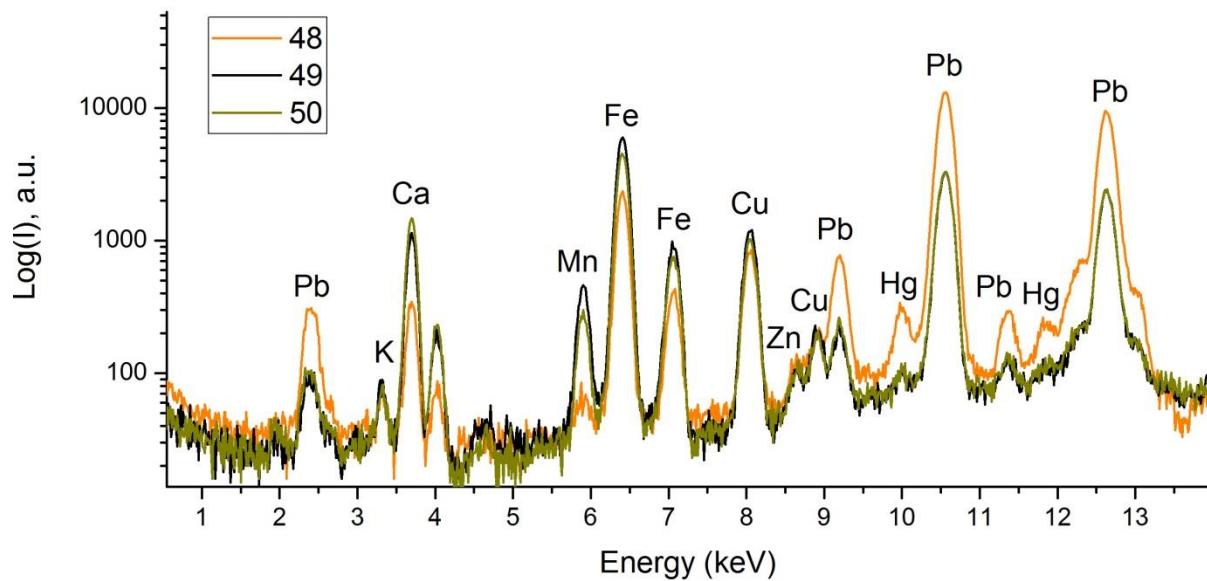


Figure 23

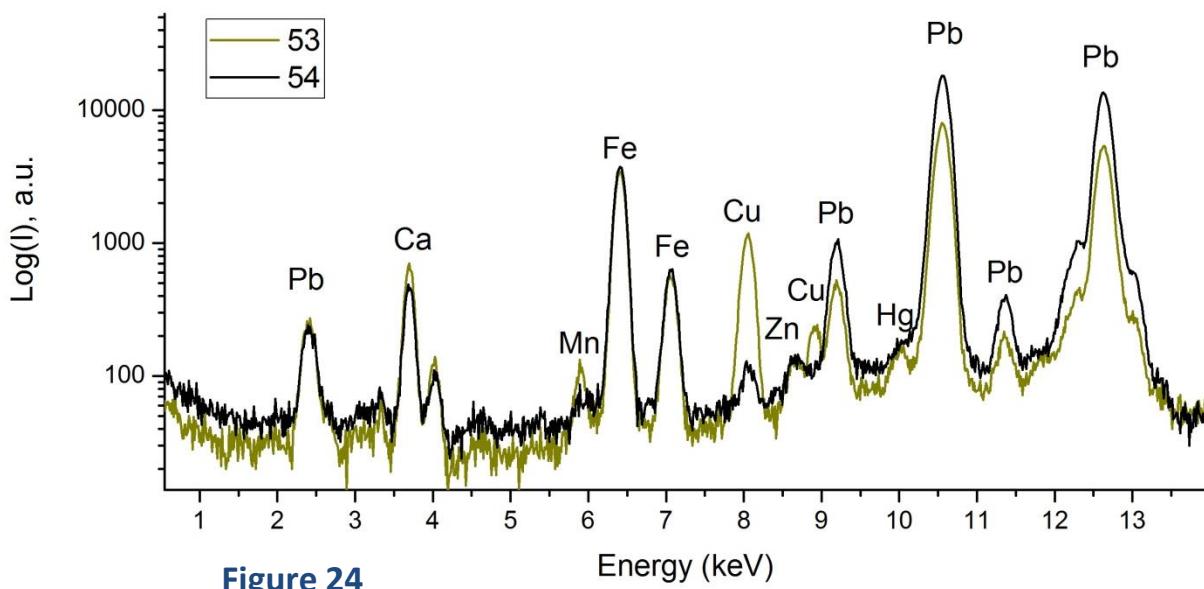


Figure 24

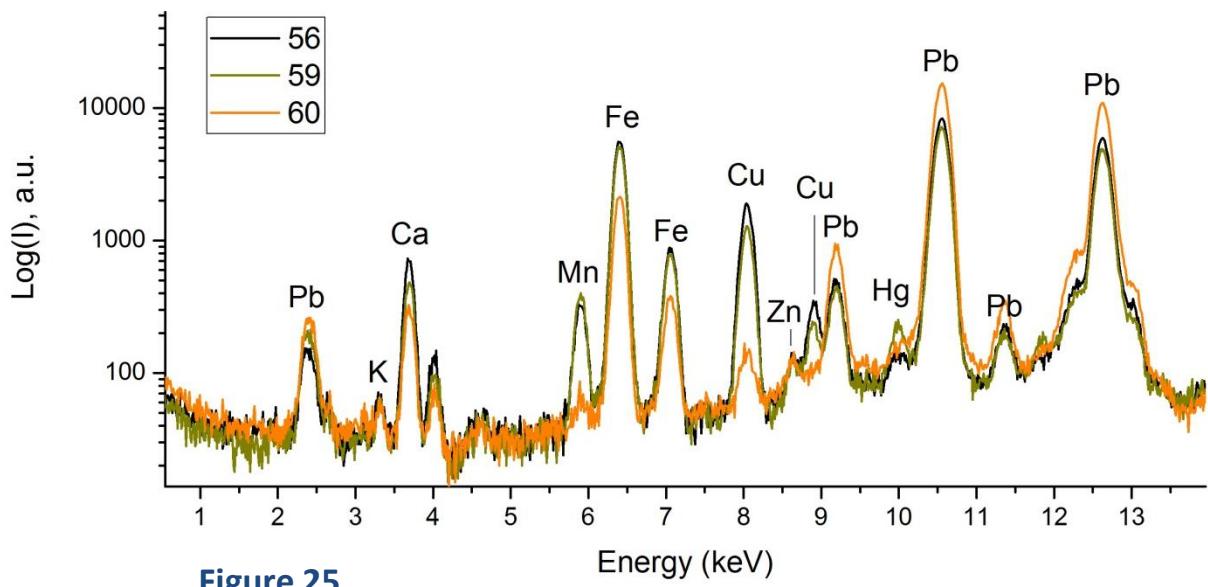


Figure 25

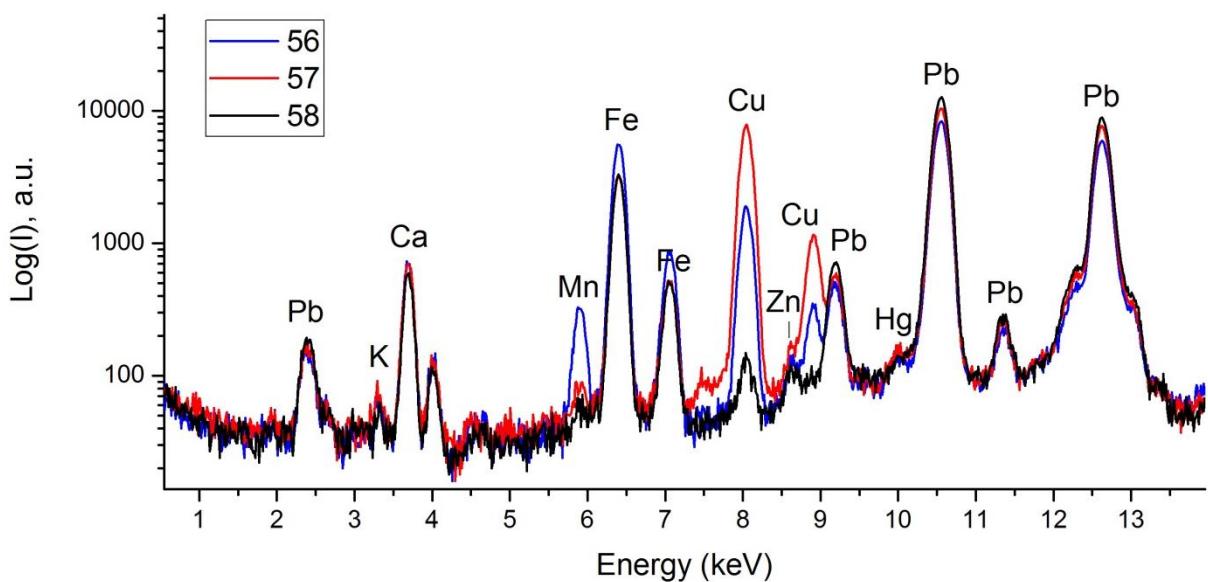


Figure 26

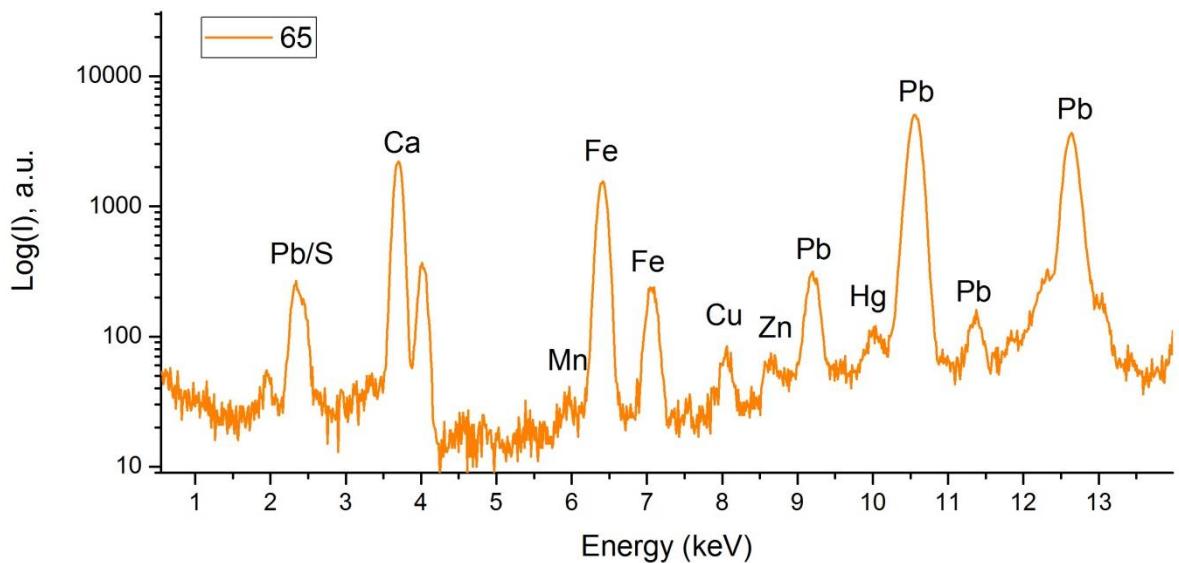


Figure 27

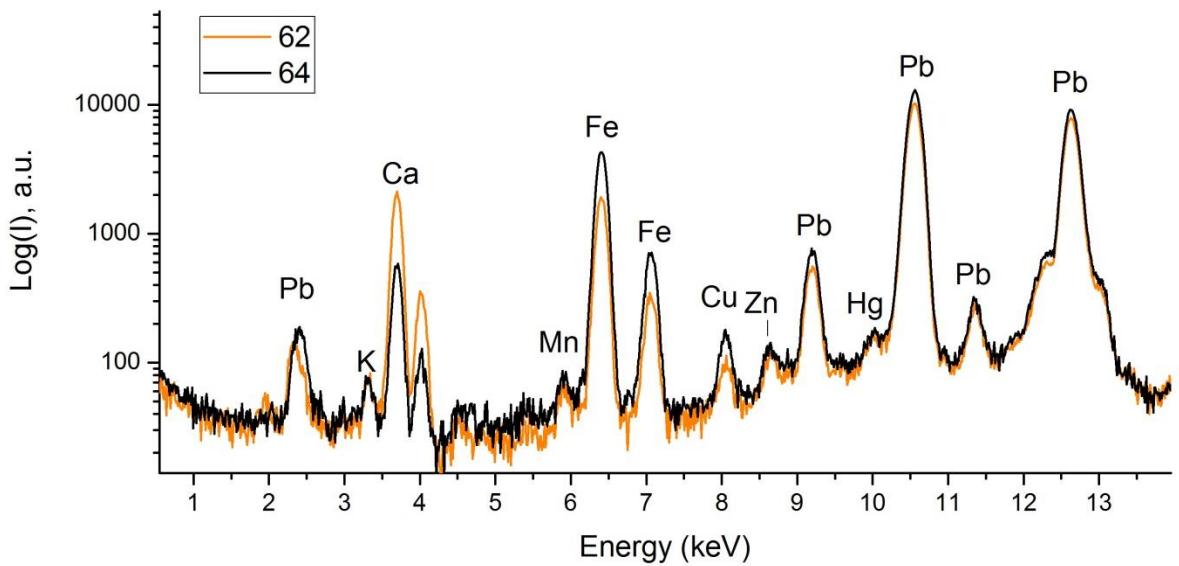


Figure 28

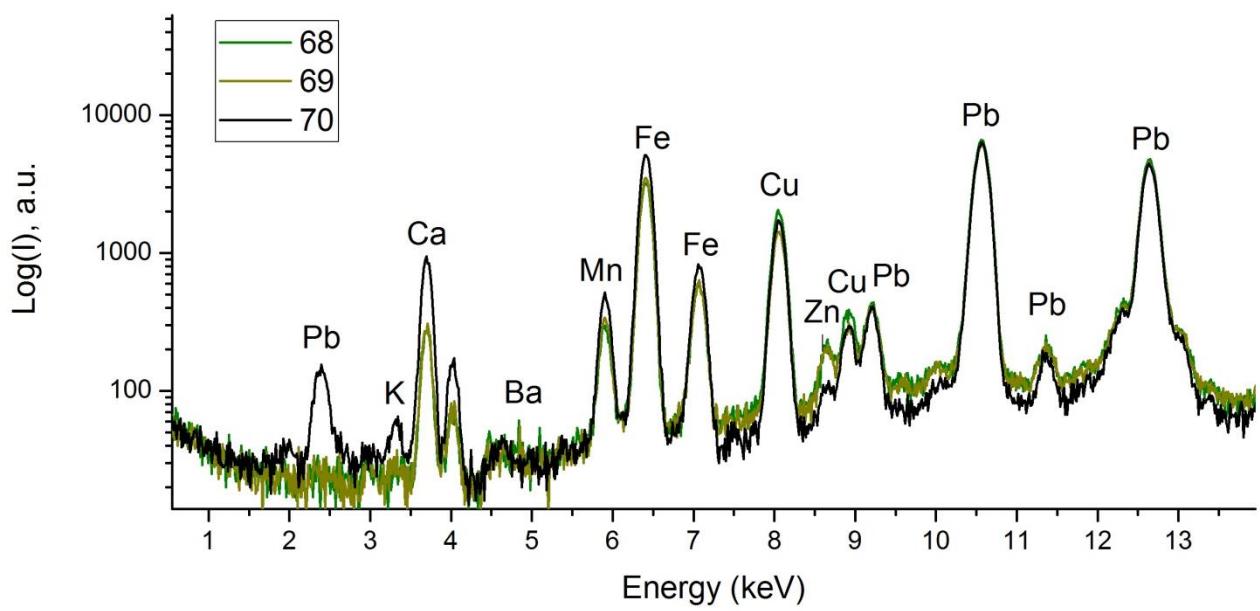


Figure 29

Digital microscopy

Microscopy

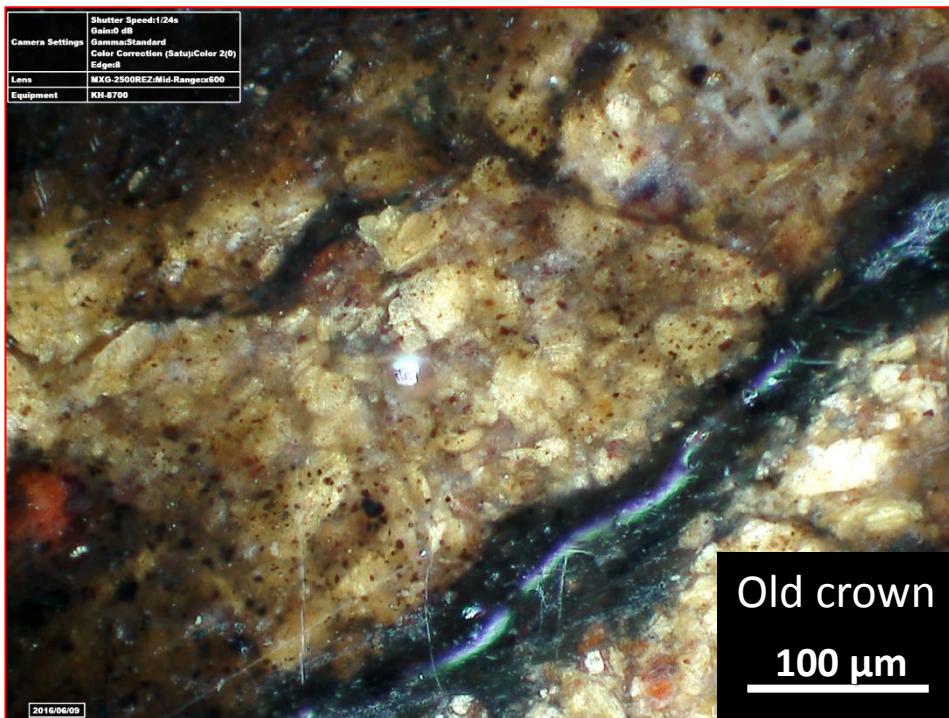


Figure 30

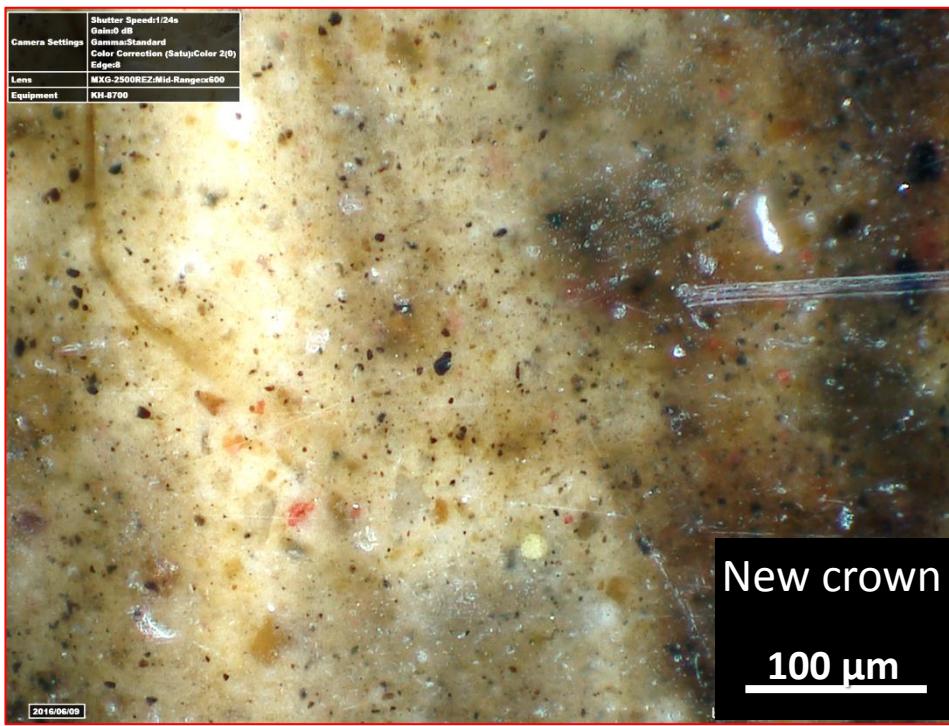


Figure 31

Microscopy

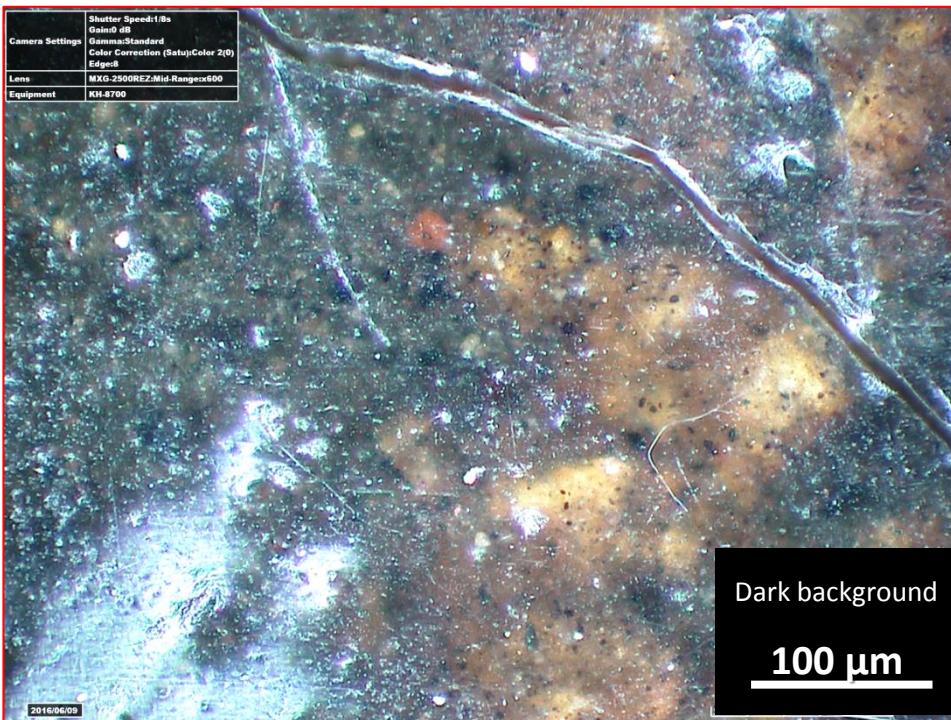


Figure 33

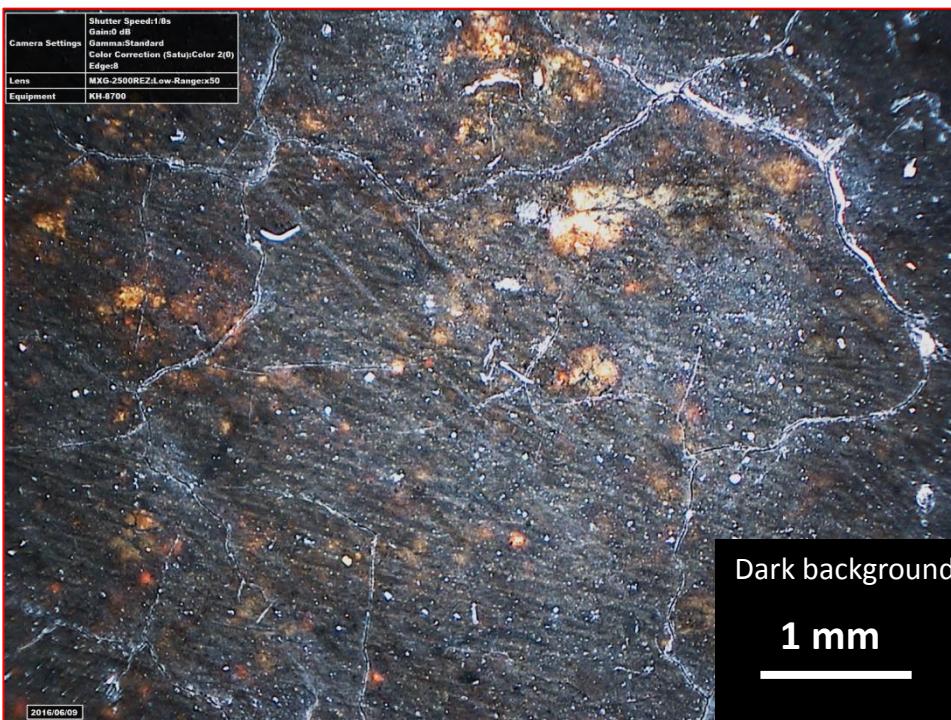


Figure 34

Microscopy

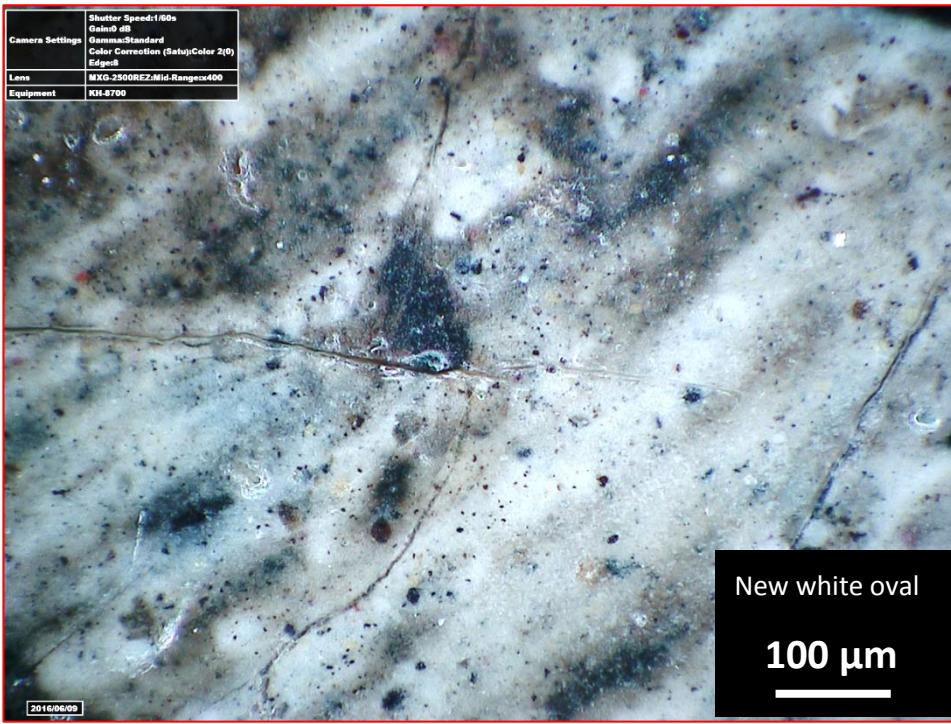


Figure 35



Figure 36

Microscopy

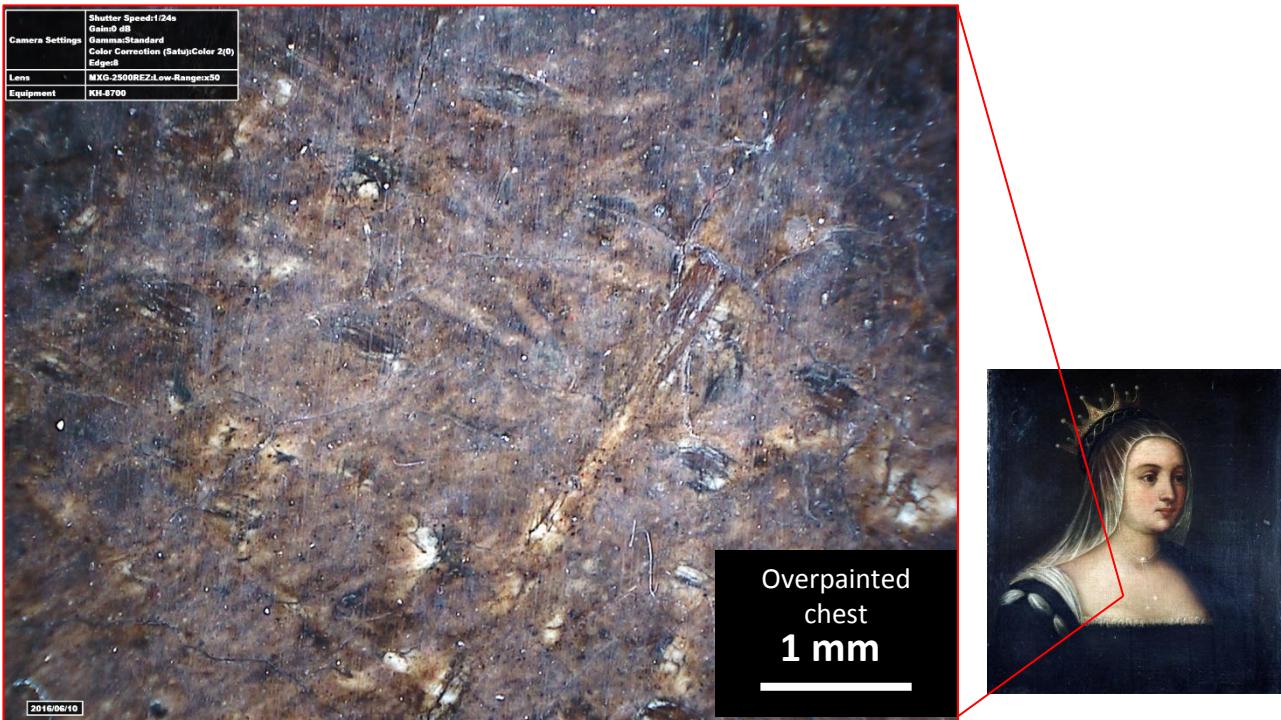


Figure 37

IR imaging

IR photography

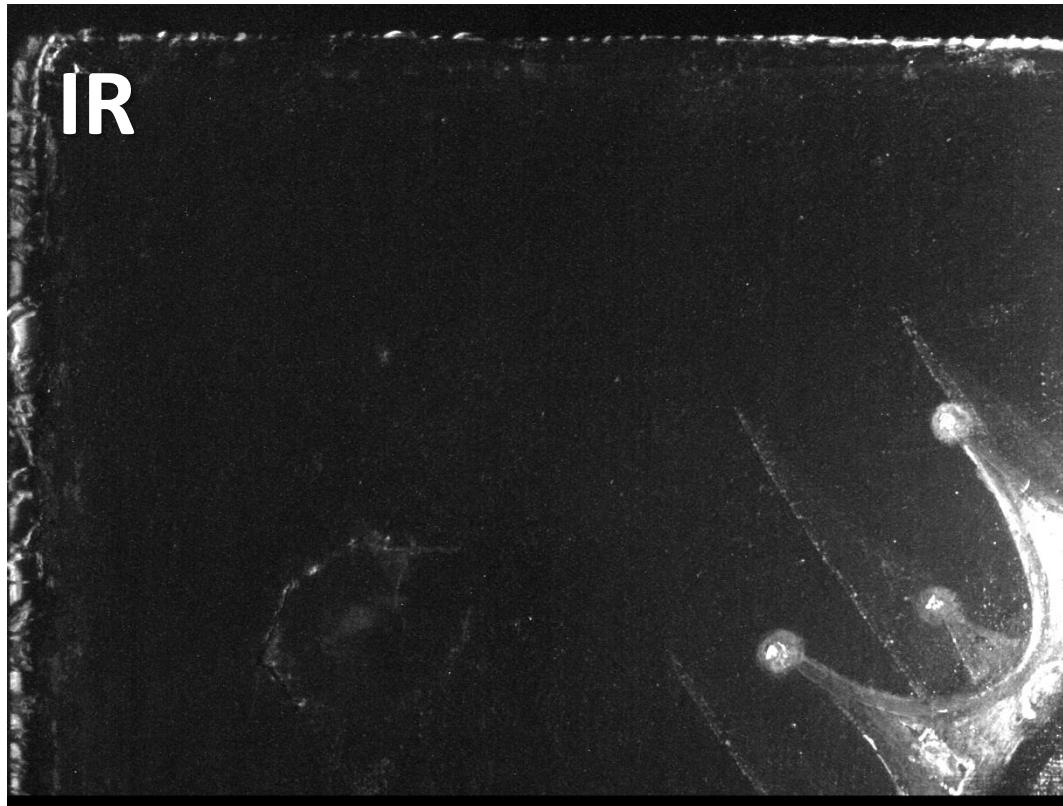


Figure 38



IR photography

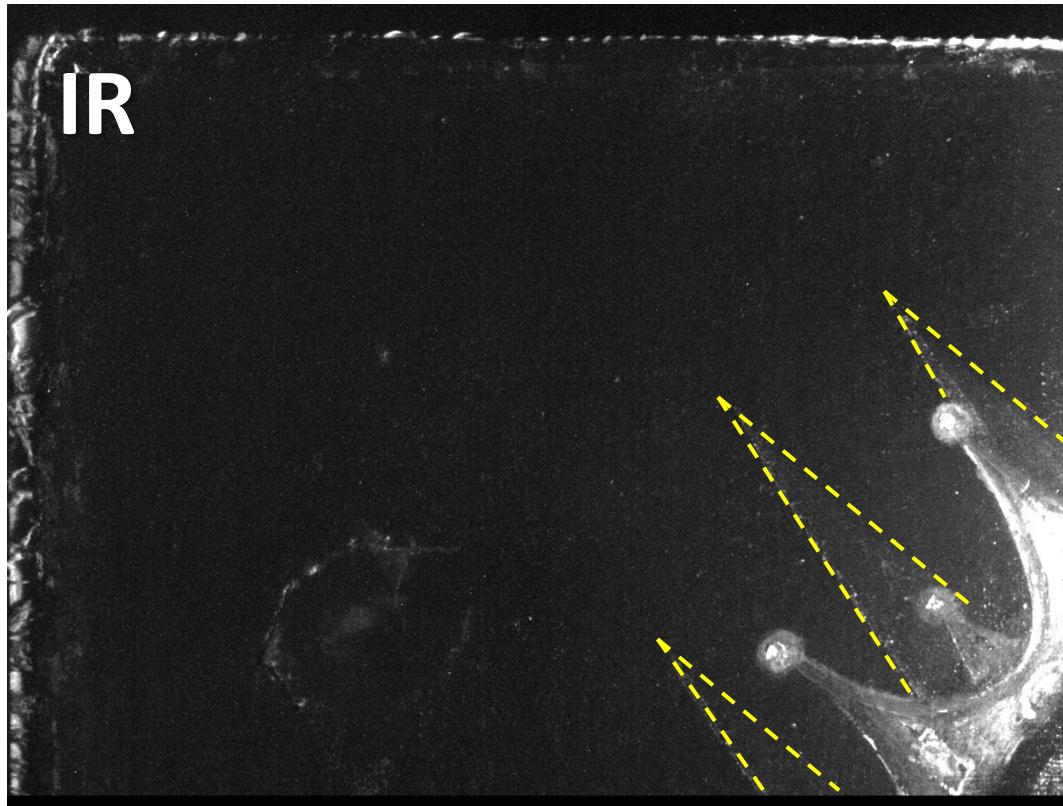
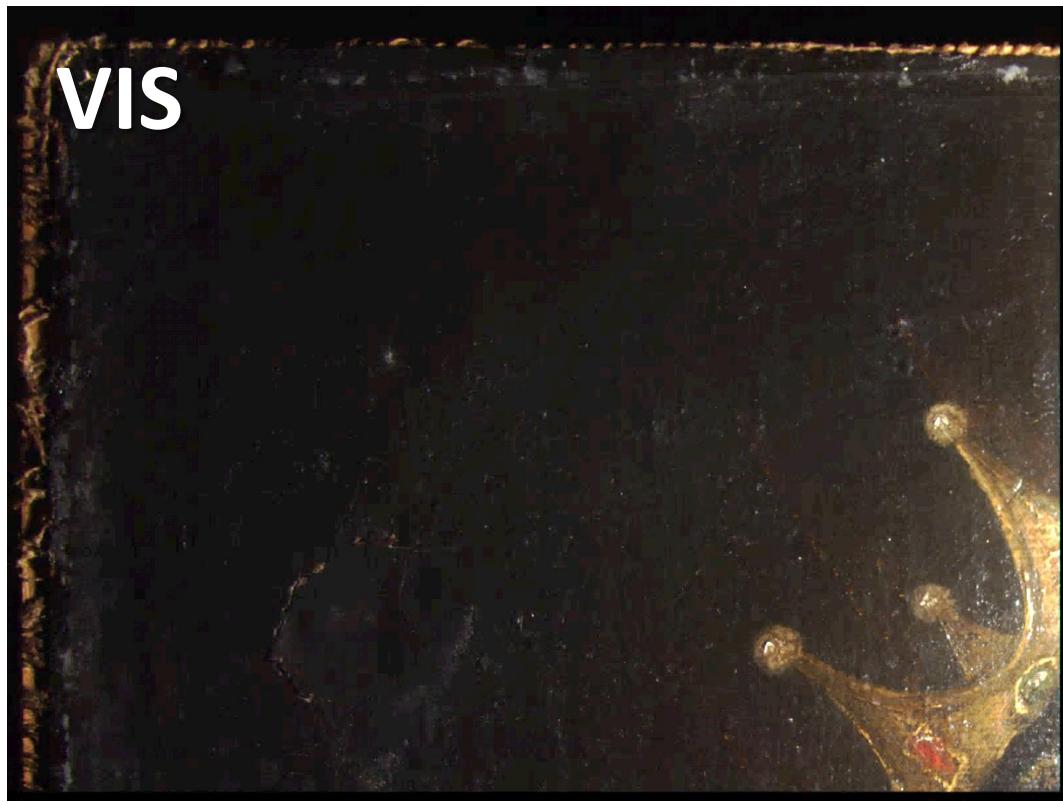


Figure 38



IR photography

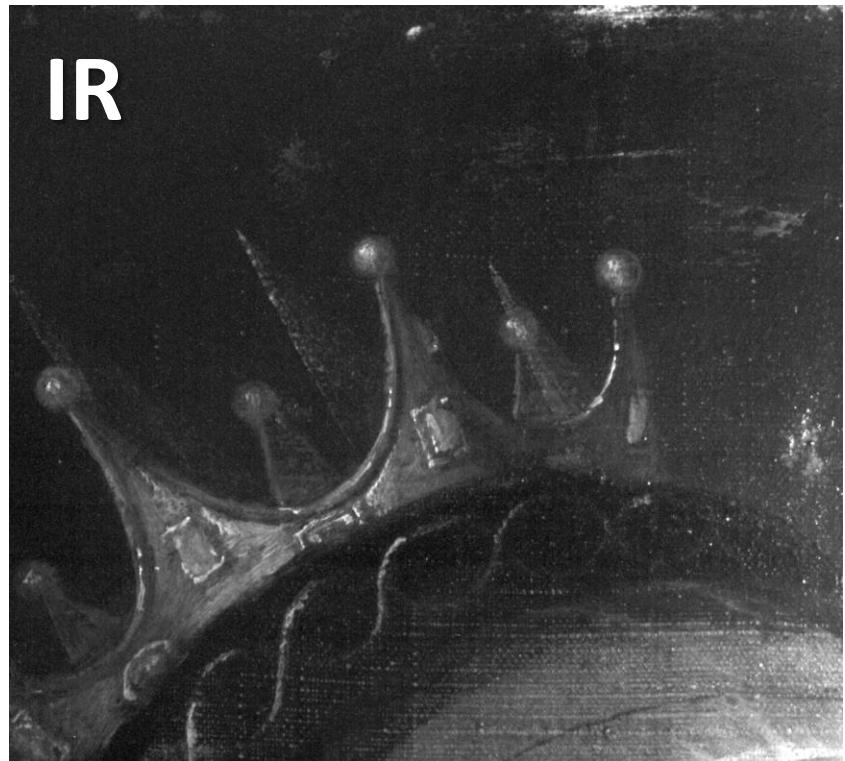
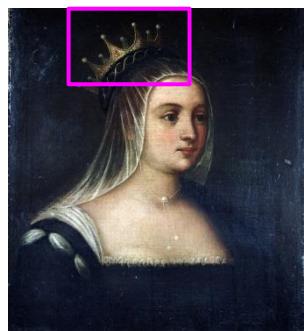


Figure 39

IR



VIS

IR photography

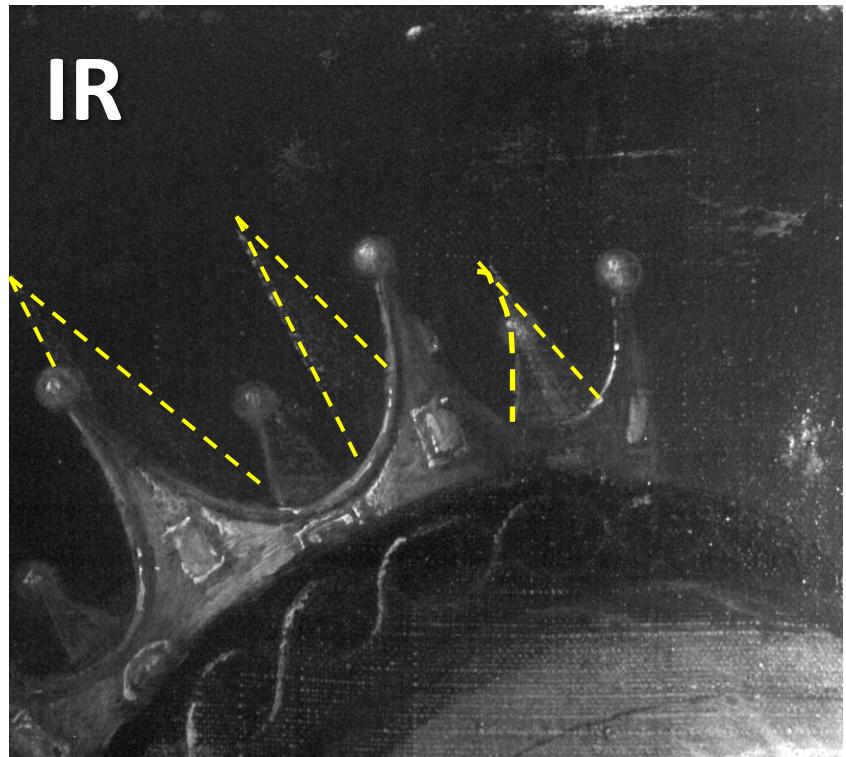
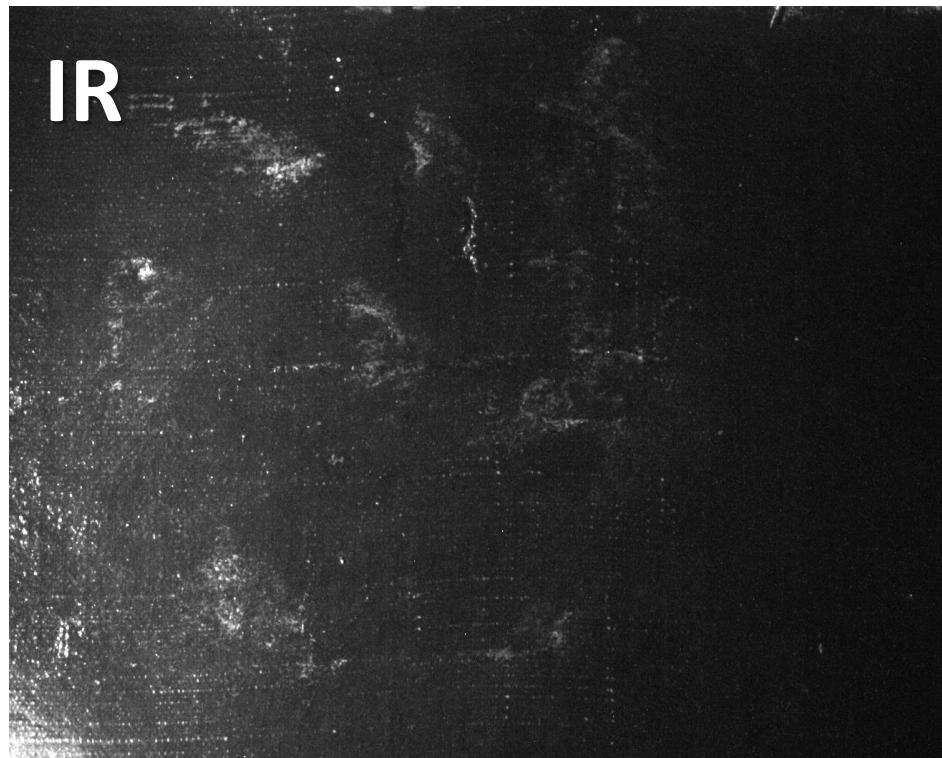


Figure 39



IR photography



IR

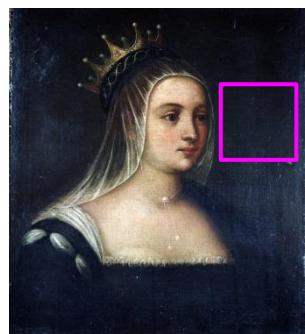
Figure 40



IR photography



Figure 41



IR photography

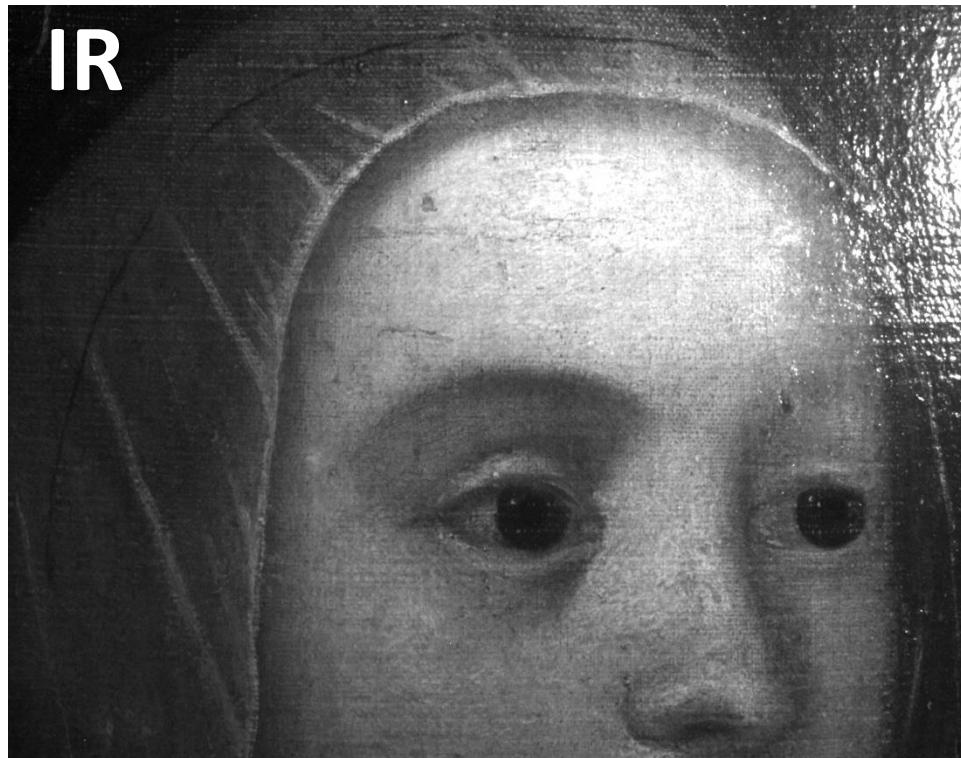
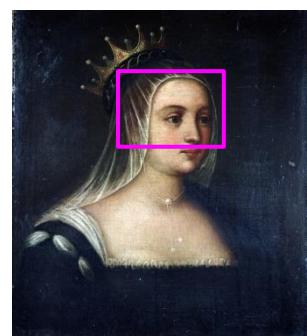
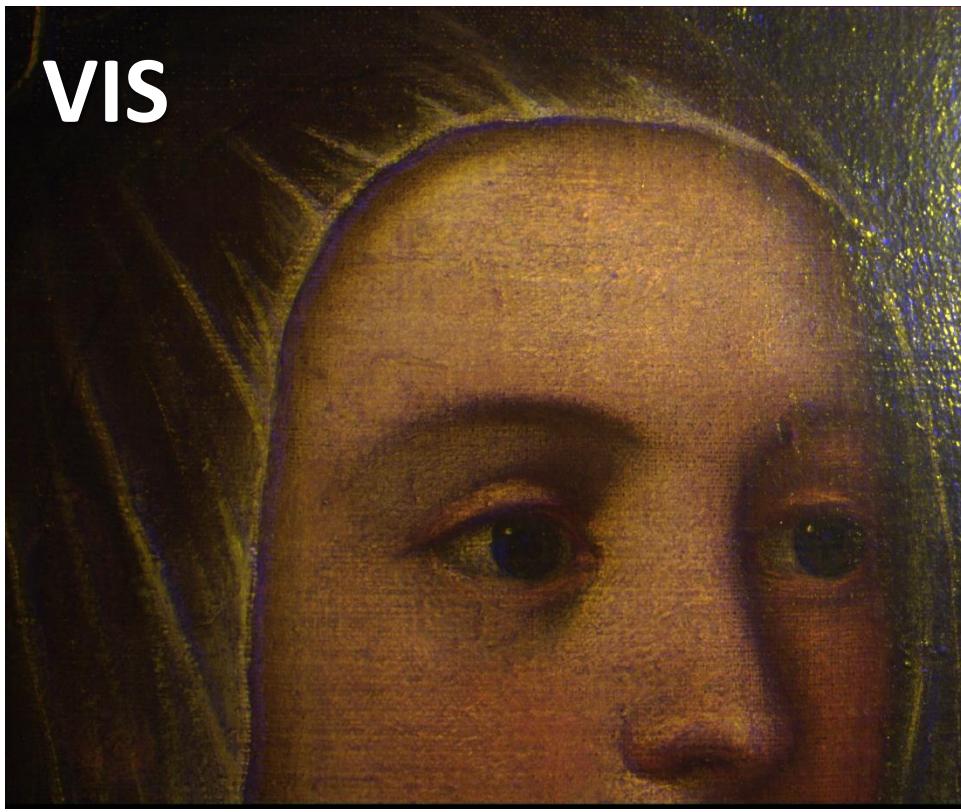
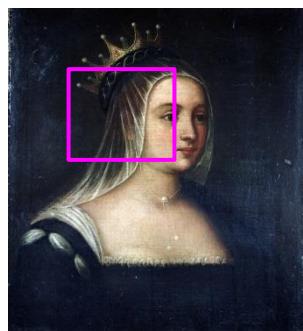
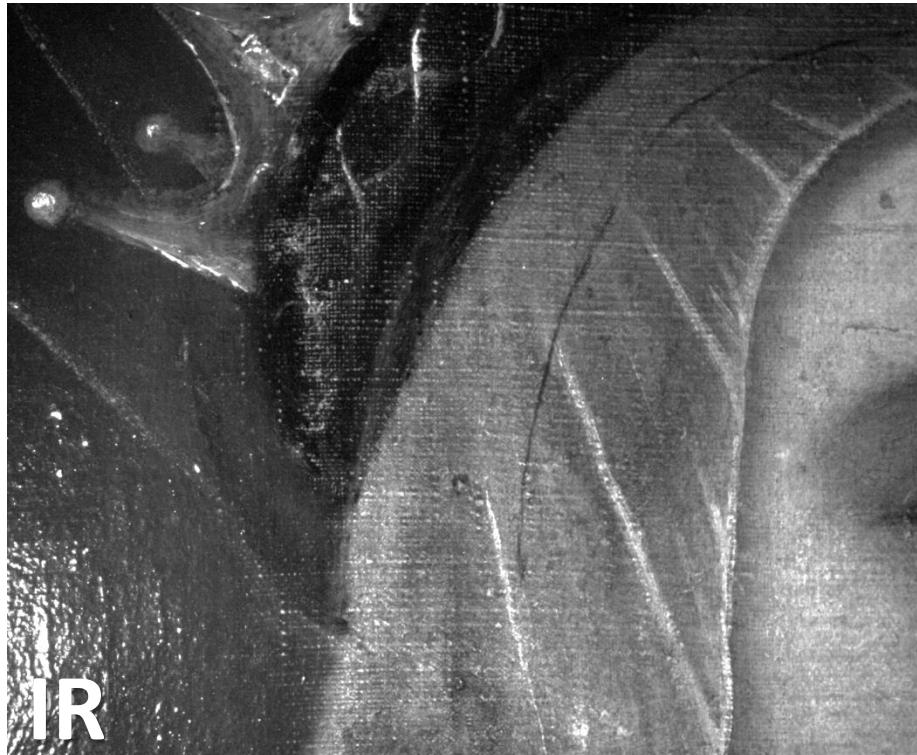


Figure 42



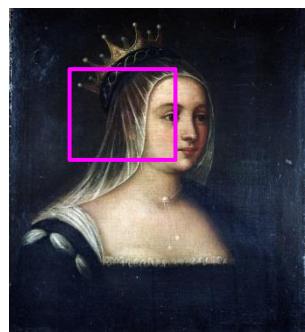
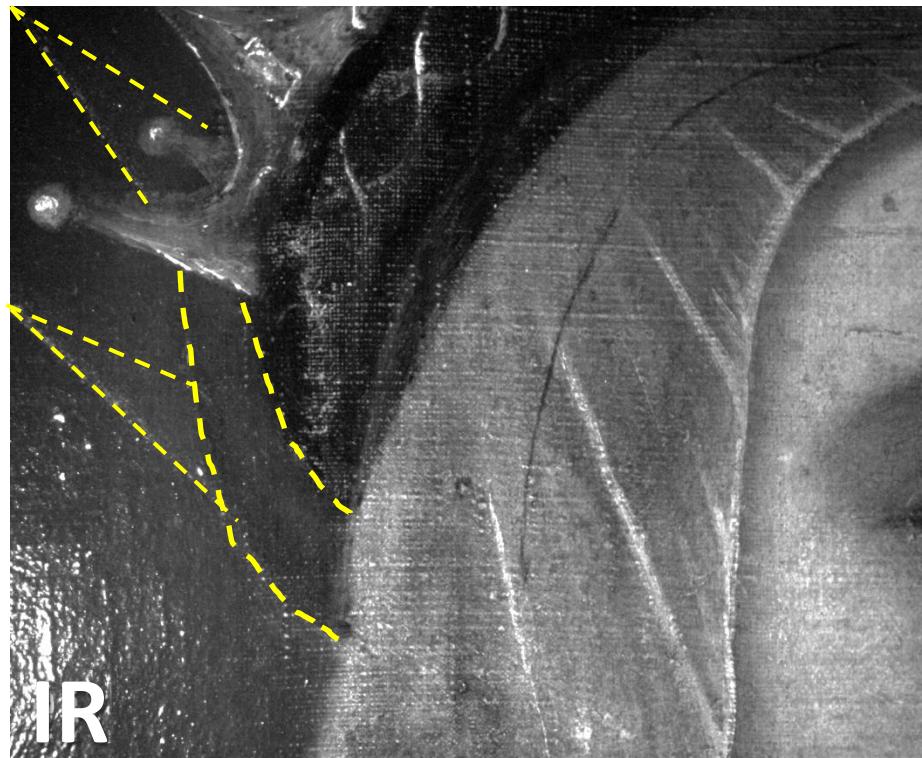
IR photography

Figure 43



IR photography

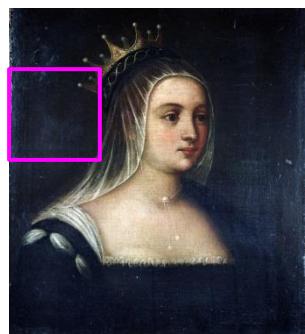
Figure 43



IR photography



Figure 44



IR photography

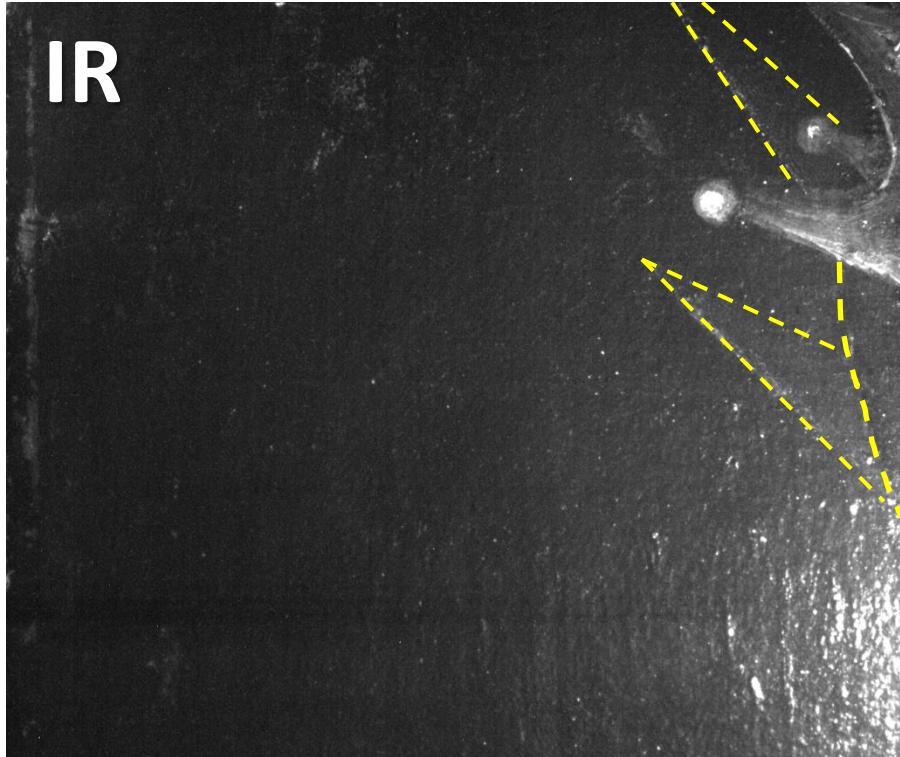
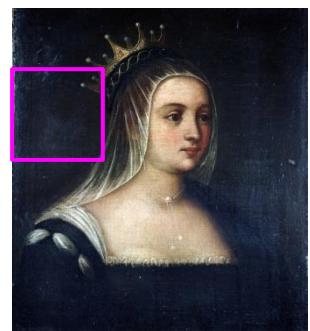


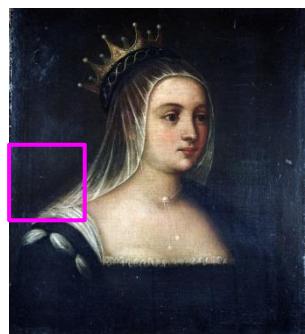
Figure 44



IR photography



Figure 45



IR photography

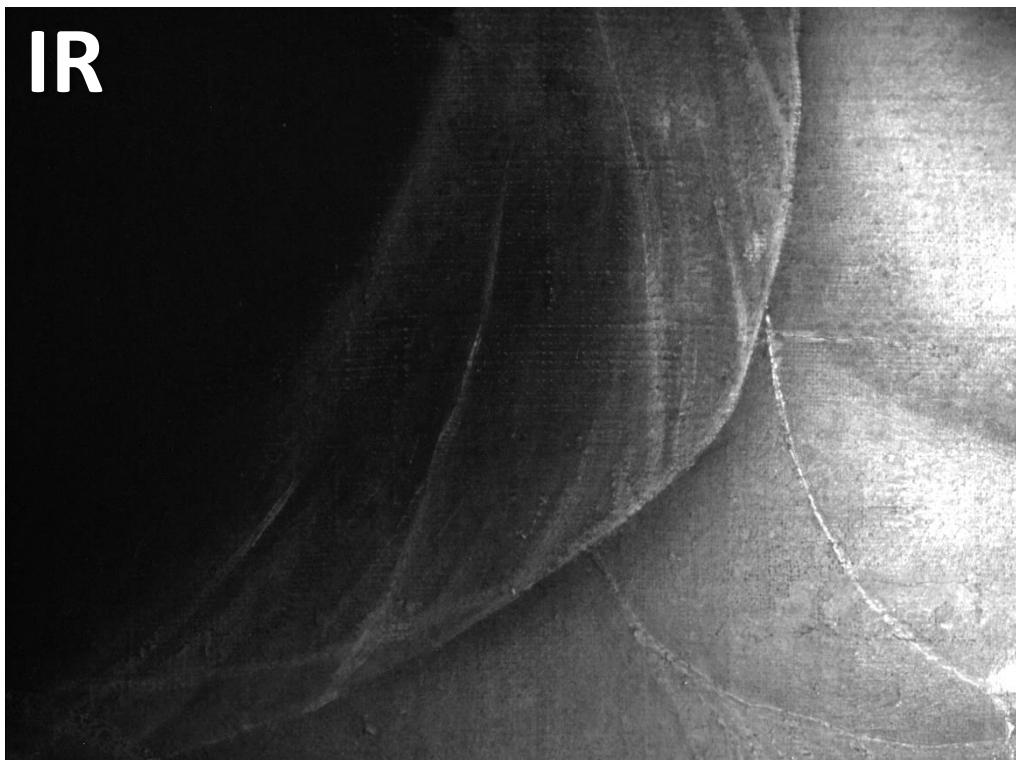
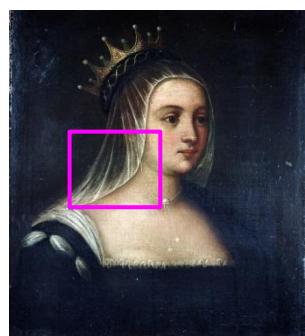


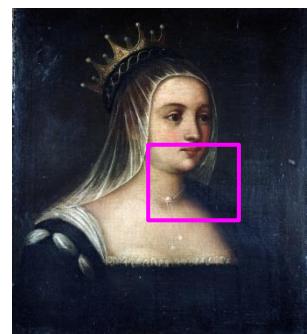
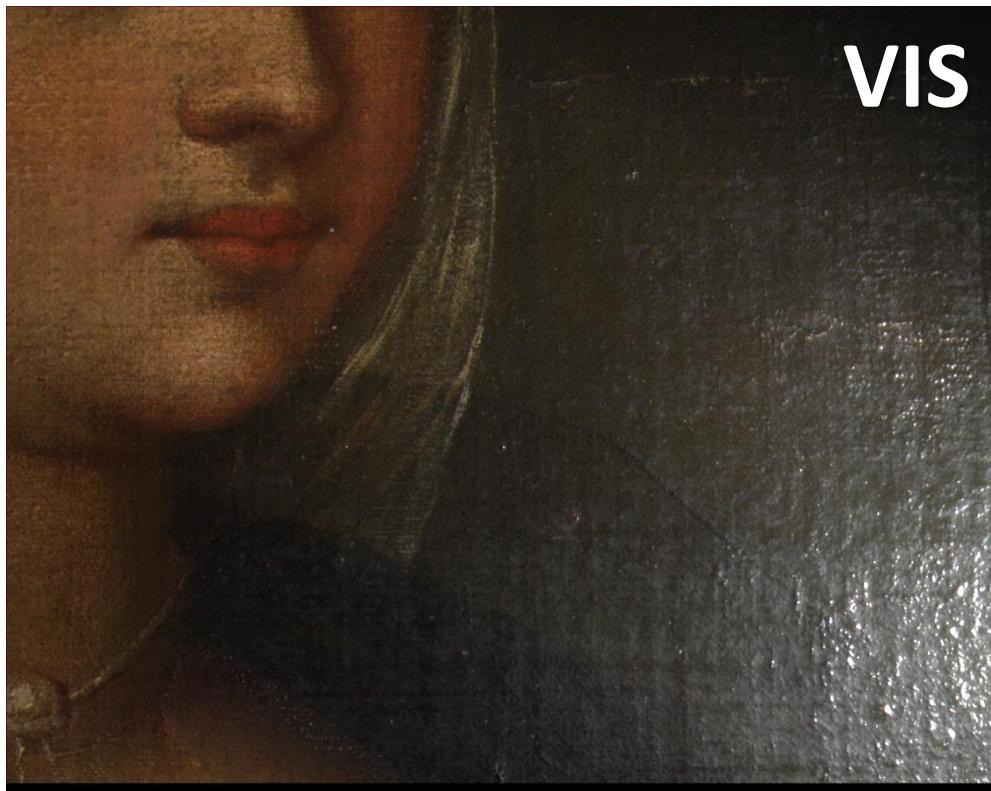
Figure 46



IR photography



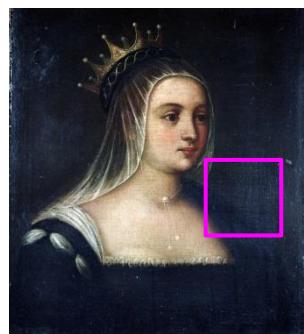
Figure 47



IR photography



Figure 48



IR photography



Figure 49



IR photography

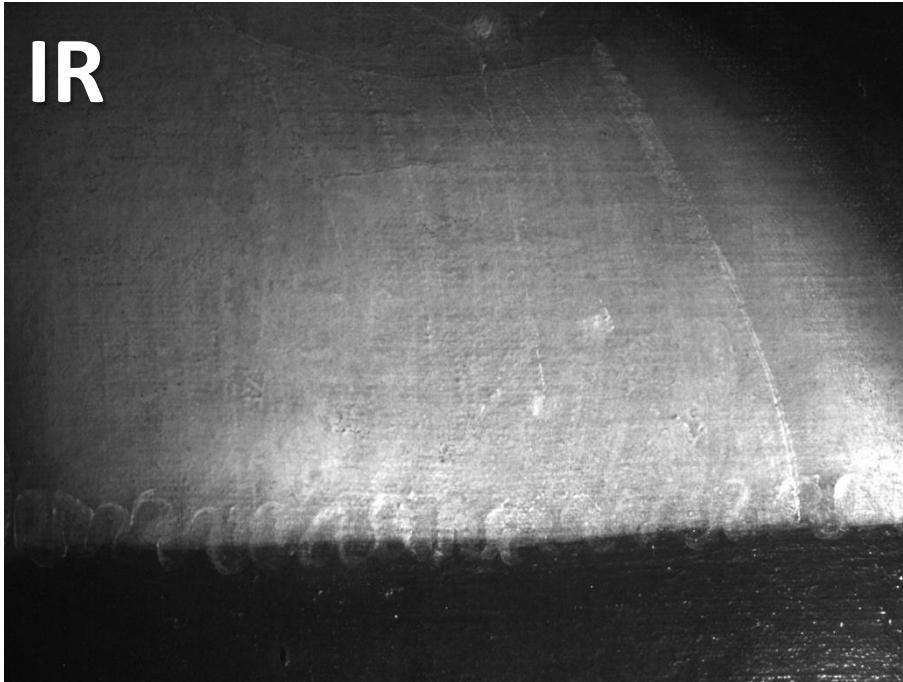


Figure 50



IR photography

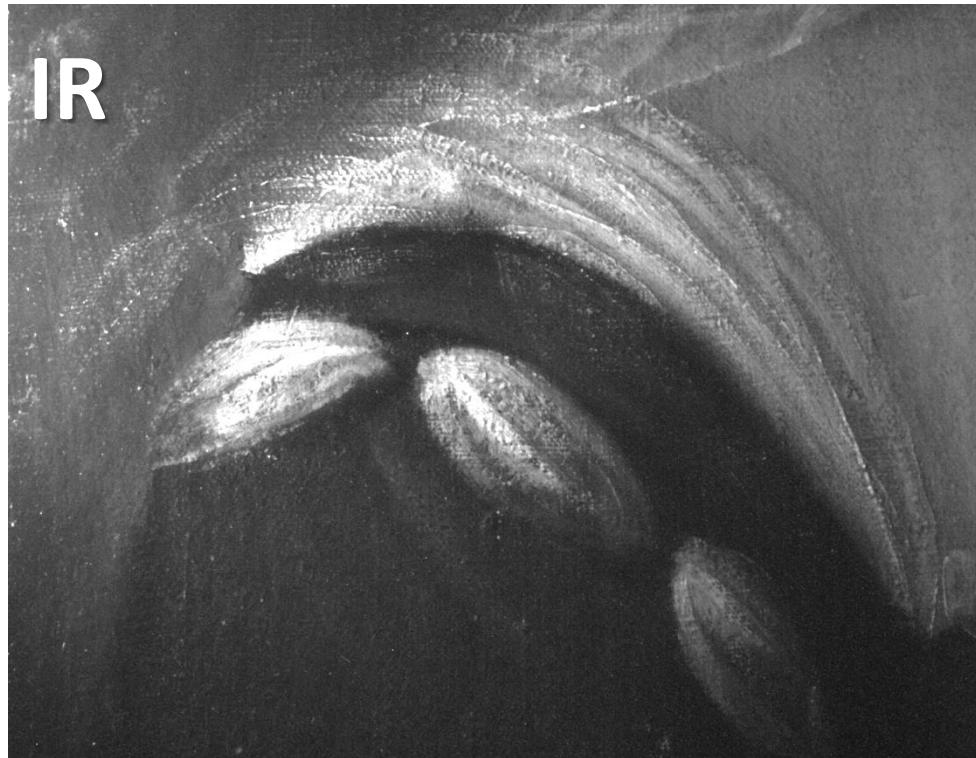


Figure 51



IR photography

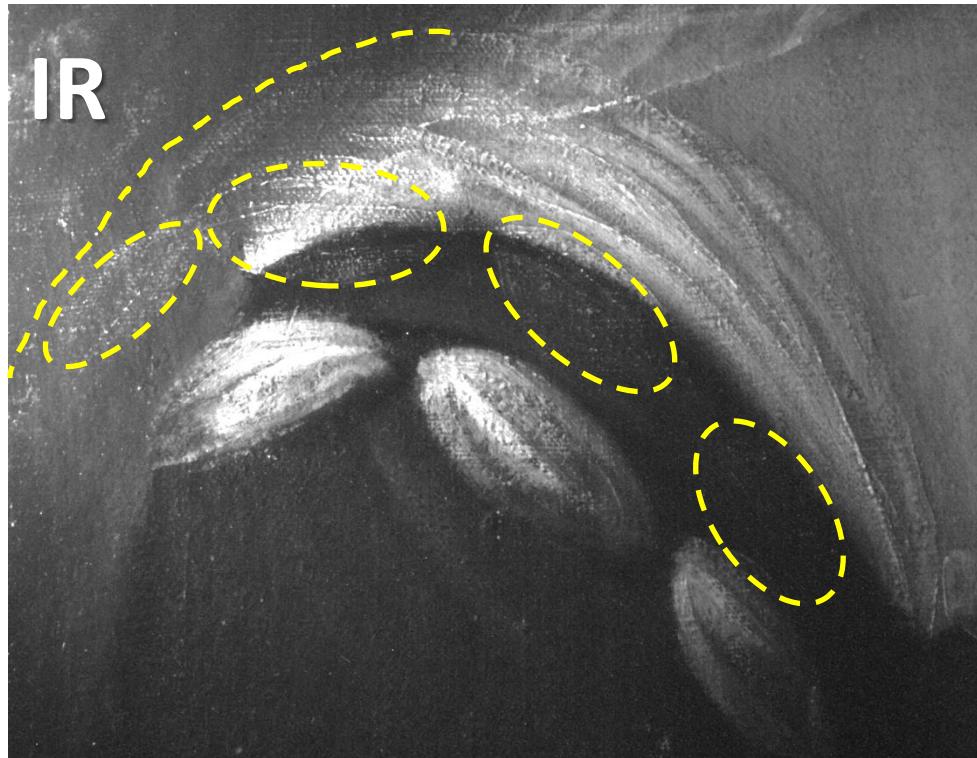


Figure 51



IR photography



Figure 52

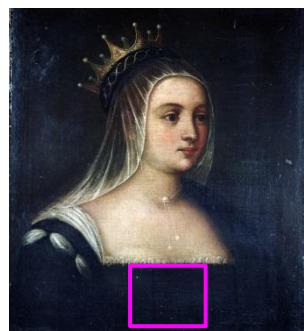


IR photography



IR

Figure 53



IR photography

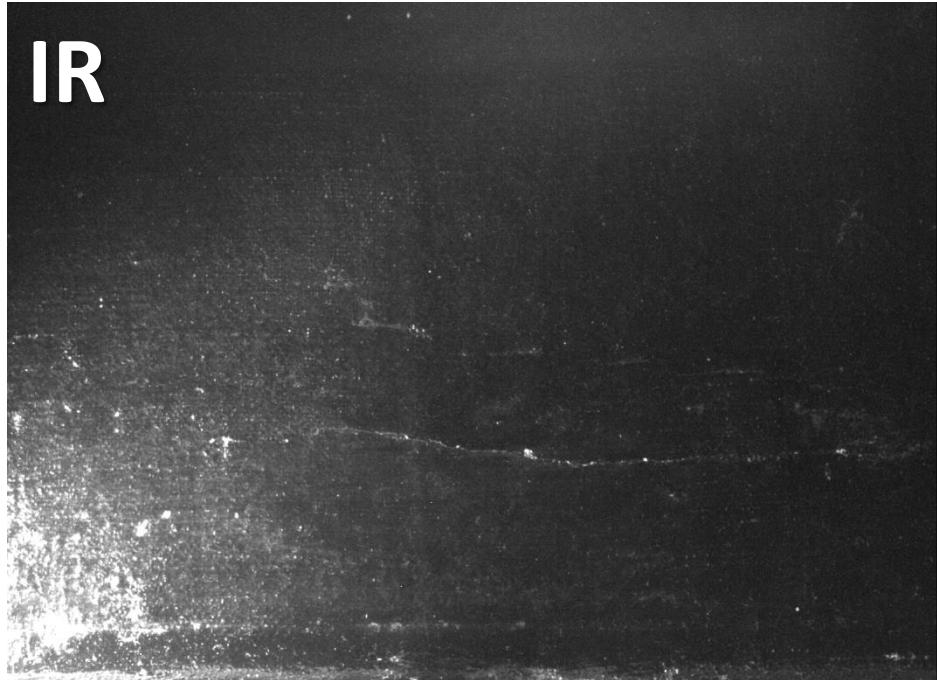


Figure 54



IR photography



Figure 55

