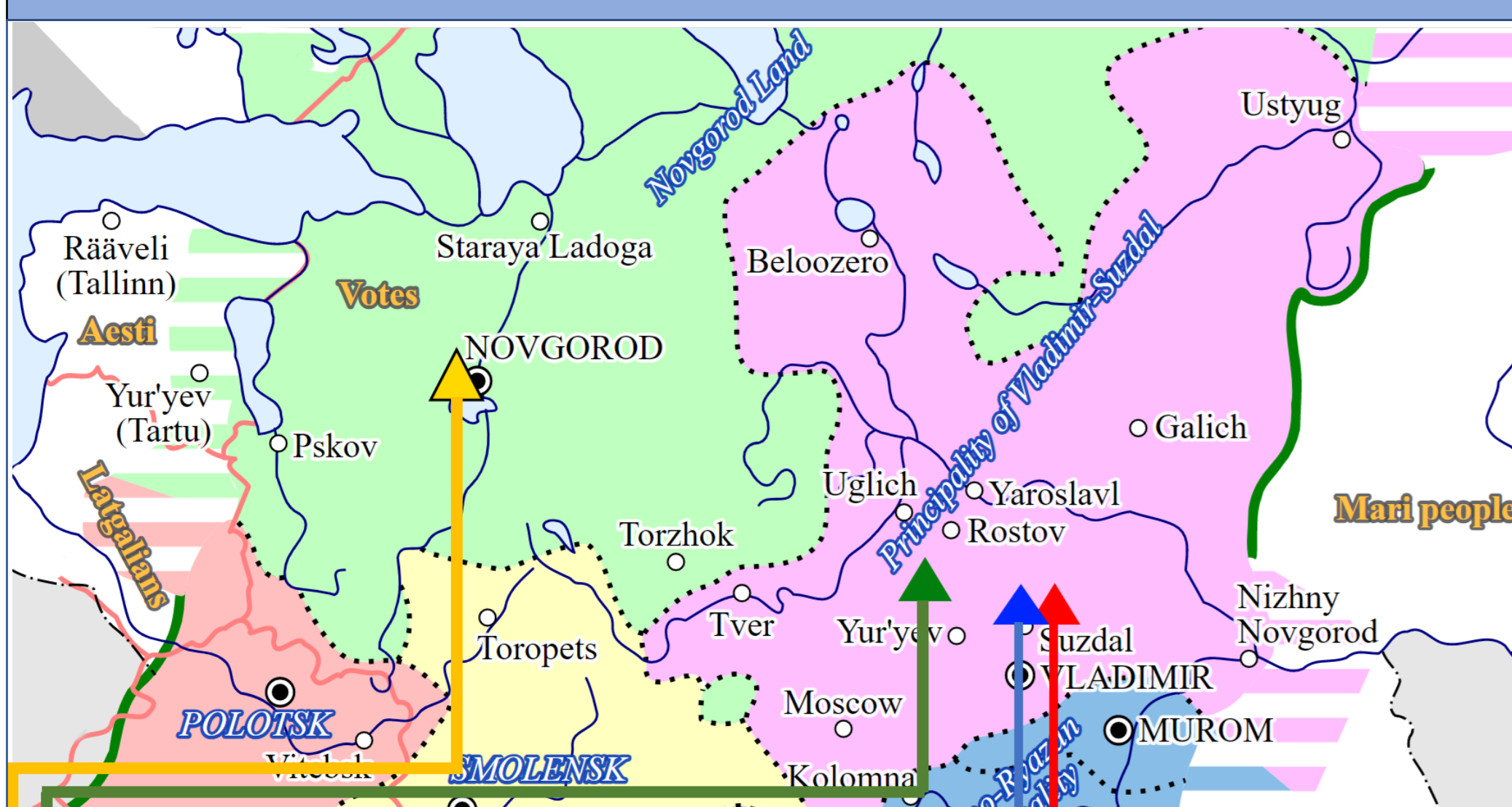


### Abstract

The paper presents the results of the study of wall painting fragments from the church of Boris and Gleb in Kideksha (mid-12th century AD). We used the following methods: optical microscopy, SEM-EDS and X-ray diffraction. As comparison, we used materials from the cathedral at Suzdal (turn of the 11-12 century AD), the Transfiguration Cathedral in Pereslavl-Zalessky (mid-12th century AD) and from the 12th century cathedral of St. George at Novgorod.

### Introduction



### Materials and methods

2021 at the Kurchatov Institute		
sampling	typical colors selection	whole fresco fragments
methods	SEM+EDS	X-ray diffraction
equipment	Dual-beam SEM VERSA (THERMO Fisher Scientific), EDX analyzer EDAX	SAR station of the Kurchatov synchrotron radiation source, Rayonix SX165 detector
conditions	Low vacuum Accelerating voltage 30 keV Beam current 45 nA.	Wavelength 0.74 E Si monochromator Measurement time 2 min Sample-detector distance 80 mm Temperature 25
2022 at the Institute of archaeology		
sampling	typical colors whole fresco fragments	Unusual fragments micro sample of pigment powder
method	Optical microscopy	SEM+EDS
equipment	Olympus BX41	SEM Tescan Vega Compact, EDX detector Xplore 15
experimental conditions	reflected light Mag 100X, 200X	High vacuum Accelerating voltage 20 keV Beam current 15 nA.

### Results and discussion

Most red pigments from Kideksha consist of Fe oxide. The Fe content increases depending on the color nuance: darker hues contain more Fe.

The average data of fragments of the same color, given below, confirm this.

tone	C	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe
Dark red	2,8	14,5	0,1	3,7	0,7	2,6	0,7	0,1	0,1	0,9	42,1	0,5	0,2	0,1	0,3	30,7
Red	2,4	20,9	0,2	5,6	3,2	9,1	1,3	0,2	0,2	1,3	44,2	0,7	0,4	0,4	0,1	9,2

In some fragments, we found a noticeable content of sulfur and mercury, indicating the use of cinnabar, sometimes mixed with ochre.[2]

In orange samples from Novgorod, we found a large amount of lead in orange-red paint, most likely indicating minium. In all yellow samples, we recorded iron, lower than in red samples, but still noticeable, suggesting the use of iron oxide pigments.[3]

X-ray diffraction showed a goethite phase in the yellow fragments, while the hematite phase is present on the red fragments. The results of X-ray diffraction are published in detail elsewhere.[4]



**The Church of Boris and Gleb at Kideksha**

**Date of construction:** 1150s

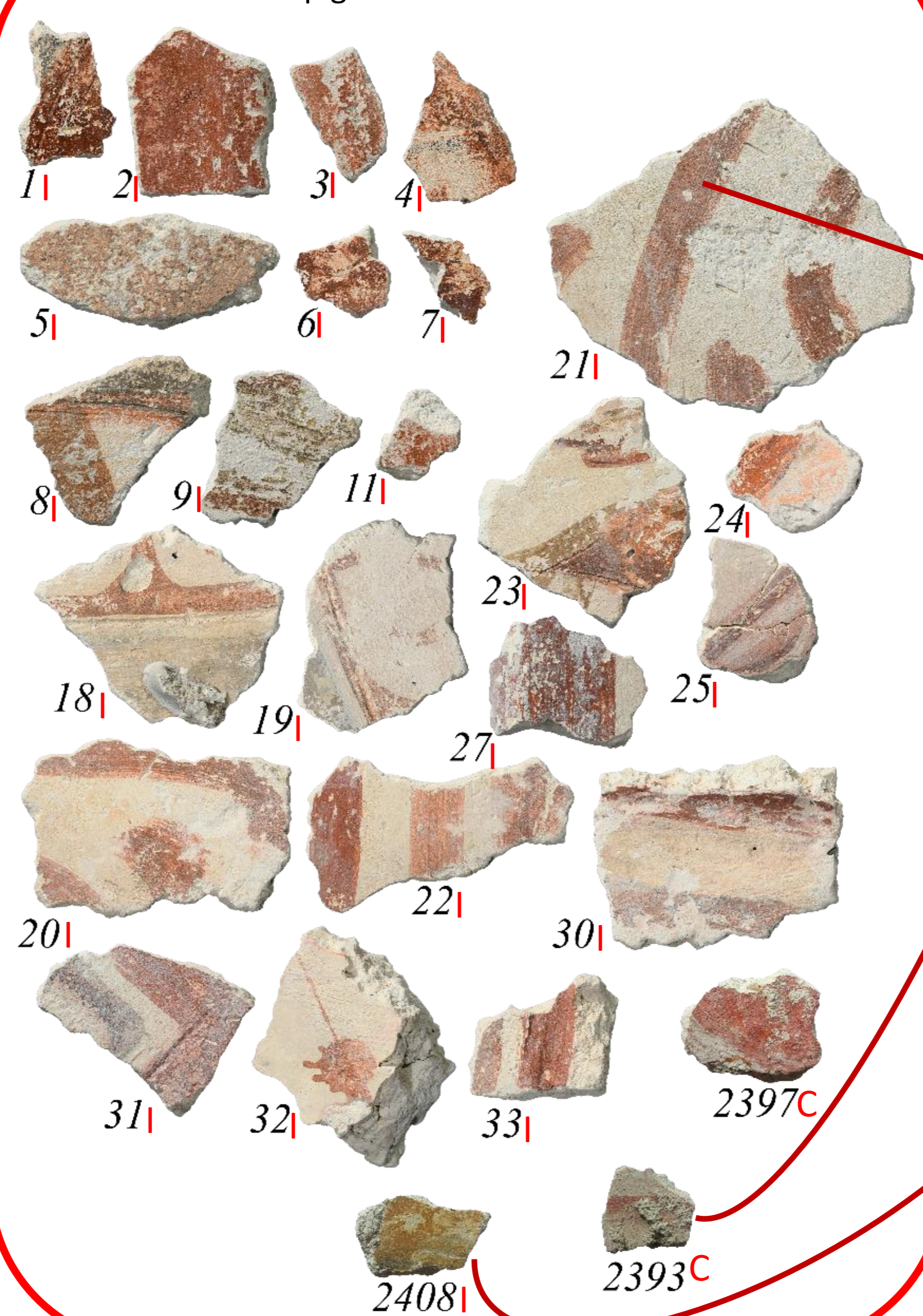
**Date of paintings:** 1150s

The Church of Boris and Gleb at Kideksha was built by order of Prince Yuri Dolgoruky.

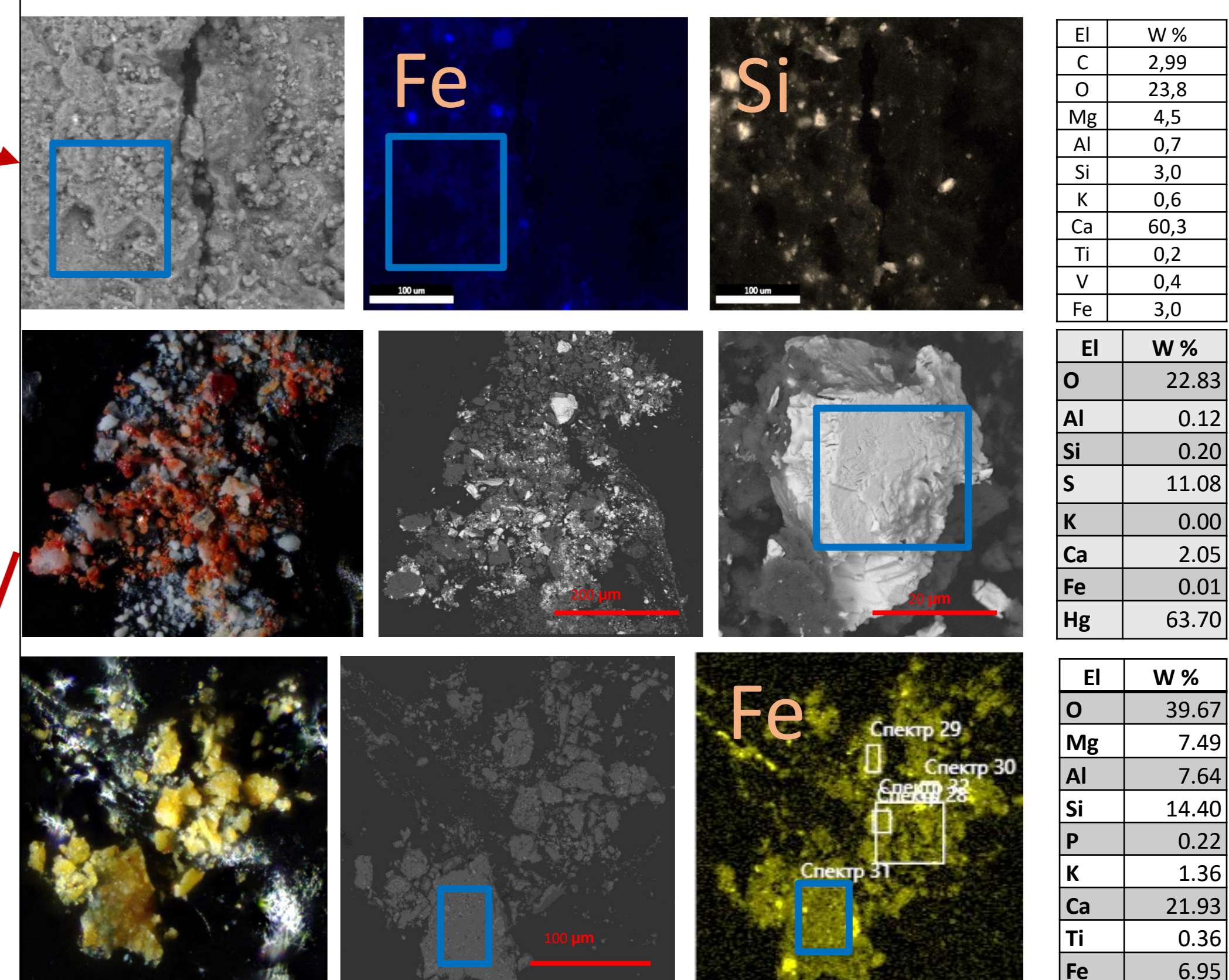
In the 60s of the 17th century, the vaults of the church and some sections of the walls collapsed inwards. Subsequently, the Church of Boris and Gleb underwent a major rebuilding. [1] Layers of lime rubble and frescoes remained inside the temple and new floors were laid on top of them.

The 2011-2012 excavations directed by V.V. Sedov reached and partially dismantled the rubble layer. A large number of fragments of frescoes, object of the present research, were found.

I – iron oxide pigment C – cinnabar M - minium



### SEM-EDS



The plaster from Kidersha is very dense, compact and solid. The mixture contains traces of flax, occasionally straw, very little brick fragments and sand, and some charcoal. The elemental composition consists of a large amount of magnesium, which may be due to the presence of dolomite in the raw material.



### Cathedral at Suzdal

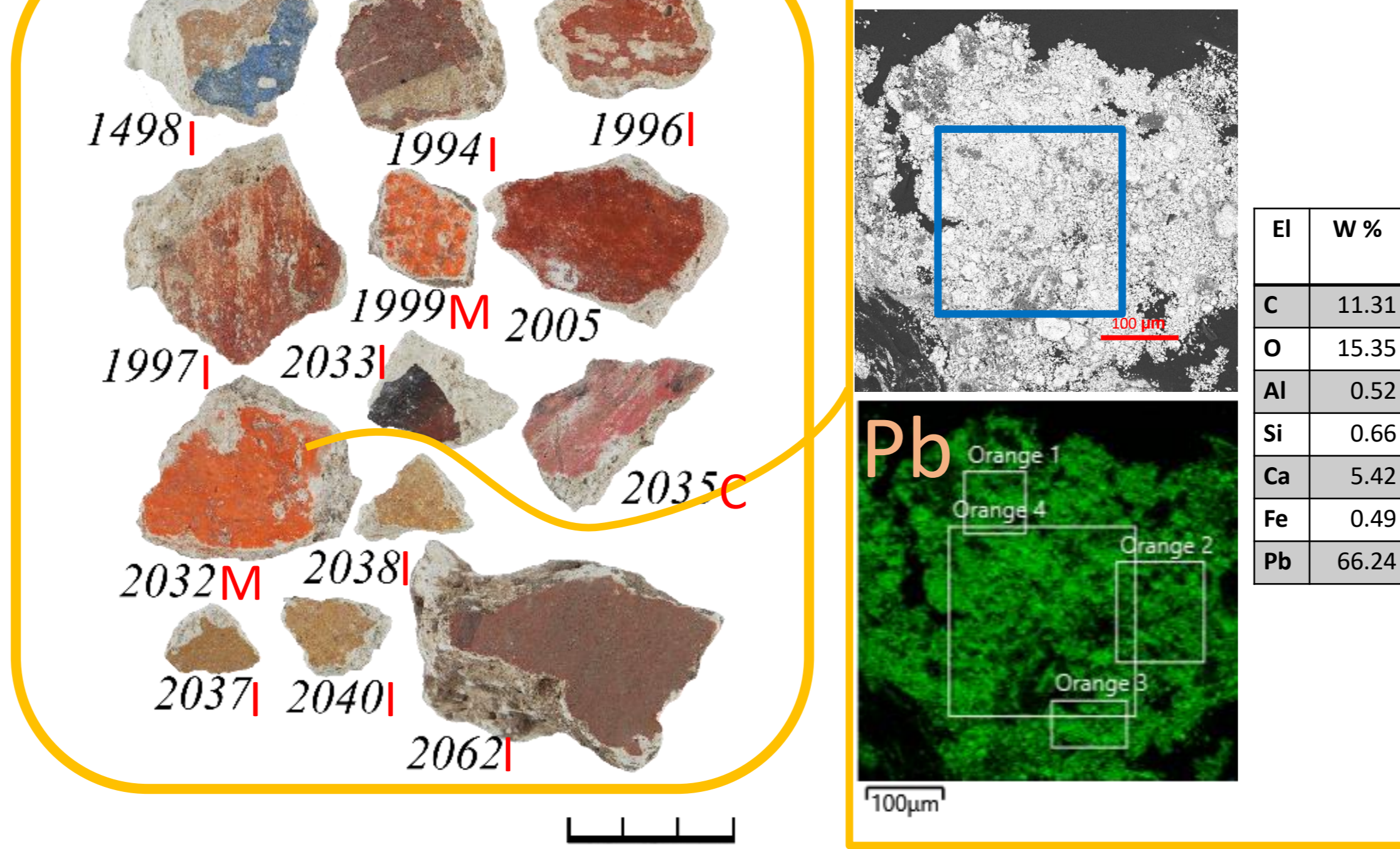
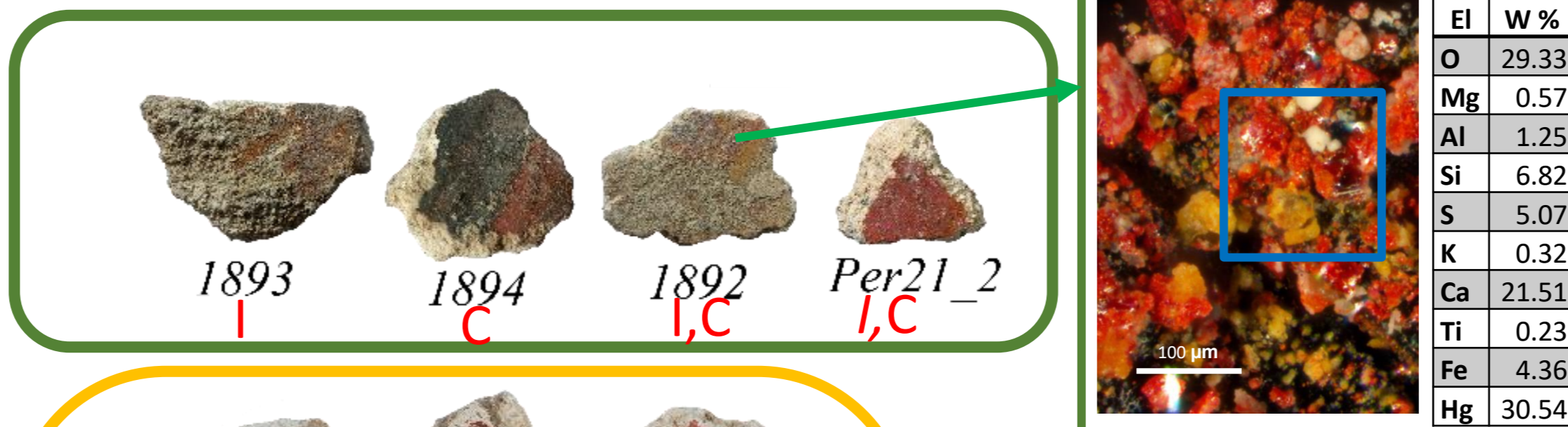
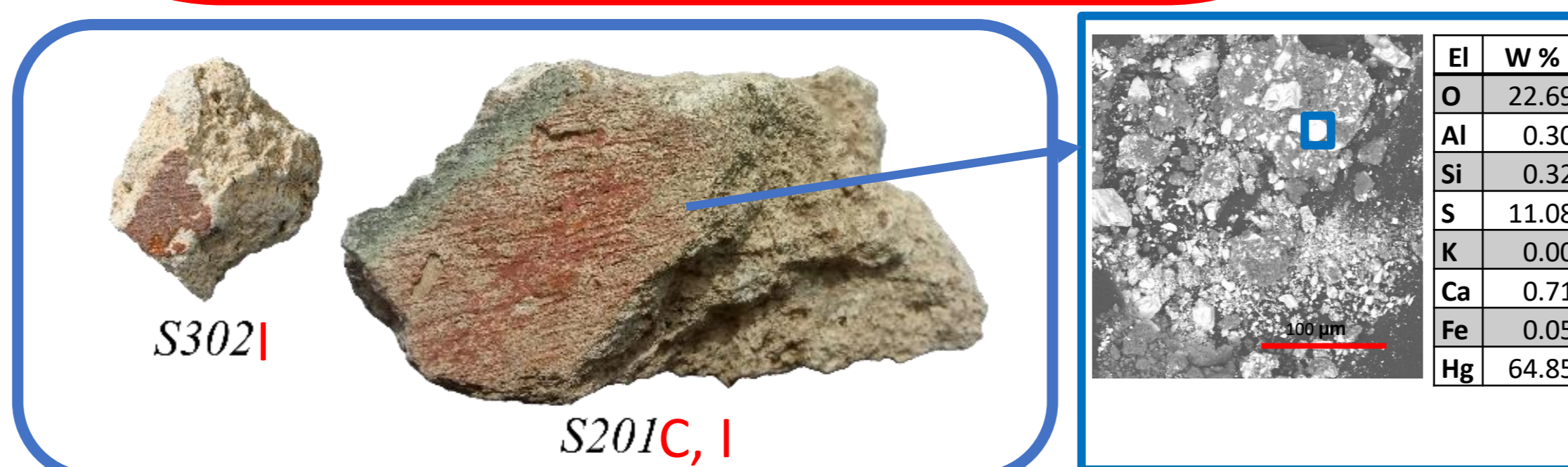
The cathedral has not survived. In 1934–1936 N.N. Voronin excavated the ruins of the cathedral made of Byzantine bricks. The latest excavations in 2014 brought to light many wall painting fragments.

### Cathedral of Transfiguration at Pereslavl-Zalessky

**Date of construction** 1152–1157  
**Date of paintings** 1150s  
The cathedral was also built by order of Prince Yuri Dolgoruky. The building is well preserved. Originally, the church at Kideksha looked like this church.[1]

### Cathedral of St Georg at Novgorod

**Date of construction** 1119-1130  
**Date of paintings** 1120-1130  
The cathedral was built by order of Prince Vsevolod Mstislavich. Our team is now actively researching this monument.



### Conclusions

Pigments such as red ochre, cinnabar and yellow ochre were employed in the church of Boris and Gleb. The wall paintings of the cathedral in Pereslavl-Zalessky consist of similar pigments, but the intonaco contains more sand. Similar red and yellow pigments were used in the Suzdal Cathedral, but its plaster contains ceramic fragments in the mixture. The main difference between northeastern Russian and Novgorod's frescoes is the use of minium in the St. George Cathedral at Novgorod, however the date of these fragments is uncertain.

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