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# ANALIZA IZVORNE POLIKROMIJE S CIBORIJA PROKONZULA GRGURA IZ ARHEOLOŠKOG MUZEJA ZADAR

Skromni ostatci izvorne polikromije na srednjovjekovnoj kamenoj skulpturi, sačuvani do današnjih dana, dragocjeni su za moguću imaginaciju originalnog izgleda. U prošlom stoljeću dosta je bojenog sloja stradalo pri „čišćenjima" kamenih eksponata od slojeva žbuke, zemlje i ostalih nečistoća. Završnom fazom bojenja, pri izradi srednjovjekovne pleterne skulpture, dodatno se naglašavao sam motiv u reljefu. Iz svega navedenoga, treba imati na umu da gledamo artefakt koji nije u svom originalnom obojenom izdanju. Iako su uistinu rijetki ostatci izvorne predromaničke polikromije na ulomcima liturgijskog namještaja na istočnoj obali Jadrana, analizama se uspjelo izdvojiti nekoliko ključnih pigmenata te rekonstruirati pretpostavljeni originalni izgled Grgurova ciborija iz Zadra. Prilikom istraživanja upotrijebljene su sljedeće metode dokumentacije analiziranih uzoraka: fotografska dokumentacija ostataka izvorne polikromije (mikrofotografije i makrofotografije), izrada kemijskih analiza (FTIR i SEM/EDS) i uvrštavanje rezultata u bazu analiziranih uzoraka te računalna rekonstrukcija pretpostavljenog izvornog izgleda.

**Ključne riječi:** ciborij prokonzula Grgura, FTIR, polikromija na kamenu, pigmenti, Arheološki muzej Zadar

# THE ANALYSIS OF THE ORIGINAL POLYCHROMY OF THE PROCONSUL GREGORY'S CIBORIUM FROM ARCHAEOLOGICAL MUSEUM ZADAR

Those few traces of the original polychromy that remain on the medieval stone sculpture to the present day are very important for picturing its possible original appearance. Over the past century, most of the paint was lost when layers of plaster, soil and other sediments were improperly removed. When medieval sculptures with the relief interlaced-ribbon pattern were made, the final layer of paint was used to underline this motif. Therefore, when observing this artifact, we should keep in mind that we cannot see it in its original painted condition anymore. Although traces of the original Pre-Romanesque polychromy are indeed rarely found on the fragments of liturgical furnishings in the Eastern Adriatic, the analyses that were carried out did yield some crucial pigments that helped us reconstruct the supposed original appearance of Gregory's ciborium from Zadar. During the research, the following methods were used to document the samples analyzed: photographing the traces of the original polychromy (micro and macro photographs), carrying out chemical analyses (FTIR and SEM/EDS) and uploading their results into a sample database, and computer reconstruction of the supposed original appearance.

**Key words:** Ciborium, Proconsul Gregory's ciborium, FTIR, stone polychromy, pigments, Archaeological Museum Zadar

## OSNOVNI PODATCI O OBJEKTU

**Naziv kulturnog dobra:** Ciborij prokonzula Grgura (sl. 1)
**Adresa/smještaj kulturnog dobra:** Arheološki muzej u Zadru; prvotno je, u razdoblju srednjeg vijeka, vjerojatno pripadao liturgijskom namještaju zadarske katedrale
**Vrijeme nastanka kulturnog dobra:** 11. stoljeće
**Umjetnik/škola (autor):** Nepoznat ?
**Materijal:** Kamen vapnenac, vjerojatno podrijetlom iz nekog kamenoloma sa zadarskog područja
**Tehnika:** Obrada kamena tradicionalnim alatima za klesanje/obradu kamena
**Dimenzije:** Dužina – 210 cm, visina – 137 cm, širina – 111 cm
**Sadašnja namjena:** Izložbeni eksponat (inv. br. 59, 60, 61, 62, 63, 64, 402), dio Srednjovjekovne zbirke zadarskog Arheološkog muzeja
**Vlasnik/korisnik:** Arheološki muzej u Zadru
**Nadležni konzervatorski odjel:** Konzervatorski odjel u Zadru
**Investitor:** Arheološki muzej u Zadru Ministarstvo kulture Republike Hrvatske
**Izvođači radova:** Umjetnička akademija u Splitu, Odsjek za konzervaciju-restauraciju, Odjel za konzervaciju arheološke baštine pod vodstvom dr. sc. Mione Miliše, dipl. konzerevator-restaurator, u suradnji s laboratorijem Umjetničke akademije u Splitu koji vodi dr. sc. Ivica Ljubenkov, pročelnik Odjela za kemiju Prirodoslovno-matematičkog fakulteta u Splitu

## BASIC INFORMATION

**Monument:** Proconsul Gregory's ciborium (Fig. 1)
**Location:** Archaeological Museum Zadar; in Middle Ages, it was probably part of the liturgical furnishings of the Zadar Cathedral
**Dated to:** 11th century
**Sculptor/School (author):** Unknown ?
**Material:** Limestone, probably quarried in the Zadar area
**Execution:** Executed with traditional stone carving/dressing tools
**Size:** Length – 210cm, height – 137cm, width – 111cm
**Current purpose:** Exhibit (Inv. No. 59, 60, 61, 62, 63, 64, 402), in the Medieval Collection of Archaeological Museum Zadar
**Owned/Used by:** Archaeological Museum Zadar
**Competent conservation department:** Conservation Department in Zadar
**Investor:** Archaeological Museum Zadar, Ministry of Culture of the Republic of Croatia
**Conservation work by:** Conservation-Restoration Department of Arts Academy in Split – Section for Conservation of Archaeological Heritage led by conservator-restorer Miona Miliša, PhD, in cooperation with the Laboratory of the Arts Academy in Split led by Ivica Ljubenkov, PhD, Head of Department of Chemistry of Faculty of Science in Split.

**Slika 1. Zatečeno stanje ciborija u ožujku 2015. god., Arheološki muzej u Zadru**
Figure 1. Ciborium as it looked in March 2015, Archaeological Museum Zadar
**foto** / photo by: **M. Miliša**

## UVOD – KRATAK OPIS RADOVA

Ciborij prokonzula Grgura imao je različite namjene tijekom vremena.[1] Prva, ujedno i izvorna namjena mu je bila dio (krovište nad glavnim oltarom) kamenog liturgijskog namještaja u zadarskoj srednjovjekovnoj katedrali.[2] Sve stranice četverostranog ciborija bile su bojene kao i većina druge srednjovjekovne sakralne skulpture. Dajući važnost ostatcima izvorne boje na kamenim ulomcima ciborija, ukrašenim pleternim motivima, koji su se do danas uspjeli sačuvati, možemo se približiti originalnom izgledu samog ciborija u vrijeme njegova nastanka. Različitim bojama naglašavali su se određeni geometrijski biljni ili zoomorfni motivi, izvedeni u pleternom reljefu.[3] U današnje vrijeme, stoljećima nakon nastanka i „života" predromaničke skulpture, često se zaboravlja da je sva pleterna kamena skulptura, i dekorativni arhitektonski dijelovi (dovratnici, nadvratnici, okviri prozora, stupovi, kapiteli), uglavnom bila bojena. Završni polikromirani sloj na predromaničkoj pleternoj skulpturi do današnjih dana sačuvao se na rijetkim artefaktima. U prethodnim vremenima polikromija bi uglavnom stradala pri „čišćenjima" predromaničkih ulomaka od slojeva žbuke, zemlje, nečistoća. Sastav kamena kao materijala mnogo je otporniji od sastava pigmenata i preparacije, od čega se i sastoji sloj polikromije. Samim time polikromirani sloj ima znatno kraći vijek trajanja.[4] Završnom fazom bojenja, pri izradi ranosrednjovjekovne pleterne skulpture, dodatno se naglašavao sam motiv izveden u pleteru.[5] Katkad su se geometrijski simboli, ili dijagonalne troprute pleterne trake, svaki zasebno isticali različitim bojama.

Pri promatranju pleternih kamenih reljefa treba uvijek imati na umu da gledamo artefakt koji nije u svom originalnom polikromiranom izdanju, pa samim time nemamo uvid u onaj motiv (ornament, geometrijski lik) koji je majstor klesar htio naglasiti, staviti u prvi plan. (Odnosno, što je glavni, a što sporedni ornament? Tu ključnu ulogu ima boja.) Unatoč uistinu malim ostatcima analizom se uspjelo izdvojiti nekoliko ključnih pigmenata te rekonstruirati originalnu polikromiju s tri stranice ciborija. Prema rezultatima analize

1 Predmet ovog istraživanja nije prvotni smještaj ovih ulomaka, već kemijski sastav ostataka izvorne polikromije na njima. No da bismo bolje razumjeli kako je propadao bojeni sloj, znanja iz arhiva itekako su korisna.

2 Danas se većina autora slaže da je pripadao kamenom liturgijskom namještaju zadarske srednjovjekovne katedrale, iako postoje i mišljenja da izvorno nije pripadao katedrali, već crkvi sv. Petra „in foro", koja se nalazila na današnjem Narodnom trgu. Više o ovim nedoumicama u I. Petricioli 1960, 17 te u P. Vežić, M. Lončar 2009, 81–82.

3 M. Miliša 2018, 45–48.

4 D. Burgess 1990, 47–52.

5 Nije samo srednjovjekovna kamena skulptura bila polikromirana. Istraživanja su još davno pokazala da isto vrijedi i za antičku skulpturu, polikromirane hramove. Vidi A. Potts 2008; G. Verri, L. Lazzarini 2014, 149–177.
Jedna od naronitanskih carskih skulptura (skulptura numerirana brojem 2, ženski kip bez glave) izrađena je od penteličkog mramora, a tragovi boje nalaze se uz unutrašnju stranu stopala lijeve noge te uzduž lijevog bedra na naborima draperije. Vidi E. Marin 2004, 126–129. Bez kemijske analize pigmenta vidljivo je da je riječ o nekakvom pigmentu iz porodice okera, vjerojatno crveni oker, kojim je bio prvotno obojan taj dio plašta, a možda i cijela haljina.

## INTRODUCTION – A SHORT DESCRIPTION OF WORK

Proconsul Gregory's ciborium had various purposes in various periods of time.[1] In the very beginning, it was part of the stone liturgical furnishings (the canopy above the main altar) in the medieval Zadar Cathedral.[2] Like in most of other medieval sacral sculptures, all sides of the four-sided ciborium were painted. Analyzing the remaining traces of the original color on the ciborium's stone fragments decorated with an interlaced-ribbon motif can help us reconstruct the approximate original appearance of the ciborium. Various colors were used to underline particular geometrical, plant or zoomorphic motifs executed in the interlaced-ribbon relief.[3] Today, centuries after the birth of Pre-Romanesque sculpture, it is often forgotten that most of the stone sculptures with interlaced-ribbon patterns and decorative architectural elements (door jambs, door lintels, window frames, columns, capitals) used to be painted. The final polychrome layer on Pre-Romanesque interlaced-ribbon sculptures has been preserved on but a few artifacts. The polychromy on the Pre-Romanesque fragments usually "fell victim" to improper removal of the layers of plaster, soil and other sediments. As the composition of stone as a material is much more resistant than the composition of the pigment and preparations of which the layer of polychromy consists, this layer has a shorter life span.[4] The final layer of paint additionally underlined the interlaced-ribbon motif on Early Middle Age sculptures.[5] Each geometrical pattern or diagonal triple-braided ribbon would sometimes be painted in a different color.

When observing stone reliefs with the interlaced-ribbon motif, we should always keep in mind that their original polychrome layers are now gone and that we cannot know which motif (ornament, geometrical pattern) the stone-mason intended to underline (or what was the main motif and what was a less important ornament – and this is where color is of crucial importance). Although the traces were scarce, the analysis managed to single out several crucial pigments and reconstruct the original polychromy on three sides of the ciborium. Based on the results of the analysis, the original

1 This paper is not focused on the original location of these fragments, but on the chemical composition of the traces of the original polychromy found on them. However, an insight into their past can certainly help us better understand the process of degradation of the layers of paint on them.

2 Most of the author today agree that it belonged to the stone liturgical furnishings of the medieval Zadar Cathedral. However, some authors believe it actually belonged to St. Peter's Church "in foro", that once stood in the present-day Narodni Square. More on these dilemmas in I. Petricioli 1960, 17 and in P. Vežić, M. Lončar 2009, 81–82.

3 M. Miliša 2018, 45–48.

4 D. Burgess 1990, 47–52.

5 Not only medieval stone sculptures were polychromed. Research has long shown that the same applies to sculptures from the Antiquity, polychromed temples. See A. Potts 2008; G. Verri, L. Lazzarini 2014, 149–177.
On one of the Imperial-period sculptures from Narona (the sculpture No. 2 – a female headless statue), made from Pentelic marble, traces of color can be seen on the inside of the left foot and on the folds of the drapery along the left thigh. See E. Marin 2004, 126–129. Even without a chemical analysis, we can tell it is an ocher pigment, probably red ocher, that once covered this part of the cloak, if not the entire gown.

napravljena je računalna rekonstrukcija originalnog sloja polikromije na kamenu. Rekonstrukcijom boje na reljefima stranica ciborija, dobivši njegov vjerojatni izvorni izgled, uspijevamo se približiti minulom vremenu nastanka i života predromaničke skulpture.

Suradnja među radionicama morala je biti intenzivna i preklapati se na mnogim područjima. U velikoj su mjeri povezani graditelj (projektant) te klesar koji izrađuje reljefne ukrase,[6] pogotovo ako promatramo samo segment prozorskih otvora, nedjeljivih od arhitekture i njihovu simultanu gradnju i dekoraciju zajedno s nastajanjem samog arhitektonskog objekta. Nakon klesanja kamenih dijelova predromaničkog liturgijskog namještaja slijedila je montaža unutar samog sakralnog objekta. Tek je tada, nakon ugradnje, nastupila faza bojenja kamenih reljefa *in situ*, jer bi se u protivnom polikromija oštetila prilikom transporta i ugradnje kamenih elemenata u arhitekturu crkve. Možda i paralelno s izradom fresaka na zidovima.[7] Ispreplitanje i povezanost uloge naručitelja, donatora, projektanta, svećenstva i majstora klesara ne smije se zanemariti. Klesari, graditelji, kovači, slikari i drugi majstori cirkulirali su od bizantskih gradskih centara do hrvatskog zaleđa, a tako i pigmenti.

Ispitivanje originalne polikromije na ciboriju prokonzula Grgura provedeno je s pomoću nekoliko tehnika. Ondje gdje bi se ustanovila prisutnost izvorne polikromije, napravljene su fotografije digitalnim mikroskopom[8] pod raznim uvećanjima (od 20 do 200X). Na istim pozicijama uzeti su uzorci za daljnje kemijske analize tehnike FT-IR[9], SEM/EDS[10] i izrade mikropresjeka (sl. 20–21; prilozi 1–7).

## KRATKI POVIJESNI PREGLED I OPIS ZATEČENOG STANJA CIBORIJA

Ciborij datira iz 11. st. i možda je izvorno bio sastavni dio prostornog koncepta katedrale. Tijekom prošlih stoljeća, kada su izgubili svoju prvotnu namjenu, dijelovi košare ciborija ugrađeni su u zvonik zadarske katedrale.[11] Krajem 19. stoljeća ti isti ulomci razmontirani su i smješteni u zadarski arheološki muzej.[12] Prva rekonstrukcija fragmenata stranica

polychromy layer on the stone was reconstructed by a computer. Having reconstructed the color of the reliefs on three sides of the ciborium, we can get the idea what did ciborium originally looked like. It can help us picture the days and life when this Pre-Romanesque sculpture was made.

The cooperation between the workshops must have been intensive and overlapping in many segments. Builders (architects) were closely connected with the stone-masons who made the relief ornaments,[6] particularly when it comes to window frames – inseparable from the rest of the structure and made and decorated simultaneously with it. After the stone parts of the liturgical furnishings had been carved, they would be installed within the sacral building. Only then, after the installation, the stone reliefs would be painted *in situ* – the polychromy could otherwise sustain damage during transportation and installation in the church. It may have also been done simultaneously with wall frescoes.[7] This entwined roles and connections of clients, donors, architects, clergy and stone-masons should not be ignored. Stone-masons, builders, blacksmiths, painters and other craftsmen circulated between Byzantine cities and Croatian hinterland, and so did the pigments.

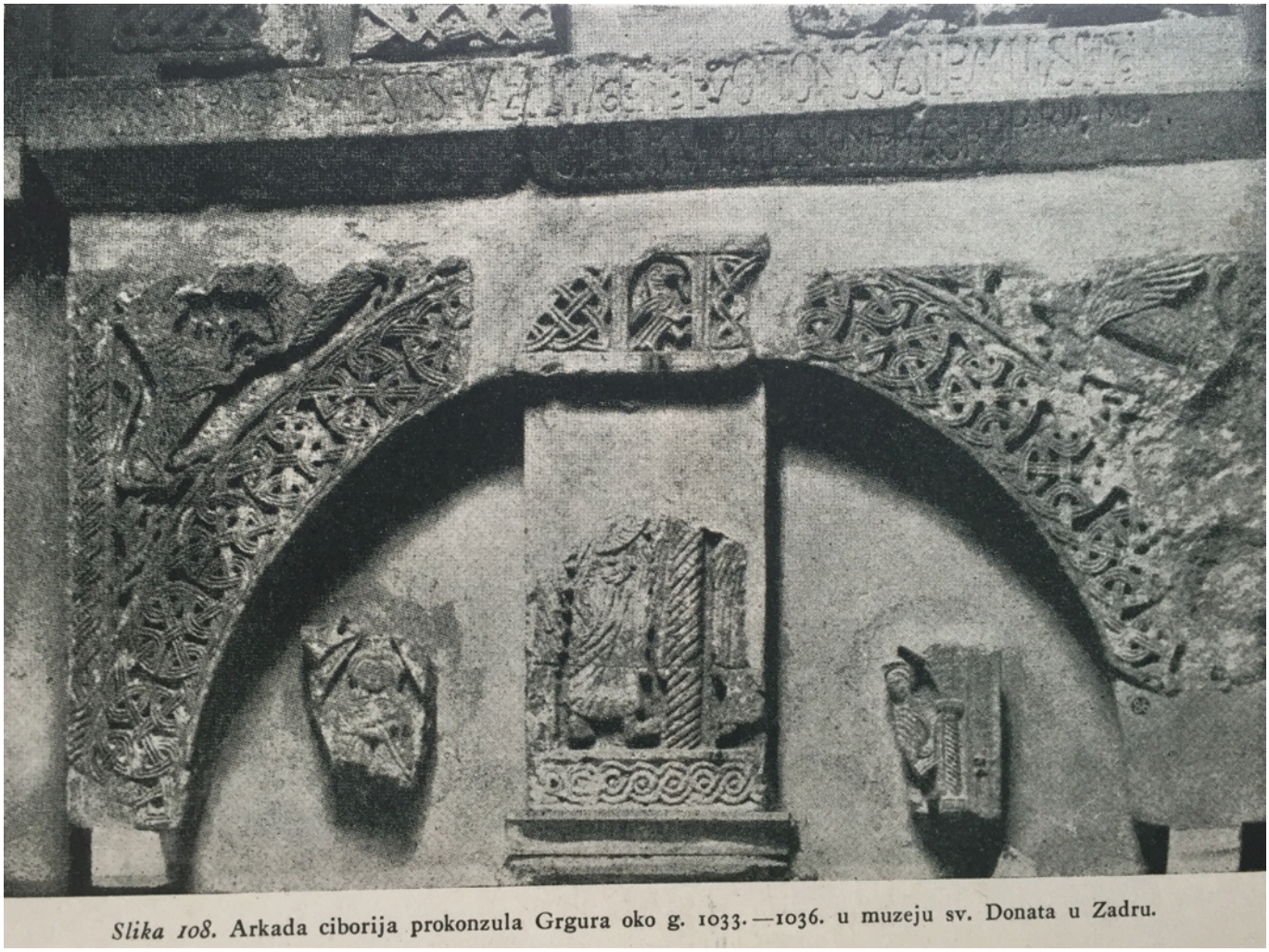
Several techniques were used for analyzing the original polychromy on Proconsul Gregory's ciborium. Where the presence of the original polychromy was established, digital microscope photographs were taken[8] using various magnifications (from 20 to 200X). Samples for additional chemical analyses (FT-IR[9], SEM/EDS[10] and micro cross-section) (Figs. 20–21; Appendices 1–7).

## A SHORT HISTORY AND DESCRIPTION OF THE CIBORIUM

The ciborium was dated to the 11th century. Originally, it could have been part of the cathedral's interior design. Over the centuries, after losing their original purpose, all fragments of the ciborium were built in the Zadar Cathedral's bell-tower.[11] In the late 19th century, these fragments were disassembled and stored in the Archaeological museum in Zadar.[12] The ciborium's fragmented sides

6 Ž. Rapanić 2008, 543–554.
7 Moguće je da je isti majstor koji je oslikavao zidove, bio i autor polikromiranog sloja na kamenim reljefima predromanike. Detaljnije o tome u M. Miliša 2014, 174–203.
8 Pri rekognosciranju polikromije i fotografiranju *in situ* uzoraka korišten je mikroskop marke Dino – Lite, digital microscope.
9 Osnovna primjena IR-a identifikacija je nepoznatih supstanci s pomoću infracrvenog zračenja. FTIR – Fourier-transform infra red (spectrometry). B. H. Stuart 2004, 18.
10 SEM/EDS - Scanning Electron Microscopy with Energy Dispersive Spectroscopy. A. Tonjec 2012, 46.
11 Zvonik nije izgrađen kad i katedrala. Počeo ga je graditi zadarski nadbiskup Valaresso oko 1480. god. Dograđen je nacrtima T. Jacksona 1892. godine. Više u V. Bianchi 1877, 123–124.
12 Prilikom izgradnje zvonika neki dijelovi su bili „utopljeni" u velike količine građevnog morta, odnosno žbuke. Već u toj fazi pretpostavljamo da je stradala izvorna polkromija u velikom postotku. Tijekom premještanja ulomaka u Sv. Donat, tadašnji prostor Arheološkog muzeja, zasigurno su ulomci čišćeni od tragova žbuke i ostalih nečistoća na površni kamenih reljefa, što je opet rezultiralo gubitkom određene količine izvorne polikromije.

6 Ž. Rapanić 2008, 543–554.
7 It is possible that the same artist who painted the walls also painted the polychromed layer on the Pre-Romanesque stone reliefs. More on this in M. Miliša 2014, 174–203.
8 A Dino – Lite digital microscope was used for surveying of the polychromy and in situ photographing of the samples.
9 IR is primarily used for identification of unknown substances by means of infrared radiation. FTIR – Fourier-transform infrared (spectrometry). B. H. Stuart 2004, 18.
10 SEM/EDS - Scanning Electron Microscopy with Energy Dispersive Spectroscopy. A. Tonjec 2012, 46.
11 The bell-tower was not built at the same time when the Cathedral was built. Bishop Valaresso of Zadar started building it around 1480. It was completed on the basis of T. Jackson's drawings in 1982. More in V. Bianchi 1877, 123–124.
12 When the bell-tower was built, some parts were amply coated with mortar or plaster. It is believed that it was in this phase that most of the original polychromy was gone. When the fragments were transported to the then premises of the Archaeological Museum in St. Donatus' Church, traces of plaster and other sediments were certainly removed from the stone reliefs, which additionally damaged the original polychromy.




**Slika 2. Prednja stranica ciborija u vrijeme dok je bila izložena u Sv. Donatu**
Figure 2. Front side of ciborium while displayed in St. Donatus' Church

**prema** / according to: **Lj. Karaman 1930, sl. 108**

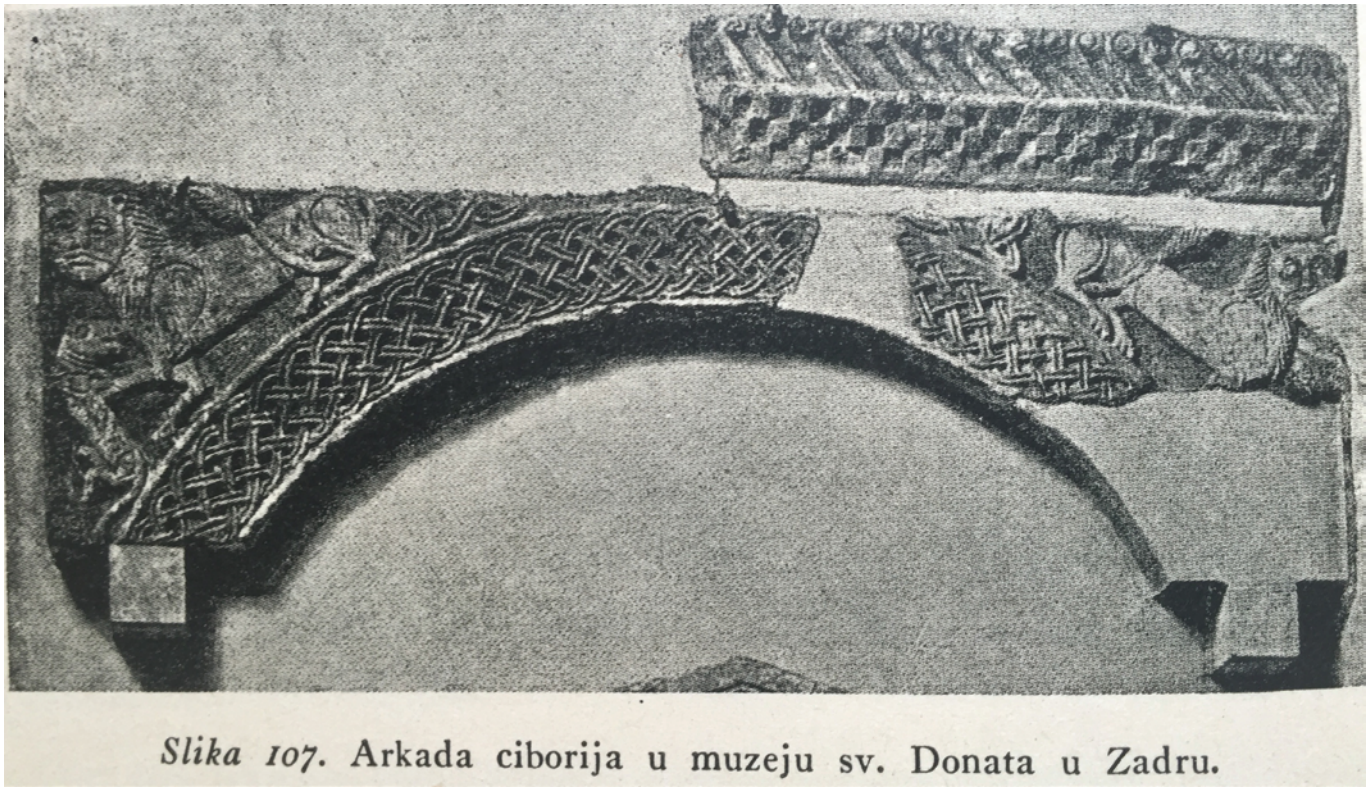
ciborija, odnosno košare u cijelosti, bila je 1954. godine. U literaturi iz druge polovine 20. stoljeća nekoliko je autora opisivalo ostatke originalne polikromije na reljefima svih četiriju stranica ciborija.[13] Nažalost, većina tih opisivanih slojeva boje danas više nije vidljiva (sl. 1). Ono što nam vrijeme u kojem živimo i djelujemo može dati jest čitav spektar analiza pigmenata, od mikroskopskih do kemijskih, te interpretacije analiziranih uzoraka u interdisciplinarnoj suradnji različitih profesija. Skulpturu na ciboriju prokonzula Grgura Petricioli je pripisao splitsko-zadarskoj grupi srednjovjekovne skulpture. Više o ikonografskim karakteristikama i skulptorskoj obradi pisali su autori I. Petricioli,[14] P. Vežić, N. Jakšić itd. U ovom izvješću riječ će biti izričito o slojevima boje na skulpturi, ne o samoj skulpturi.

Prilikom dograđivanja zvonika zadarske katedrale 1891. godine pronađeno je 8 kamenih ulomaka četverostrane

were reconstructed for the first time in 1954. In the second half of the 20th century, several authors described the traces of the original polychromy found on the reliefs of all four sides of the ciborium.[13] Unfortunately, most of these described layers of paint are not visible anymore (Fig. 1). What we can do today is carry out a wide range of analyses of the pigments, from microscopic to chemical ones, and interpret their results through interdisciplinary cooperation of various professions. Petricioli attributed the sculptures on Proconsul Gregory's ciborium to the Split-Zadar medieval sculpture group. More on the iconographic characteristics and execution of the sculptures can be found in I. Petricioli,[14] P. Vežić, N. Jakšić etc. This paper confines itself to the paint layers on the sculpture only, not on the sculpture as such.

13 Lj. Karaman 1930, 70; P. Vežić, M. Lončar 2009, 83.
14 I. Petricioli 1960, 7–8, 15–18.

13 Lj. Karaman 1930, 70; P. Vežić, M. Lončar 2009, 83.
14 I. Petricioli 1960, 7–8, 15–18.




**Slika 3. Arkada ciborija s prikazom lavova u vrijeme dok je Arheološki muzej bio u Sv. Donatu**
Figure 3. Ciborium arcade depicting lions, while Archaeological Museum was in St. Donatus' Church **prema** / according to: **Lj. Karaman 1930, sl. 107**

košare ciborija.[15] Svi su bili dekorirani pleternim motivima. Preneseni su u Arheološki muzej koji je tada bio smješten u crkvi sv. Donata. Postoje stare fotografije na kojima se mogu vidjeti ulomci arkada ciborija izloženi u Sv. Donatu.[16] Kao što je pretpostavljeno u bilješci 5, kronološki, od prestanka njegove prvotne funkcije – ciborija, kameni ulomci prolazili su kroz različite lokacije i radove prilikom montaže i demontaže. S polikromijom se za to vrijeme zbivalo sljedeće: vjerojatno je degradirana do faze da nije bila čiljiva u izvornom stanju, što je rezultiralo „čišćenjem" svih reljefa dva puta prilikom postava 1891. pa prilikom montaže svih dijelova u cjelinu 1954. godine (sl. 2, 3). Prednjoj strani ciborija sigurno je pripadao i vijenac s natpisom, iako i tu postoje nedoumice.[17] Zavjetni je natpis u dva reda, slova su zbijena, ima mnogo ligatura i nekoliko sigla.[18] Riječi uklesane u kamenu svjedoče o Grgurovoj donaciji, a ujedno i da su ti ondašnji moćni i imućni ljudi dali napraviti ciborij i crkvu. Iako su to sve konvencije kojih ima i u drugim krajevima Europe i šire, one

When the bell-tower was added to the Cathedral in 1891, eight stone fragments of the ciborium were found.[15] They were all decorated with interlaced-ribbon motifs. They were moved to the Archaeological Museum which was then housed in St. Donatus' Church. Old photographs show the fragments of ciborium arcades displayed in the church.[16] In accordance with the assumption made in Note 5, the stone fragments were assembled and disassembled in various locations and in various periods of time after they had stopped serving their original purpose – as a ciborium. In the meantime, the polychromy was probably degraded to such an extent that it was not visible in its original condition, so all the reliefs were "cleaned" two times prior to being displayed in 1891 and then when they were assembled together in 1954 (Figs. 2, 3). The inscribed cornice must have belonged to the ciborium's front side, although it is not certain.[17] The votive inscription extends in two lines, the letters are dense and there are many ligatures and a few sigla.[18] The words

15 Po dva ulomka pripadala su svakoj stranici ciborija, dva vijencu s natpisom i dva vijencu s dekoracijom. Stranice ciborija dobile su inventarne brojeve 59, 60 i 61 (po dva fragmenta), broj 63 dobio je vijenac s natpisom, a 64 vijenac s dekoracijom. I. Petricioli 1960, 15–16.
16 Slike dviju arkada ciborija mogu se vidjeti na fotografijama u Lj. Karaman 1930, sl. 107 i 108.
17 P. Vežić, M. Lončar 2009, 81–83.
18 I. Petricioli 1960, 16.

15 Two fragments belonged to each side of the ciborium – two to the inscribed cornice and two to the decorated cornice. The sides of the ciborium were assigned inventory numbers 59, 60 and 61 (two fragments each), No. 63 – the inscribed cornice, and No. 64 – the decorated cornice. I. Petricioli 1960, 15–16.
16 The photos of the ciborium's two arcades can be seen in Lj. Karaman 1930, figs. 107 and 108.
17 P. Vežić, M. Lončar 2009, 81–83.
18 I. Petricioli 1960, 16.

nam upotpunjuju sliku onog vremena, dalmatinskih gradova i zaleđa.[19] Najdetaljnije o samom natpisu na ciboriju piše M. Lončar 2009. godine.[20]

LJ. Karaman je već 1930. godine primijetio i napisao: „Pleterni ukrasi starohrvatskog crkvenog pokućstva u svom su dekorativnom dojmu pokadšto pojačani bojadisanjem. U zadarskom muzeju sv. Donata nalaze se neke skulpture s jasnim tragovima zlatne, modre i crvene boje."[21] I. Petricioli je to mnogo detaljnije opisao 1960.: „Ovaj je spomenik rijedak primjerak ranosrednjovjekovne skulpture na kojoj su se sačuvali tragovi polikromije. Ima tragova plave crvene i žute boje (koju su neki autori smatrali pozlatom). Polihromija se dade rekonstruirati. Pletenice su bile žute, okviri pletenica i unutarnje plohe lukova crvene, a pozadina kao i kod pletenica, tako i kod figura plava. Šahovski ornament bio je tako bojadisan da su po tri udubljena kvadrata u kosim redovima bili bojadisani naizmjenice crveno i plavo. Na životinjskim figurama našao sam na tragove samo žute boje, ali ne isključujem mogućnost da je bilo i drugih boja, naročito pak na paunovima."[22] Oba opisa donosimo u cijelosti, upravo zato što se na ulomcima ciborija danas ne vidi većina onoga što su opisali autori u prošlom stoljeću. Ostatci polikromije na ulomcima ciborija spominju se još u *Vodiču*.[23] Tamo se također pretpostavlja da je ciborij bio nad glavnim oltarom katedrale. Među ostalim ostatcima spominju se i tragovi smeđe i zlatne boje, za što je I. Petricioli pretpostavio da je zapravo žuta boja.

„Bit će zadaća naših zbirki[24] i naše znanosti, da od tih fragmenata rekonstruiraju sliku propalog starohrvatskog crkvenog namještaja. To će trebati učiniti ne samo grafičnom rekonstrukcijom na papiru prigodom znanstvenih publikacija, već, gdje to bude moguće, i materijalnom uspostavom samih spomenika od ostataka, što su sačuvani u našim zbirkama. Malo što naime pomaže i stručnjaku i laiku do zorne predodžbe starohrvatske crkve u njezinu izvornom dojmu i karakteru kao rekonstrukcija njezina crkvenog pokućstva."[25]

## METODOLOŠKI POSTUPCI, OPIS RADOVA PO FAZAMA:

### 1. Izrada grafičke i fotodokumentacije zatečenog stanja

Mikroskopska ispitivanja i uzimanje uzoraka rađeni su 2015. godine. Svaku stranicu ciborija bilo je potrebno izmjeriti te fotografirati prvo u totalu, a onda snimiti što

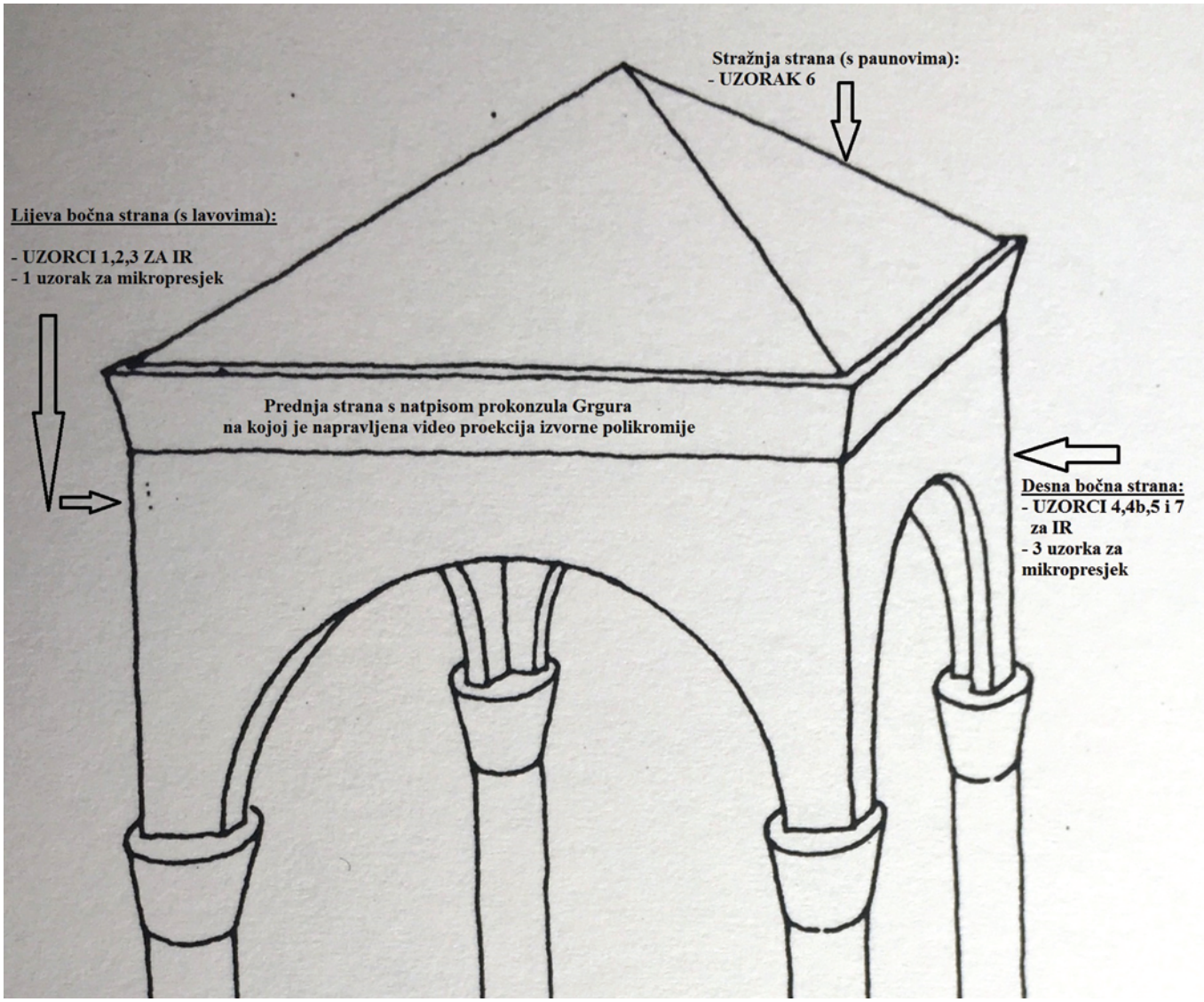
carved in stone evidence Proconsul Gregory's donation and the fact that the powerful and wealthy people of the time commissioned the construction of the ciborium and church. While these are the conventions found also in other parts of Europe and elsewhere, they nevertheless add to our insight into the life in the Dalmatian cities on the coast and its hinterland in those days.[19] The inscription on the ciborium is the most minutely analyzed by M. Lončar 2009.[20]

Back in 1930, Lj. Karaman noted and wrote: "The impression of the interlaced-ribbon decorations on the Old Croatian church furnishings is sometimes emphasized with paint. In the St. Donatus' Museum in Zadar, some sculptures with clear traces of gold, blue and red paint can be seen."[21] I. Petricioli described it more minutely in 1960: "This monument is a rare source of the Early Middle Age sculpture on which traces of polychromy have been preserved. There are traces of blue, red and yellow color (believed by some to be gilding). It is possible to reconstruct this polychromy. The braids were yellow, their frames and the inner surfaces of arches were red and the rear surfaces of both braids and figures were blue. The checkered ornament was painted in such way that the three recessed squares in each diagonal line were painted alternately red and blue. I only found traces of yellow color on the animal figures, but I cannot rule out the possibility that there were other colors there, particularly on the peacocks."[22] Both descriptions are quoted here in their entirety because most of the things described by authors in the past century cannot be seen on the ciborium fragments anymore. The traces of polychromy on the ciborium fragments are also mentioned in *Vodič*.[23] It is also believed there that the ciborium once stood above the main altar of the cathedral. Traces of brown and gold color are also mentioned in that source (the color believed by I. Petricioli to be yellow).

"It will be the duty of our collections[24] and our science to reconstruct the original appearance of the dilapidated Old Croatian church furnishings. This will have to be done not only by making their graphic reconstructions in scientific journals but also – where possible – by reassembling the monuments from their remaining fragments kept in our collections. Nothing can help both experts and laymen get a better insight into the original appearance and character of the Old Croatian churches as reconstruction of their furnishings."[25]

19 Ž. Rapanić 1987, 148.
20 Autor na jednom mjestu objavljuje sve tri varijante prijevoda. P. Vežić, M. Lončar 2009, 204–205.
21 Lj. Karaman 1930, 73.
22 I. Petricioli 1960, 17.
23 *Führer durch das K. K. Staatsmuseum in S. Donato in Zara* 1912, br. 85–89, 64–65.
24 Onda je LJ. Karaman mislio na zbirke u Splitu (Arheološki muzej i zbirka društva „Bihać"), u Kninu (Muzej starinarskog društva), u Zagrebu (arheološki odio Narodnog muzeja), u Trogiru (zbirka društva „Radovan"), u Dubrovniku (općinska zbirka) i u Zadru (Muzej sv. Donata). Lj. Karaman, 1930.
25 Lj. Karaman 1930, 74.

19 Ž. Rapanić 1987, 148.
20 The author published all three versions of the translation in one place. P. Vežić, M. Lončar, 2009, 204–205.
21 Lj. Karaman 1930, 73.
22 I. Petricioli 1960, 17.
23 *Führer durch das K. K. Staatsmuseum in S. Donato in Zara* 1912, no. 85–89, 64–65.
24 Karaman refers to the collections in Split (the one of the Archaeological Museum and the one of Bihać Society), Knin (the Antiquarian Society Museum), Zagreb (Archaeological Section of the People's Museum), Trogiru (the collection of Radovan Society), Dubrovnik (the municipal collection) and Zadar (St. Donatus' Museum). Lj. Karaman 1930.
25 Lj. Karaman 1930, 74.




**Slika 4. Označene pozicije na grafičkoj skici ciborija na kojima su uzeti svi uzorci na kojima su rađene analize**
Figure 4. Sketch of ciborium showing spots from where all analyzed samples were taken
**crtež** / drawing by: **M. Miliša**

više fotografija na kojima su vidljivi izvorni ostatci boje. Mjesta na kojima su uzeti svi uzorci na kojima su rađene analize, označena su na grafičkoj skici ciborija (sl. 4). Reljefe je bilo potrebno snimiti zasebno, pod različitim osvjetljenjem, kako bi izvorna polikromija što više bila vidljiva. U konačnici su se *in situ* skicirali reljefi, svaka stranica ciborija zasebno, na kojima su se odmah numerirale i označavale detaljne pozicije s kojih su uzeti

## METHODOLOGICAL PROCEDURES AND DESCRIPTION OF WORK BY PHASES:

### 1. Charts and photographs of the monument's fragments

Microscopic analyses and sampling were carried out in 2015. Each side of the ciborium had to be measured and photographed in its entirety and then as many photographs of the spots with traces of the original color had to be taken. The spots from which the analyzed samples were taken are designated on the sketch of the ciborium (Fig. 4). The reliefs had to be photographed separately, under different lights, so that the original polychromy would be as visible as possible. Finally, the reliefs were sketched *in situ* – each side of the ciborium separately – and spots on them from which samples had been taken for further analyses were immediately numbered and

**Slike 5a i 5b. Označavanje pozicija i dokumentiranje postupka uzorkovanja**
Figures 5a and 5b. Designating spots and documenting sampling procedure
**foto** / photo by: **M. Miliša**

uzorci za daljnje analize (sl. 5a, 5b).[26] Nakon analize, pri interpretaciji uzoraka vrlo je važna komunikacija osobe koja je provodila uzrokovanje s kolegom koji provodi analize u laboratoriju.

**2. Snimanje digitalnim mikroskopom i uzimanje uzoraka sačuvane izvorne polikromije na stranicama ciborija**

Poteškoće pri uzimanju uzoraka specifične su kod muzejskih eksponata. Uzorak je ponekad vidljiv okom u nekom konkavnom području reljefa gdje je teško upravljati skalpelom (sl. 6a, 6b). Često se dogodi da se u spektrima uzoraka pronađe i spektar raznih nečistoća ili $CaCO_3$. Na crtežima ciborija, prvo skiciranim na terenu, a kasnije u mjerilu, označavaju se točne pozicije na kojima su uzete prvo snimke digitalnim mikroskopom, a zatim uzorci polikromije za laboratorijske analize.

U ožujku 2015. godine uzeti su uzorci sa tri stranice ciborija prokonzula Grgura, sveukupno sedam uzoraka originalnog pigmenta. Svi su uzorci snimljeni digitalnim mikroskopom pod povećanjem od 50 do 200 x *in situ* na površini kamena prije uzorkovanja (sl. 7, 10a, 10b, 13, 15, 17–19). Tragovi okera snimljeni su digitalnim mikroskopom na svim stranicama, ali zbog uistinu neznatnih ostataka nisu se mogli uzorkovati. Neki pigmenti koji su se ponavljali na svim stranicama (crveni, plavi, crni), selektirani su tako da je uzet uzorak koji se činio najpodobnijim za FT-IR analizu

designated (Figs. 5a, 5b).[26] After the analysis, it is very important that the person who carried out the sampling establishes good communication with the colleague carrying out the lab analyses.

**2. Digital microscope photographs and sampling of traces of the original polychromy on the ciborium's sides**

The sampling of museum exhibits is sometimes connected with specific problems. A sample can sometimes be seen with the naked eye in some concave area on a relief which is hard to reach with a scalpel (Figs. 6a, 6b). It often happens that a spectrum of various sediments or $CaCO_3$ is found in the spectrum of samples. The spots where digital microscope photographs were taken and where the polychromy was sampled for the lab analyses are designated on the sketches of the ciborium, first made *in situ* and subsequently made to scale.

26 Čitav se projekt realizirao u sklopu edukacije studenata 4. god. konzervacije-restauracije na Umjetničkoj akademiji Sveučilišta u Splitu. Cilj je i obučiti nove generacije konzervatora-restauratora kako bi u budućnosti što više ostataka izvornih slojeva prošlosti bilo adekvatno sačuvano i interpretirano. Studentice (F. Dragičević, J. Marić i I. Vukadin) radile su dio dokumentacije na terenu pri uzimanju uzoraka te izradile neke od crteža.

26 The whole project was carried out as part of the training for the students of the 4th year of the conservation-restoration study program at the Arts Academy of the University of Split. The goal was to train new generations of conservators-restorers in order to ensure that as many remains of the original layers of the past be adequately preserved and interpreted. The students (F. Dragičević, J. Marić and I. Vukadin) helped document some of the samplings *in situ* and they also made some drawings.

**Slike 6a i 6b. Uzimanje uzoraka**
Figures 6a and 6b. Sampling
**foto** / photo by: **V. Kundić**

i mikropresjek (sl. 8, 9, 11, 14a, 14b). Mikropresjeci uzoraka u polikarbonatnoj smoli važni su zbog svoje trajnosti za buduće generacije kada će nam kemijske analize i tehnologija moći dati i dodatne perspektive i odgovore (sl. 12, 14c, 16).

Povodom Europske noći muzeja i Međunarodnog dana muzeja 16. i 18. svibnja 2015. godine Arheološki muzej u Zadru priključio se akciji obilježavanja s temom „Održivost boje".[27] U sklopu javnih predavanja i radionica predstavljeni su i rezultati ovih istraživanja (sl. 33, 34). V. Kundić autor je multimedijalne prezentacije koja se tada projicirala na prednju stranu ciborija. Digitalnom rekonstrukcijom boje na samom izvorniku pokušao se posjetiteljima dočarati njegov prvotni izgled.[28]

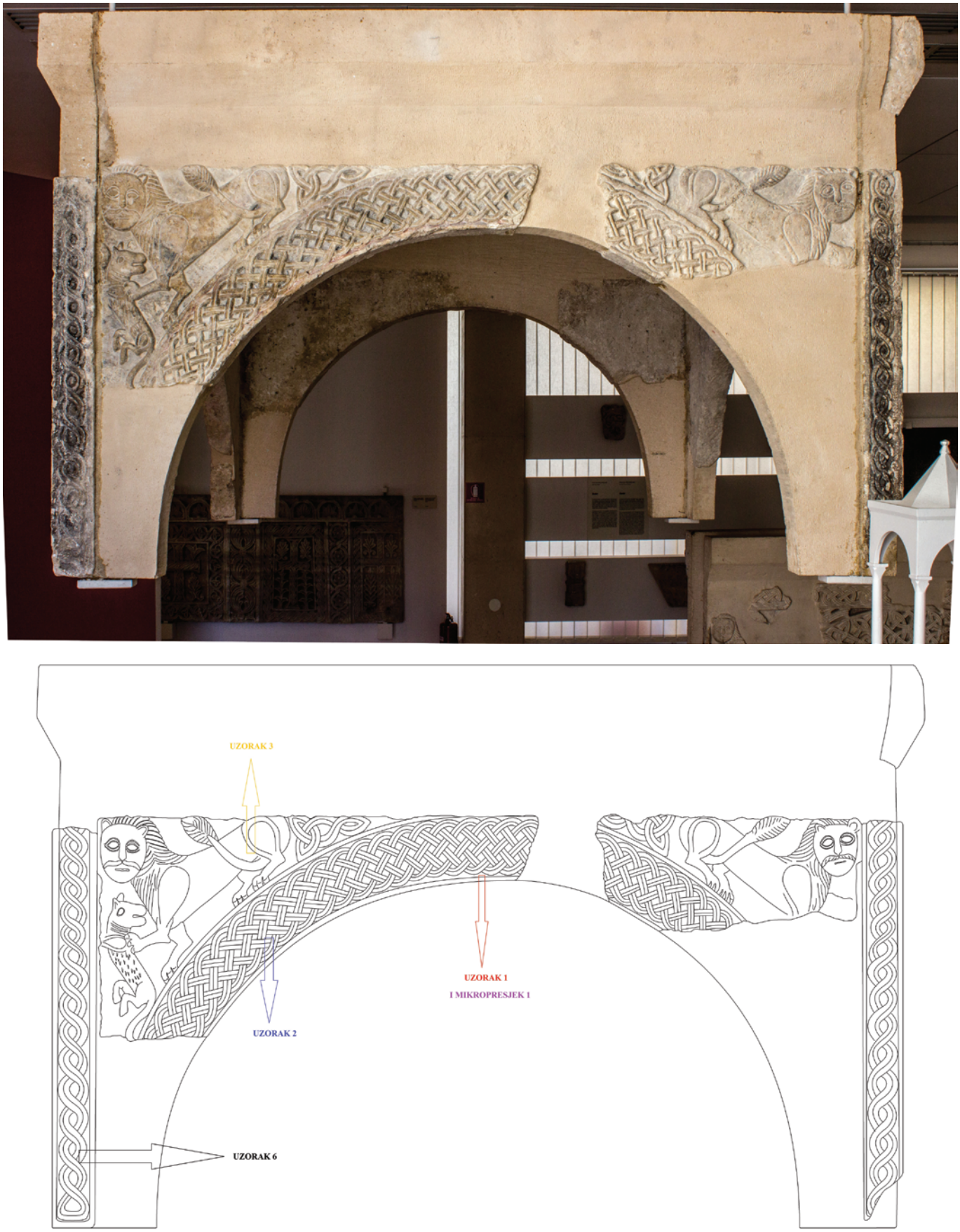
**Slika 7. Detalj na kojem je uočen crveni pigment te njegova makrofotografija nakon uklanjanja površinske nečistoće kojom je bio pokriven sloj originalne boje**
Figure 7. Detail with red pigment and its macro photograph after removal of surface sediments that covered original layer of paint
**foto** / photo by: **M. Miliša**

In March 2015, samples were taken from three sides of Proconsul Gregory's ciborium – a total of seven samples of the original pigment. All the samples were photographed with a digital microscope using 50x to 200x magnification i*n situ* on the stone surface before sampling (Figs. 7, 10a, 10b, 13, 15, 17–19). The digital microscope photos of the traces of ocher were taken on all sides but – as they were indeed scanty – they could not be sampled. Some of the pigments found on all sides (the red, blue and black ones) were selected in such way that the sample seemingly the most suitable for an FT-IR analysis and micro cross-section would be taken (Figs. 8, 9, 11, 14a, 14b). The micro cross-sections of samples in a polycarbonate resin are important because of their durability: some time in future, when chemical analyses and technology develop further, future generations will be able to obtain more answers and perspectives (Figs. 12, 14c, 16).

In 2015, Archaeological Museum Zadar joined the European Night of Museums and International Museum Day on 16 May and 18 May, respectively, by organizing the exhibition Durability of Color.[27] The results of this research were presented as part of public lectures and workshops (Figs. 33, 34). V. Kundić made a multimedia presentation projected on the ciborium's upper part at the occasion. By digitally reconstructing the color on the original itself, he tried to make the visitors picture the original appearance of the ciborium.[28]

27 Projekt je vodila J. Vekić Bašić, voditeljica Pedagoško-andragoškog odjela Arheološkog muzeja u Zadru.
28 Video je nastao komparirajući rezultate kemijskih analiza i mikrosnimke uzoraka boje na stranicama ciborija. Cilj je bio multimedijalnom prezentacijom – restauracijom prosječnog promatrača približiti prvotnom stanju i obliku ciborija. Ne zadirući u sam predmet, rekonstruirala se boja koja je s vremenom propala.

27 The project was led by J. Vekić Bašić, the heads of the Department of Pedagogy and Andragogy of Archaeological Museum Zadar.
28 The video was made by comparing the chemical analysis results and the micro photographs of the color samples on the sides of the ciborium. The goal of the multimedia presentation (restoration) was to acquaint the average viewer with the original condition and shape of the ciborium. Without actually touching the artifact itself, the degraded color was thus reconstructed.




**Slika 8. Lijeva bočna arkada ciborija, originalni ulomci – zatečeno stanje i pozicije uzorkovanja za IR (U1–3 i U6) i mikropresjek 1.**
Figure 8. Ciborium's left lateral arcade, original fragments – as found; sampling spots for IR (U1–3 and U6) and micro cross-section 1.
**foto i crtež** / photo and drawing by: **M. Miliša**

**Slika 9. Uzorak 1. Crveni pigment, prema laboratorijskim analizama ispostavilo se da je venecijansko crvena (željezo oksid)**
Figure 9. Sample 1. Red pigment; lab analyses identified it as Venetian red (iron oxide)
**foto** / photo by: **M. Miliša**

**3. Analize, mikropresjeci i interpretacija rezultata analiza ispitivanja originalne polikromije**

Na ispitivanje su doneseni uzorci polikromije na kamenu podijeljeni u dvije skupine (sl. 4):

A. Uzorci za mikropresjek
1. Crveno područje pletera
2. Pozadina pletera
3. Plave kuke
4. Pleterni luk – crveni pigment

B. Uzorci za FT-IR
1. Crveni pigment i žbuka
2. Sivi pigment i žbuka
3. Podloga – siva
4. Crveni pigment – donja strana pletera

4B. Luk donja strana – crveni pigment

5. Pozadina pletera – sivo crna
6. S lijevog bočnog vertikalnog pletera – siva
7. Pozadina – crna

Važno je napomenuti da su uzorci A-1 i B-1 isti uzorak kao i A4, B4 i B-4B, samo su označeni različito jer se na njima

**3. Analyses, micro cross-sections and interpretation of the results of the analyses of the original polychromy**

Samples of the polychromy on stone were brought to the analysis. They were divided in two groups (Fig. 4):

A. Samples for micro cross-section
1. Red area of interlaced ribbon
2. Rear side of interlaced ribbon
3. Blue hooks
4. Interlaced-ribbon arch – red pigment

B. Samples for FT-IR
1. Red pigment and plaster
2. Gray pigment and plaster
3. Base - gray
4. Red pigment – lower side of interlaced ribbon

4B. Lower side of arch – red pigment

5. Rear side of interlaced ribbon – gray and black
6. From vertical interlaced ribbon on left side – gray
7. Rear side – black

It is important to note that the samples A-1 and B-1 are the same as the samples A4, B4 and B-4B; they are designated differently because both micro cross-sections and IR

radio i mikropresjek i IR ispitivanje.[29] Svi su ostali uzorci različiti. Ispitivanja su provedena u Laboratoriju za konzervatorska istraživanja Odsjeka za konzervaciju-restauraciju Umjetničke akademije Sveučilišta u Splitu.[30]

**Izrada mikropresjeka**

Uzorci za mikropresjek izrađeni su u polikarbonatnoj smoli i snimljeni na stereomikroskopu s digitalnom kamerom[31] (sl. 21a–21d). Kako je bilo potrebno radi potpune identifikacije pigmenata napraviti i elementarnu analizu, napravljeni su i mikropresjeci u polikarbonatnoj smoli s dodatkom aktivnog ugljena (sl. 20a–20d). Na taj su način uzorci učinjeni vodljivim i pogodnim za SEM/EDS[32] analizu.

Elementarna analiza napravljena je u Sisku na Metalurškom fakultetu, na uređaju SEM Tescan Vega TS 5136 MM, Bruker EDS.[33]

**Uzorak A1 i B1 – crveni pigment i žbuka**

IR spektar uzorka A1 prikazuje uobičajenu sliku za uzorak polikromije na kamenu. Najizraženije su apsorpcijske vrpce kalcijeva karbonata ($CaCO_3$) pri 1427, 875 i 711 $cm^{-1}$. Dva manja signala pri 1799 i 1618 $cm^{-1}$ također pripadaju signalima kalcijeva karbonata. Signali pri 1143 i 1116 te 669 i 601 $cm^{-1}$ mogu biti signali koji ukazuju na prisutnost venencijansko crvene (koja je po sastavu $Fe_2O_3$), (sl. 21a; prilog 1). Međutim, gotovo potpuno jednak spektar ima i gips (kalcijev sulfat $CaSO_4$) koji je nepoželjna sol, jer uzrokuje postupno propadanje kamenih objekata. Prisutnost kalcijeva sulfata dokazuje elementarna analiza uzorka A1 (tab. 1) koja je pokazala prisutnost sumpora (S), jednog

tests were carried out on them.[29] All other samples are different. The tests were carried out in the Laboratory for Conservation Research of the Conservation-Restoration Department of the Arts Academy of the University of Split.[30]

**Preparing a micro cross-section**

Samples for the micro cross-section were made in a polycarbonate resin and their photographs were taken on a stereomicroscope with a digital camera[31] (Figs. 21a–21d). As complete identification of the pigment also required an elemental analysis, micro cross-sections in a polycarbonate resin with active carbon were also prepared (Figs. 20a–20d). This way, the samples were made conductive and suitable for an SEM/EDS[32] analysis.

The elemental analysis was made at the Faculty of Metallurgy in Sisak, on the SEM Tescan Vega TS 5136 MM, Bruker EDS device.[33]

**Samples A1 and B1 – red pigment and plaster**

The IR spectrum of the A1 sample shows and image typical of a polychromy sample of stone. The absorption bands of calcium carbonate ($CaCO_3$) are the most noticeable at 1427, 875 and 711$cm^{-1}$. Two minor signals at 1799 and 1618 $cm^{-1}$ also belong to calcium carbonate signals. The signals at 1143 and 1116 and at 669 and 601$cm^{-1}$ can be the signals indicating the presence of Venetian red pigment ($Fe_2O_3$ by its composition), (Fig. 21a; Appendix 1). Gypsum, however, has an almost identical spectrum. As calcium sulfate ($CaSO_4$), it is an undesirable salt that causes gradual degradation of stone objects. The presence of calcium sulfate was proven by the

29 Infracrvena spektroskopija (IR) tehnika je analize materijala koja se koristila dulje od 70 godina, a FT-IR (*Fourier Transform Infrared*) tehnika je koja se isključivo koristi u suvremenoj IR spektroskopiji. U toj tehnici IR zračenje prolazi kroz uzorak i šalje informacije računalu. Rezultirajući spektar predstavlja molekulsku apsorpciju stvarajući molekulski „otisak prstiju" (engl. *fingerprint*) uzorka. Ne postoje dvije molekulske strukture koje proizvode jednak infracrveni spektar. Upravo ta odlika infracrvenu spektroskopiju čini korisnom za nekoliko vrsta analiza kao što je identifikacija nepoznatih materijala, kvaliteta i konzistentnost uzorka. FT-IR razvijen je kako bi se prevladala ograničenja koja nude instrumenti s dispergiranom zrakom. Danas je vrijeme potrebno da se analizira jedan uzorak svedeno na samo nekoliko sekundi. A. Braithwaite, F. J. Smith 1996, 388–390, 548.

30 Od 2010. godine u laboratotoriju Umjetničke akademije u Splitu počeli smo stvarati bazu analiziranih uzoraka polikromije s kamenih umjetnina. Povijesni pregled pigmenata, sistematizacija pigmenata prema vremenu u kojem su korišteni, napravljen je u svrhu lakšeg određivanja vrste pigmenata pri interpretaciji rezultata analiza uzorka. Često se događa da se spektar uzorka preklapa sa spektrima različitih pigmenata, a tada je dodatno znanje o pigmentima od velike koristi.

31 Korišten je mikroskop marke Leica MZ75, istraživački stereomikroskop s digitalnom kamerom.

32 Elektronski mikroskop uređaj je kojim se, s pomoću uskog snopa elektrona, dobija uvid u mikrostrukturu promatranog uzorka, uz vrlo veliko povećanje. Glavna je prednost svih elektronskih mikroskopa njihova velika rezolucija koja nam omogućava korištenje izuzetno velikih povećanja bez značajnijeg gubitka oštrine slike. Postoje dvije osnovne vrste elektronskih mikroskopa, transmisijski (TEM) i skenirajući elektronski mikroskop. Kod skenirajućeg elektronskog mikroskopa (SEM) slika se dobiva pravilnim pomicanjem snopa elektrona po površini uzorka. Koristi se za proučavanje strukture i uz dodatni uređaj za određivanje kemijskog sastava materijala. A. Tonjec 2012, 52.

33 Ovim putem zahvaljujemo izv. prof. dr. sc. Zdenki Zovko Brodarac s Metalurškog fakulteta Sveučilišta u Zagrebu koja nam je izašla u susret pri izradi navedenih analiza.

29 Infrared spectroscopy (IR) is a technique used for analyzing materials for more than 70 years. The FT-IR (*Fourier Transform Infrared*) technique is only used in modern IR spectroscopy. This technique uses IR radiation that passes through a sample and sends data to a computer. The resulting spectrum represents molecule absorption and creates the molecule fingerprint of the sample. No two molecule structures can produce identical infrared spectrums. It is this feature that makes infrared spectroscopy useful for several types of analyses, such as identification of unknown materials and sample quality and consistency. The FT-IR was developed in order to surpass the limitations of dispersed-ray instruments. Today, the time required for analyzing a sample is reduced to only a few seconds. A. Braithwaite, F. J. Smith 1996, 388–390, 548.

30 Since 2010, a base of analyzed polychromy samples from stone monuments has been created in the Arts Academy in Split Lab. The historical overview of pigments was made and the pigments were systematized by the period of time in which they had been used. This facilitates determining the type of pigments when interpreting the results of sample analyses. It often happens that the spectrum of a sample overlaps with the spectrums of various pigments. This is when additional knowledge of pigments can be of great use.

31 A Leica MZ75 microscope was used. It is a research microscope with a digital camera.

32 Electron microscope is a device using a very thin electronic beam and large magnification to show the microstructure of the observed sample. The major advance of all electron microscopes is their high resolution that allows the use of very large magnifications without substantial loss of resolution. There are two basic types of electron microscopes: transmission (TEM) electron microscope and scanning electron microscope (SEM). In scanning electron microscope, the image is obtained by scanning focused electron beams over a sample surface. It is used for analyzing the structure and (with an additional device) chemical composition of a material. A. Tonjec 2012, 52.

33 We are using the opportunity to express our gratitude to Zdenka Zovko Brodarac, PhD, Associate Professor at the Faculty of Metallurgy of the University of Zagreb, who helped us with the said analyses.

**Slika 10a. Uzorak 2, snimljen digitalnim mikroskopom pod povećanjem 60 x. Pigment s pozadine između pletera na luku lijeve bočne strane ciborija. Mikropresjek ovog uzorka pokazao je žute i narančaste čestice, zbog čega je odlučeno da se napravi i IR spektar i elementarna analiza**

Figure 10a. Sample 2, photographed with digital microscope using 60x magnification. Pigment from rear side, between interlaced ribbons on arch of ciborium's left lateral side. As the micro cross-section of this sample showed yellow and orange particles, it was decided that IR photographing and an elemental analysis should also be made.

**foto** / photo by: **M. Miliša**

**Slika 10b. Uzorak 1, snimljen digitalnim mikroskopom pod povećanjem 60 x**

Figure 10b. Sample 1, photographed with digital microscope using 60x magnification

**foto** / photo by: **M. Miliša**



od gradivnih elemenata kalcijeva sulfata. Njegovu će prisutnost dodatno potvrditi i spektri ostalih uzoraka. Nadalje, situaciju dodatno komplicira i činjenica da i oker-zlatni talijanski ima jako sličan spektar kao i venecijansko crvena (željezo-oksid). Kako se iz mikropresjeka vidi živa crvena boja koja je karakteristika venencijansko crvene u odnosu na boju oker-zlatnog talijanskog, možemo reći da se radi o venecijansko crvenoj. Dodatnu potporu tome daje i činjenica da u spektru uzorka A1 nema signala 908 i 796 $cm^{-1}$ koji su prisutni u spektru oker-zlatnog talijanskog (prilog 1).

**Uzorak A2**

Kako je mikropresjek tog uzorka pokazao žute i narančaste pjege, odlučili smo napraviti i IR spektar i elementarnu analizu. IR spektar uzroka A2 (sl. 21b; prilog 2) prikazuje uobičajenu sliku za uzorak polikromije na kamenu, najizraženije su apsorpcijske vrpce kalcijeva karbonata, uz mali broj malih signala. Međutim, elementarna analiza dala je interesantan rezultat, a to je prisutnost arsena (As) (tab. 2). To ukazuje na korištenje auripigmenta ($As_2S_3$, tzv. arsenov blistavac) ili realgara ($As_4S_4$) kao pigmenta i oni su odgovorni za žuto-narančasto obojenje.

elemental analysis of the sample A1 (Tab. 1). It showed the presence of Sulphur (S), one of the elements contained in in calcium sulfate. Its presence will be additionally confirmed by the spectrums of other samples. The situation is additionally complicated by the fact that the Italian gold ocher pigment has a spectrum very similar to the one of the Venetian red (iron oxide). As the micro cross-section shows a bright red color typical of the Venetian red and not of the Italian gold ocher, we can safely say that the pigment in question is the Venetian red. Additional support to this claim is the fact that the spectrum of the A1 sample lacks the 908 and 796$cm^{-1}$ signals that are found in the spectrum of the Italian gold ocher (Appendix 1).

**Sample A2**

As the micro cross-section of this sample showed yellow and orange spots, we decided to do also an IR spectrum and an elemental analysis. The IR spectrum of sample A2 (Fig. 21b; Appendix 2) shows an image typical of a polychromy sample on stone. The absorption bands of calcium carbonate are the most noticeable and there is a small number of signals. However, the elemental analysis yielded an interesting result: the presence of arsenic (As) (Tab. 2). This indicates the use of orpiment ($As_2S_3$) or realgar ($As_4S_4$) as a pigment; they are responsible for the yellow-orange color.

**Sample A3**

The micro cross-section of this sample showed the presence of tiny blue and deep blue particles (Fig. 21c). If we compare the IR spectrums of sample A3 (the upper spectrum – Appendix 3) and a pure natural ultramarine blue

**Slika 11. Desna bočna arkada ciborija**
Figure 11. Ciborium's right lateral arcade
**foto** / photo by: **V. Kundić**

### Uzorak A3

Mikropresjek ovog uzorka pokazao je prisutnost sitnih i modrih i plavih čestica (sl. 21c). Usporedbom IR spektara uzroka A3 (gornji spektar – prilog 3) i uzorka čistog prirodnog ultramarina (donji spektar – prilog 3) vidimo da se ti spektri poklapaju u području apsorpcijskih vrpci svojstvenih ultramarinu 1020 (1006) i 453 (449) $cm^{-1}$. Taj se plavi pigment u srednjem vijeku dobivao iz poludragog kamena lapis lazulija[34] (lapis lazuli spada u skupinu silikata $Na_6Ca_2(AlSiO_4)_6$ (SO4,S,Cl)). Dodatni dokaz prisutnosti ultramarina dala je i elementarna analiza (tab. 3) koja je pokazala prisutnost natrija, aluminija, silicija i kisika, gradivnih elemenata prirodnog ultramarina.

### Uzorak A4

Iz mikropresjeka ovog uzorka vidi se da je nijansa crvene boje drukčija, tamnija, u odnosu na crvenu boju uzorka A1 (sl. 21d). IR spektar uzroka A4 (prilog 4) prikazuje uobičajenu sliku za uzorak polikromije na kamenu, najizraženije

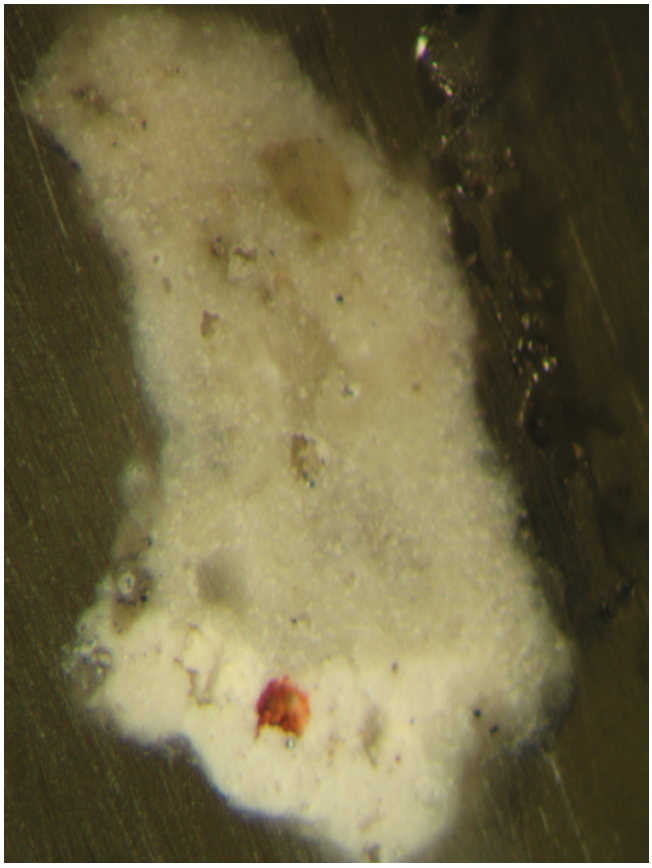
sample (the lower spectrum – Appendix 3), we can see that these spectrums overlap in the area of the absorption bands typical of ultramarine blue, 1020 (1006) and 453 (449) $cm^{-1}$. In Middle Ages, this blue pigment was obtained from the semi-precious stone lapis lazuli[34] (a member of a silicate group, $Na_6Ca_2(AlSiO_4)_6$ (SO4,S,Cl)). The elemental analysis gave additional evidence of the presence of ultramarine blue (Tab. 3). It showed the presence of sodium, aluminum, silicon and oxygen – all the elements found in the natural ultramarine blue.

### Sample A4

The micro cross-section of this sample shows that its red color has a different, darker shade that the red color of sample A1 (Fig. 21d). The IR spectrum of sample A4 (Appendix 4) shows an image typical of a polychromy sample on stone. The absorption bands of calcium carbonate are the most noticeable, with signals at 1163 and 1120$cm^{-1}$ indicating the presence of gypsum. The signals at 1068 and 1039$cm^{-1}$ are found in the ocher absorption area ($Fe_2O_3$). The elemental analysis gave additional evidence of the presence of ocher. It also showed the presence of aluminum, silicon and iron (Tab. 4) – all the elements found in ocher pigment.

34 Kasnije se ultramarin počeo proizvoditi umjetnim putem, prvenstveno zbog skupoće lapis lazulija.

34 Production of artificial ultramarine blue pigment later began, mostly because lapis lazuli was very expensive.



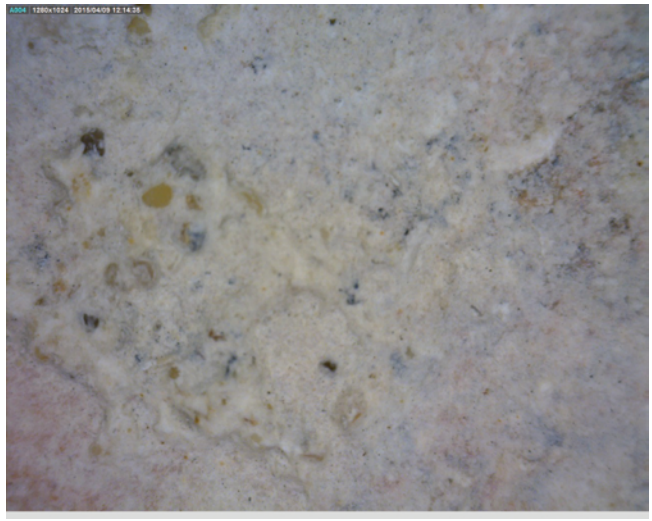
**Slika 12. Mikropresjek uzorka 2 u žutoj smoli**
Figure 12. Micro cross-section of sample 2 in yellow resin
**foto /** photo by: **I. Ljubenkov**

su apsorpcijske vrpce kalcijeva karbonata, uz signale pri 1163 i 1120 $cm^{-1}$ koji ukazuju na prisutnost gipsa. Signali pri 1068 i 1039 $cm^{-1}$ se nalaze u području apsorpcije okera ($Fe_2O_3$). Prisutnost okera potvrdila je i elementarna analiza koja je pokazala prisutnost aluminija, silicija i željeza (tab. 4), gradivnih elementa okera.

**Uzorci B2, B3, B5 i B7**

IR spektre ovih uzoraka razmatramo zajedno jer su veoma slični, a njihova boja opisana je kao siva ili crna. IR spektri uzoraka B2 (prilog 5), B3 (prilog 7), B5 (prilog 6) i B7 (prilog 8) prikazuju uobičajenu sliku za uzorak polikromije na kamenu. Najizraženije su apsorpcijske vrpce kalcijeva karbonata, uz signale pri 1163 i 1120 $cm^{-1}$ koji ukazuju na prisutnost gipsa. Uzorci B3 i B7 imaju još apsorpcijsku vrpcu pri 1024 $cm^{-1}$, odnosno 1045 $cm^{-1}$. U tom području apsorpcijske vrpce ima pigment koštano crne.[35] Koštano crna pigment je organskog podrijetla, po sastavu smjesa

35 Ovi su uzorci poslani naknadno (2018. god.) i na elementarnu analizu. Konačni zaključak moći će se donijeti kada stignu rezultati analiza.



**Slika 13. Snimka digitalnim mikroskopom uzorka 2 pod povećanjem 60 x**
Figure 13. Sample 2 photographed with digital microscope using 60x magnification
**foto /** photo by: **M. Miliša**

**Samples B2, B3, B5 and B7**

The IR spectrums of these samples are analyzed together because of their similarity. Their color is described as gray or black. The IR spectrums of samples B2 (Appendix 5), B3 (Appendix 7), B5 (Appendix 6) and B7 (Appendix 8) show an image typical of a polychromy sample on stone. The absorption bands of calcium carbonate are the most noticeable, with signals at 1163 and 1120 $cm^{-1}$ indicating the presence of gypsum. Samples B3 and B7 also have an absorption band at 1024$cm^{-1}$ and 1045$cm^{-1}$, respectively. There is a bone black pigment in this area of the absorption band.[35] The bone black pigment is of organic origin. It is composed of carbon, tricalcium phosphate and calcium carbonate ($C + Ca_3(PO_4)_2 + CaCO_3$).

**Sample B6**

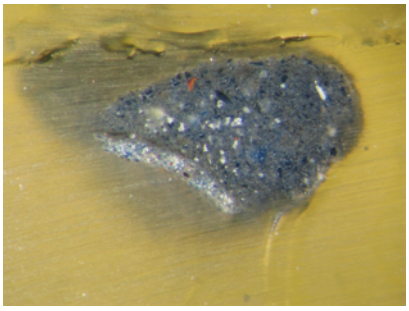
The IR spectrum of this sample (Appendix 9) is analyzed separately because it features an advantage compared to all other IR spectrums and spectrums of gray-and-black samples B2, B3, B5 and B7. Its IR spectrum shows an image typical of a polychromy sample on stone. The absorption bands of calcium carbonate are the most noticeable, with signals at 1163 and 1120$cm^{-1}$ indicating the presence of gypsum. It also has an absorption band at 1045$cm^{-1}$. The special quality of this sample is the presence of calcium

35 These samples were sent subsequently (in 2018), including for an elemental analysis. The final conclusion will be possible after the analysis results are known.

**Slike 14a i 14b. Detalji reljefa na arhitravu desne strane ciborija s najviše sačuvane polikromije**

Figures 14a and 14b. Relief on architrave on ciborium's right side, with most polychromy preserved – detail

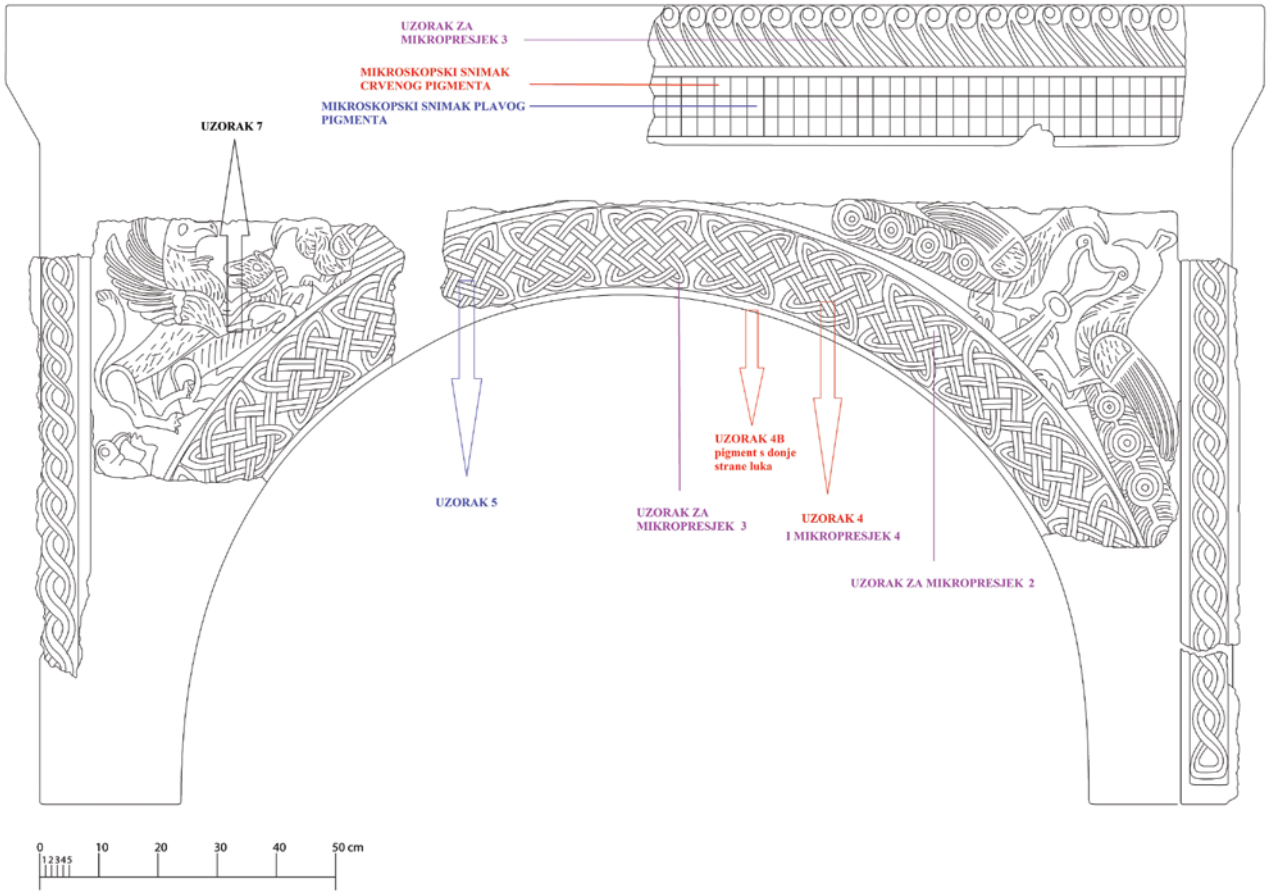
**foto** / photo by: **M. Miliša**



**Slika 14c. Uzorak A3 u žutoj smoli**

Figure 14c. Sample A3 in yellow resin

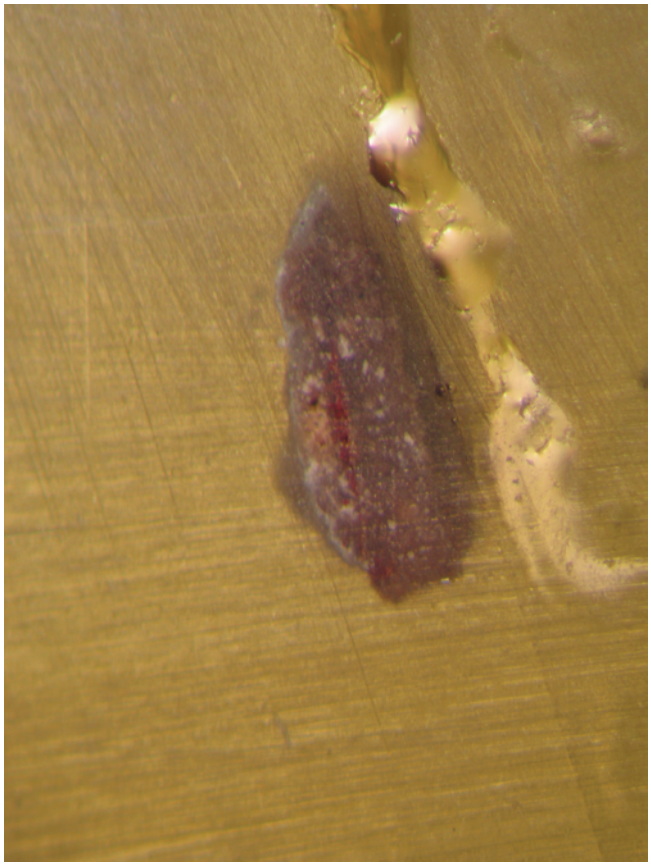
**foto** / photo by: **I. Ljubenkov**




**Slika 15. Desna bočna arkada ciborija, originalni ulomci – crtež zatečenog stanja i pozicije uzorkovanja za IR (U4, 5 i 7) i mikropresjeci 2, 3 i 4. Vidi sl. 4.**

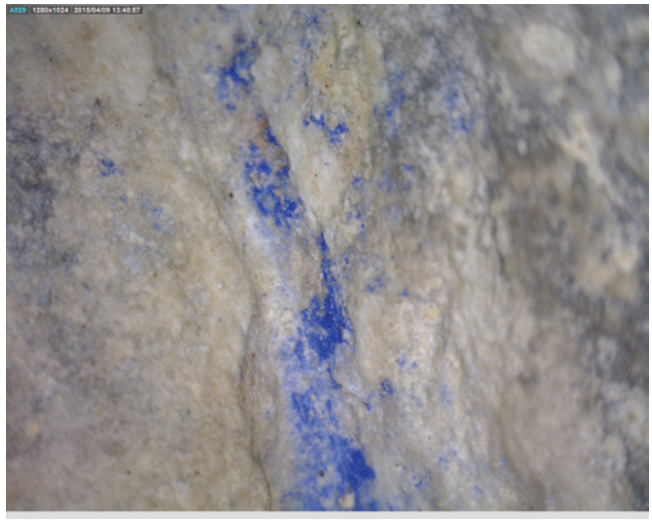
Figure 15. Ciborium's right lateral side, original fragments – as found; sampling spots for IR (U4, 5 and 7) and micro cross-sections 2, 3 and 4. See Fig. 4.

**crtež** / drawing by: **V. Kundić**



**Slika 16. Uzorak 4. Mikropresjek u smoli (pozicija – pleterni luk – crveni pigment)**
Figure 16. Sample 4. Micro cross-section in resin (spot – interlaced-ribbon arch – red pigment)
**foto** / photo by: **I. Ljubenkov**

**Slika 18. Crveni pigment uz luk pletera, snimljen digitalnim mikroskopom pod povećanjem 70 x**
Figure 18. Red pigment next to interlaced-ribbon arch, photographed with digital microscope using 70x magnification
**foto** / photo by: **M. Miliša**

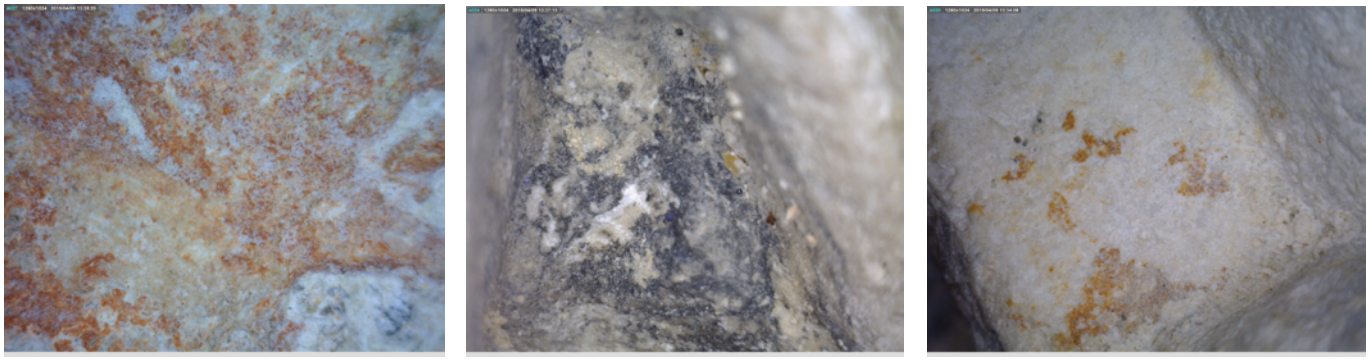


**Slike 17a i 17b. Gornji arihitrav desne strane ciborija, šahovsko polje, crveni i plavi pigment. Uzorci su snimljeni digitalnim mikroskopom pod povećanjem 70 x**
Figures 17a and 17b. Upper architrave on ciborium's right side, checkered pattern, red and blue pigments. The samples were photographed with digital microscope using 70x magnification
**foto** / photo by: **M. Miliša**

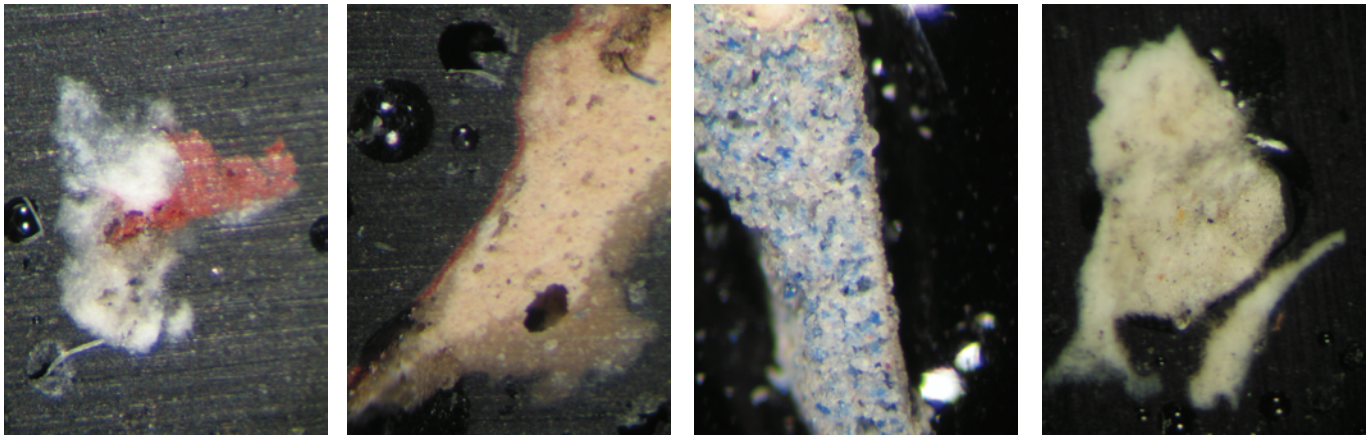
oxalate ($CaC_2O_4$), which is considered a stable salt – the one that stabilizes a stone object. The presence of calcium oxalate can be seen in Appendix 9, where the spectrums of sample B6 and pure calcium oxalate overlap. Overlapping of the main signals of calcium oxalate and the sample's absorption bands at 1637 and 1323$cm^{-1}$ are clearly visible.

## 4. Drawings to scale of the ciborium and graphic reconstructions of its supposed original appearance

Based on the chemical analysis results and detection of the original pigments, a digital reconstruction of the original polychromy on the ciborium's front side was made (Figs. 22–25). Marking the International Museum Day 2015, the results of this research was presented in such way that the supposed original appearance was projected on the ciborium's arcade



**Slike 19. Uzorci polikromije snimljeni digitalnim mikroskopom pod povećanjem 70 x 19a) Uzorak 4B. Podnožje luka; 19b) Uzorak 5. Pozadina pletera na luku arkade; 19c) Tragovi boje na dvoprutoj pletenici na luku arkade**
Figures 19. Causes of polychromy photographed with digital microscope using 70x magnification 19a) Sample 4B. Arch base; 19b) Sample 5. Rear side of interlaced ribbon on arch; 19c) Traces of color on double-braided ribbon on arch
**foto** / photo by: **M. Miliša**



**Slike 20a–20d. Mikropresjeci uzoraka u tamnoj smoli za SEM/EDS analizu: 20a) Uzorak A1; 20b) Uzorak A2; 20c) Uzorak A3; 20d) Uzorak A4.**
Figures 20a–20d. Micro cross-sections of samples in dark resin for SEM/EDS analysis: 20a) Sample A1; 20b) Sample A2; 20c) Sample A3; 20d) Sample A4.
**foto** / photo by: **I. Ljubenkov**

ugljika, trikalcijeva fosfata i kalcijeva karbonata (C + $Ca_3(PO_4)_2$ + $CaCO_3$).

### Uzorak B6

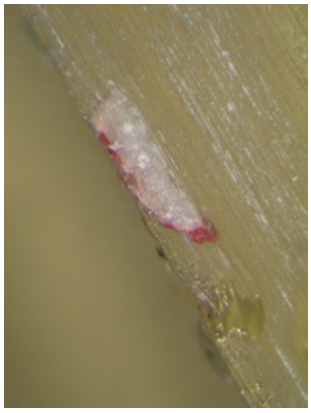
IR spektar ovog uzorka (prilog 9) razmatramo odvojeno jer on ima jednu posebnost u odnosu na sve ostale IR spektre kao i spektre sivocrnih uzoraka B2, B3, B5 i B7. Njegov IR spektar prikazuje uobičajenu sliku za uzorak polikromije na kamenu, najizraženije su apsorpcijske vrpce kalcijeva karbonata, uz signale pri 1163 i 1120 $cm^{-1}$ koji ukazuju na prisutnost gipsa. Ima još apsorpcijsku vrpcu pri 1045 $cm^{-1}$. Posebnost je ovog uzorka u prisutnosti kalcijeva oksalata ($CaC_2O_4$) koji se smatra stabilnom soli, odnosno onom koja stabilizira kameni objekt. Prisutnost kalcijeva oksalata vidi se iz priloga 9 gdje su preklopljeni spektri uzorka B6 i čistog kalcijeva oksalata. Jasno se vidi preklapanje glavnih signala kalcijeva oksalata s apsorpcijskim vrpcama uzorka u području 1637 i 1323 $cm^{-1}$.

(Figs. 33a, 33b).[36] Using the same procedures and methodology, digital reconstructions of the original polychromy on the right (Figs. 26–28) and left (Figs. 29–30) lateral sides of the ciborium were made. The rear arcade of the ciborium is the only one where not even a microscope analysis yielded any traces of the original polychromy (Figs. 31–32).

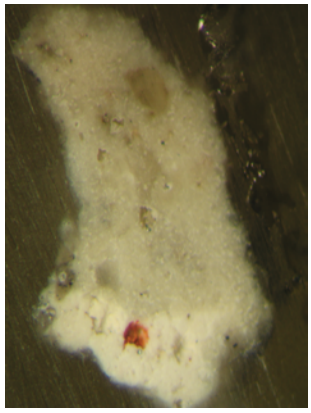
### 5. A recommendation for conservation of the ciborium and for consolidation of the traces of the original color

Since calcium sulfate (gypsum) was found in most of the samples, desalinization and consolidation of the ciborium fragments should be carried out as soon as possible. Next to chlorides, sulfates are the most widespread cause of degradation of stone architecture and stone sculptures. Although this paper is not focused on the presence of salts

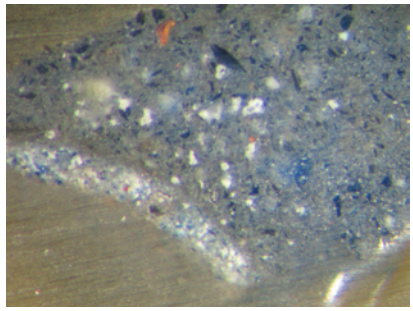
36 See n. 23 and 24.



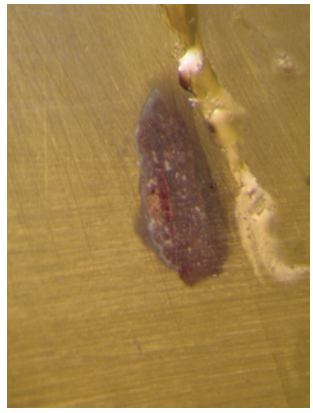
**Slika 21a. Mikropresjek uzorka A1 u polikarbonatnoj smoli**
Figure 21a. Micro cross-section of A1 in polycarbonate resin
**foto** / photo by: **I. Ljubenkov**



**Slika 21b. Mikropresjek uzorka A2 u polikarbonatnoj smoli**
Figure 21b. Micro cross-section of A2 in polycarbonate resin
**foto** / photo by: **I. Ljubenkov**



**Slika 21c. Mikropresjek uzorka A3 u polikarbonatnoj smoli**
Figure 21c. Micro cross-section of A3 in polycarbonate resin
**foto** / photo by: **I. Ljubenkov**



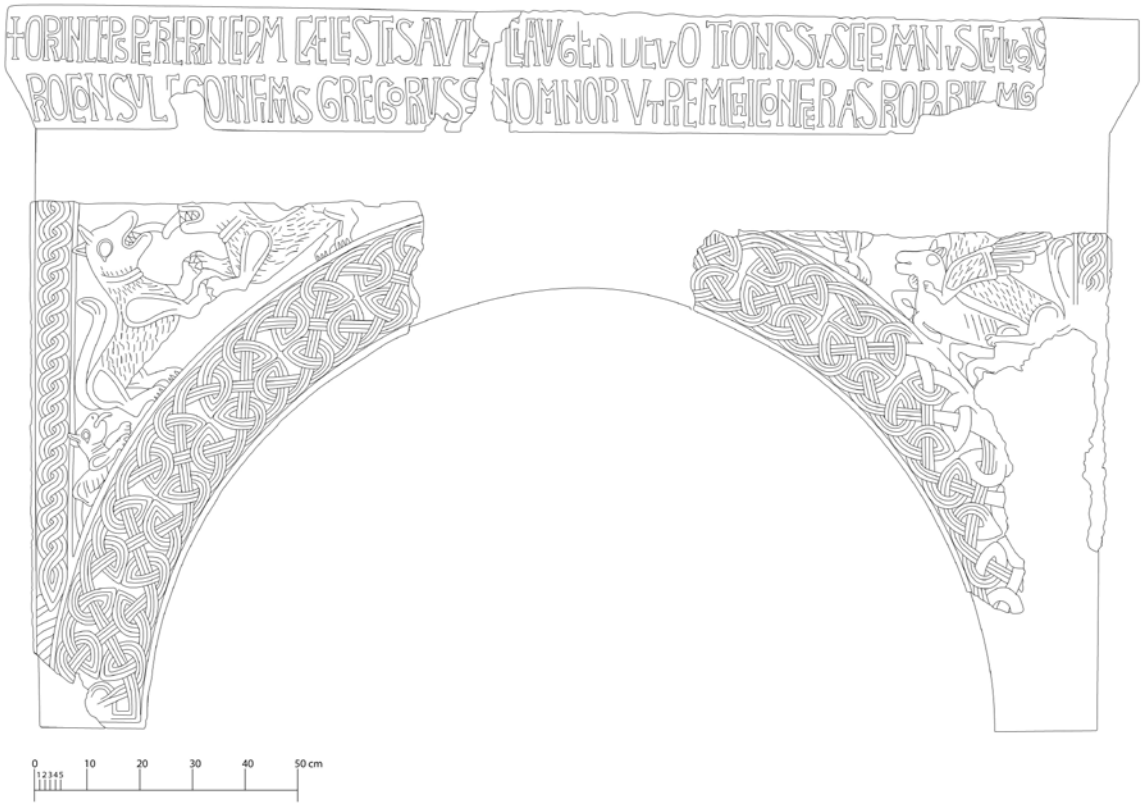
**Slika 21 d. Mikropresjek uzorka A4 u polikarbonatnoj smoli**
Figure 21 d. Micro cross-section of A4 in polycarbonate resin
**foto** / photo by: **I. Ljubenkov**

**Slika 22. Prednja stranica ciborija s natpisom na vijencu. Zatečeno stanje**
Figure 22. Ciborium's front side with inscribed cornice. As found.
**foto** / photo by: **V. Kundić**

**4. Crteži ciborija u mjerilu i izrada grafičkih rekonstrukcija pretpostavljenog originalnog izgleda ciborija**

Prema rezultatima kemijskih analiza i detektiranju izvornih pigmenata napravljena je digitalna rekonstrukcija izvorne polikromije na prednjoj strani ciborija (sl. 22–25).

in the stone, the analyses have shown excessive presence of these salts. The original polychrome layer on the reliefs should also be treated. Proper cleaning of the surface sediments and adequate consolidation of the preserved paint layers are required.



**Slika 23. Crtež u mjerilu, zatečeno stanje ulomaka koji čine prednju stranicu ciborija**
Figure 23. Drawing to scale of fragments making up ciborium's front side, as found
**izradio** / made by: **V. Kundić**

**Slika 24. Crtež rekonstrukcije dijelova koji nedostaju, prednja strana ciborija**
Figure 24. Drawing of reconstructed missing parts, ciborium's front side
**izradio** / made by: **V. Kundić**


**Slika 25. Prednja arkada ciborija, grafička rekonstrukcija pretpostavljenog izgleda**
Figure 25. Ciborium's front arcade, graphic reconstruction of its supposed appearance
**izradio** / made by: **V. Kundić**

Povodom Međunarodnog dana muzeja 2015. godine predstavljeni su rezultati ovih istraživanja tako što je na arkadu projeciran snimak (sl. 33a, 33b) pretpostavljenog originalnog izgleda.[36] Slijedeći iste postupke i metodologiju rada napravljene su i digitalne rekonstrukcije izvorne polikromije na desnoj (sl. 26–28) i lijevoj (sl. 29–30) bočnoj arkadi ciborija. Stražnja arkada ciborija jedina je na kojoj ni mikroskopskim pregledom nisu pronađeni tragovi izvorne polikromije (sl. 31–32).

**5. Preporuka za konzervaciju ciborija i konsolidaciju ostataka izvorne boje**

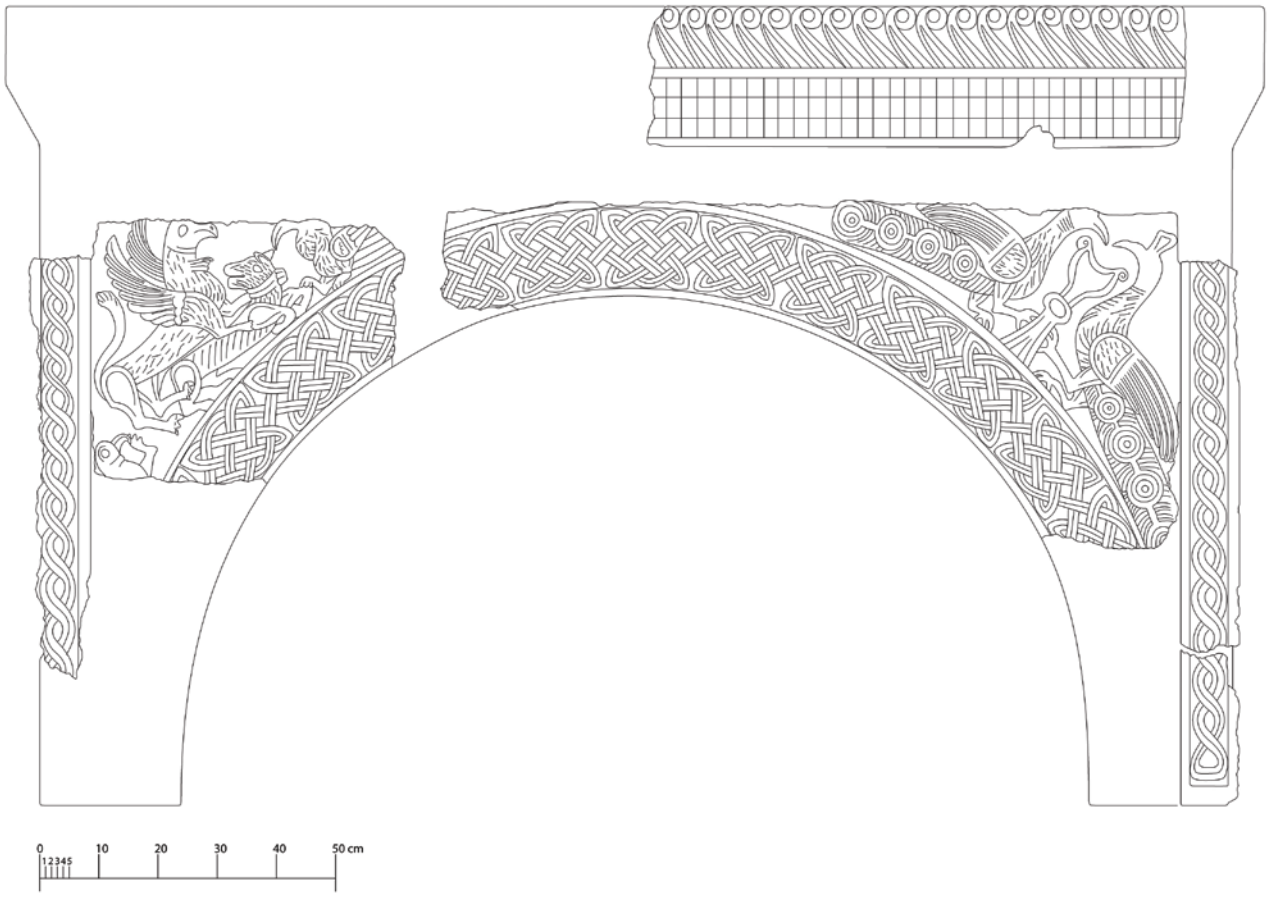
Budući da je u većini uzoraka nađen kalcijev sulfat (gips), promptno bi trebalo provesti desalinizaciju i konsolidaciju ulomaka ciborija. Sulfati su uz kloride najčešći uzročnici propadanja kamenih arhitektonskih i skulpturalnih detalja. Iako tema ovog istraživanja nisu bile soli prisutne u kamenu, analize su pokazale njihovu prisutnost u prekomjernoj količini. Izvorni polikromirani sloj na reljefima također bi trebalo tretirati. Potrebno je čišćenje od površinskih nečistoća te adekvatna konsolidacija bojenog sloja tamo gdje se uspio sačuvati.

After the stone parts of the Pre-Romanesque liturgical furnishings had been carved, they would be installed within the sacral building. Only then, after the installation, the stone plutei would be painted *in situ* – the polychromy could otherwise sustain damage during transportation and installation of stone reliefs in the church. It may have also been done simultaneously with wall frescoes

Understanding the chemical composition and degradation of the objects which are to be protected is crucial for preserving our cultural heritage for the generations to come. Identifying various pigments is important for deciding what materials to use in the restoration and for anticipating their reaction with the binding material, the effect of weather on the degradation process and the effect of the conservation-restoration treatment itself. A pigment analysis should provide a better insight into the composition and age of the polychromed stone. Some future

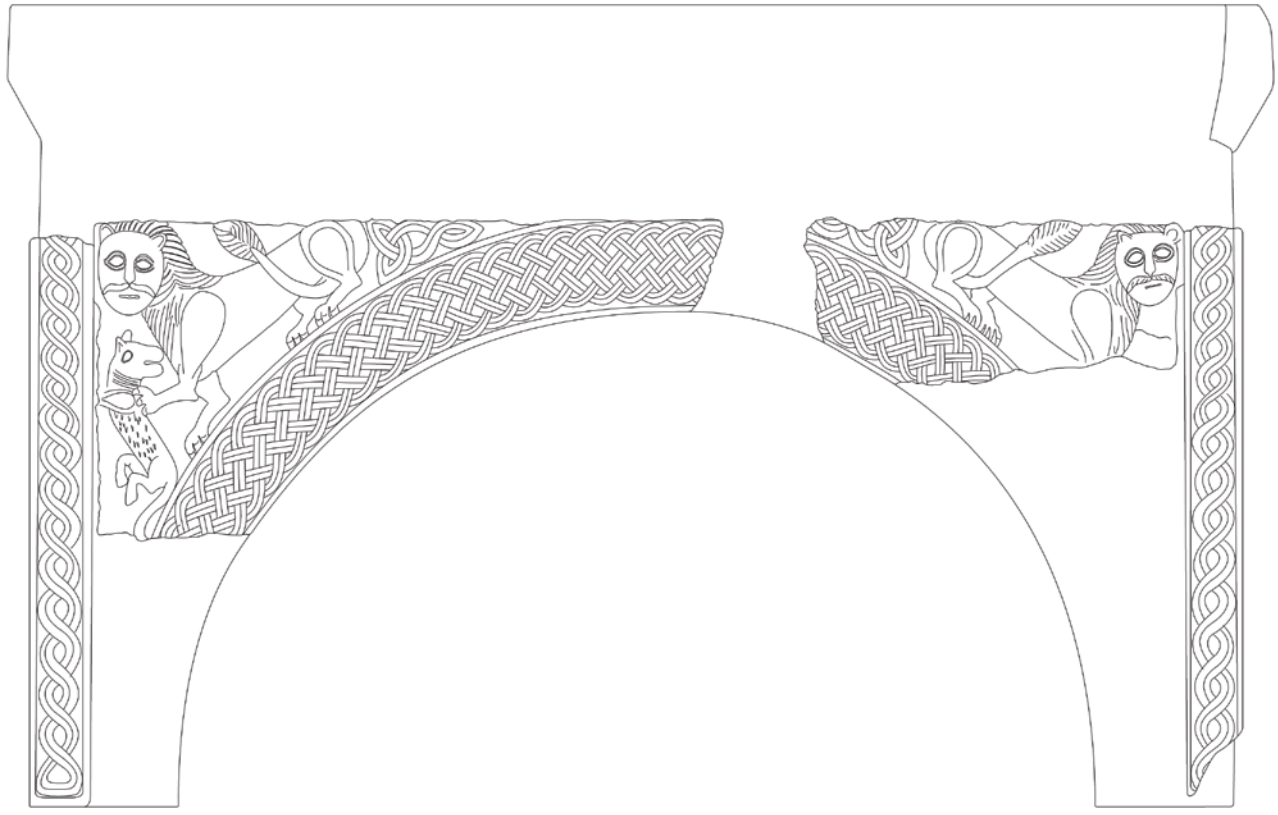
36 Vidi bilj. 23 i 24.

**Slika 26. Desna bočna arkada ciborija, zatečeno stanje**
Figure 26. Ciborium's right lateral side, as found
**foto** / photo by: **M. Miliša**




**Slika 27. Crtež u mjerilu, zatečeno stanje ulomaka koji čine desnu stranicu ciborija**
Figure 27. Drawing to scale of fragments making up ciborium's right side, as found
**izradio** / made by: **V. Kundić**

**Slika 28. Prema rezultatima kemijskih analiza i detektiranju izvornih pigmenata napravljena je grafička rekonstrukcija pretpostavljenog izgleda desne bočne arkade ciborija**
Figure 28. Graphic reconstruction of supposed appearance of ciborium's right lateral arcade based on results of chemical analyses and original pigments detected
**crtež** / drawing by: **I. Vukadin**



**Slika 29. Crtež u mjerilu, zatečeno stanje ulomaka koji čine lijevu stranicu ciborija**
Figure 29. Drawing to scale of fragments making up ciborium's left side, as found
**izradio** / made by: **V. Kundić**

Nakon klesanja kamenih dijelova predromaničkog liturgijskog namještaja slijedila je montaža unutar samog sakralnog objekta. Tek je tada nastupila faza bojenja kamenih pluteja *in situ*, nakon ugradnje, jer bi se u protivnom polikromija oštetila prilikom transporta i ugradnje kamenih reljefa u arhitekturu crkve. Možda i paralelno s izradom fresaka na zidovima.

Razumijevanje kemijskog sastava i procesa degradacije predmeta zaštite ključno je za očuvanje kulturnog nasljeđa za sljedeće generacije. Identifikacija različitih pigmenata važna je za donošenje odluke o tome koji će se materijali koristiti u restauraciji predmeta, za predviđanje njihove reakcije s vezivom i utjecaj atmosferilija na proces degradacije, isto kao i utjecaj samog konzervatorsko-restauratorskog tretmana. Analiza pigmenata trebala bi pružiti bolji uvid u kompoziciju i starost polikromiranog kamena, dok bi buduća baza podataka mogla omogućiti pronalazak poveznica s ostalim polikromiranim umjetninama te pronaći mjesto podrijetla i vrijeme nastanka.[37]

## ZAKLJUČAK

Percepcija polikromije i njezine važnosti u diferencijaciji motiva do sada je često zanemarivana. Usmjerujući pozornost na neke, možda na prvi pogled malo manje bitne detalje, kao što je sama priroda materijala, njegov kemijski sastav, zatim tragovi spajanja kamenih elemenata, ostatci žbuke na poleđini ili ostatci boje u utorima reljefa, može se zaokružiti spoznaja o nekom spomeniku.

Danas vidimo kamene ulomke nekadašnjeg liturgijskog namještaja bez izvornog završnog sloja polikromije.[38] Različite boje diferencirale su pleterne motive. Iako je tijekom vremena mnogo toga propalo, ono što naše vrijeme može dati jest upravo mogućnost korištenja čitavog interdisciplinarnog znanstvenog aparata kojem je dovoljan samo mali uzorak boje kako bismo detektirali o kojem je pigmentu riječ. Uzimanjem uzoraka izvornih slojeva boje

database could enable us to associate it with other polychromed monuments, identify its origin and date it.[37]

## CONCLUSION

The perception of polychromy and its relevance in differentiation of motifs has often been ignored. Drawing one's attention to some seemingly less important details, such as the very nature of a material, its chemical composition, traces of affixing of stone elements to each other, remains of plaster on the rear surface or traces of color in grooves of the reliefs can help one get a deeper insight into a monument.

Today, the original final layer of polychromy is missing on the stone fragments of former liturgical furnishings.[38] Various colors were used to differentiate the interlaced-ribbon motifs. Although most of the colors have degraded over time, we are now in a position to use a wide-range interdisciplinary scientific apparatus which requires but a single color sample to identify the pigment in question. By sampling the original layers of color from a stone sculpture and then taking IR photographs of them, we can identify the pigment. Graphic reconstructions of the supposed original appearance of each side of the ciborium were made on the basis of sample analyses (Figs. 25, 28, 30). By watching the multimedia reconstruction of the ciborium's original polychromy projected on the monument, the visitors of Archaeological Museum Zadar could get a glimpse of Middle Ages and of the sacral buildings that once contained such relief-decorated liturgical furnishings (Figs. 33a, 33b).

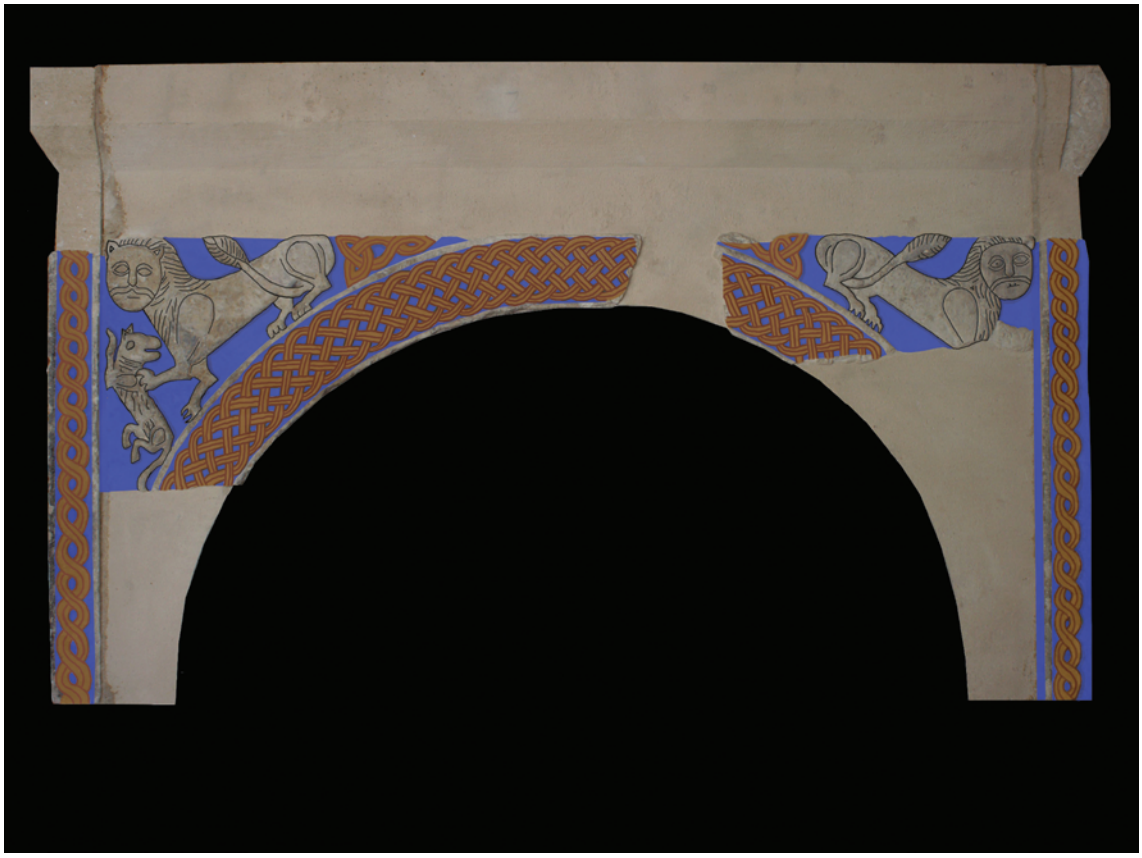
Upon analyzing the samples of the original polychromy preserved on Early Middle Age interlaced-ribbon sculptures, several conclusions can be made. Pigments are mixed with lime binders. Inorganic pigments prevail. Darker and colder colors were primarily used for painting the rear sides of relief, surfaces behind interlaced ribbons

37 Za nastavak istraživanja bilo bi najpoželjnije uzeti uzorke pigmenata u svim ranosrednjovjekovnim crkvama gdje su evidentirani tragovi polikromije na kamenu, i paraleno pigmenata s fresaka. Na taj način stvarala bi se baza podataka analiziranih pigmenata, odnosno baza uzoraka polikromije (uzorci bi bili obrađeni forografski, načinjeni mikropresjeci te analizirani metodama FTIR, IRS, XRF). U laboratoriju na Umjetničkoj akademiji u Splitu trenutno imamo oko 50-ak srednjovjekovnih, 20 antičkih te 30-ak novovjekovnih uzoraka polikromije na kamenu. Komparacijom analiziranih uzoraka (odnosno rezultata analize sastava pigmenata, načina izrade preparacije i polikromije) mogli bi se donositi kvalitetni zaključci, a ujedno bi se mogla raditi i dokumentacija o sastavu uzorkovanih pigmenata, što je potrebna predradnja eventualnim budućim radovima na zaštiti te vrste spomeničke baštine. Izradom ujednačene baze podataka rezultata analiza laboratorijskih istraživanja dobio bi se kvalitetan uzorak za usporedbu, jer sama analiza za sebe ne govori mnogo, pravi kontekst dobiva se tek usporedbom analize ostalih pigmenata iz istog perioda, zatim pigmenata iz ranijih i kasnijih vremenskih epoha.

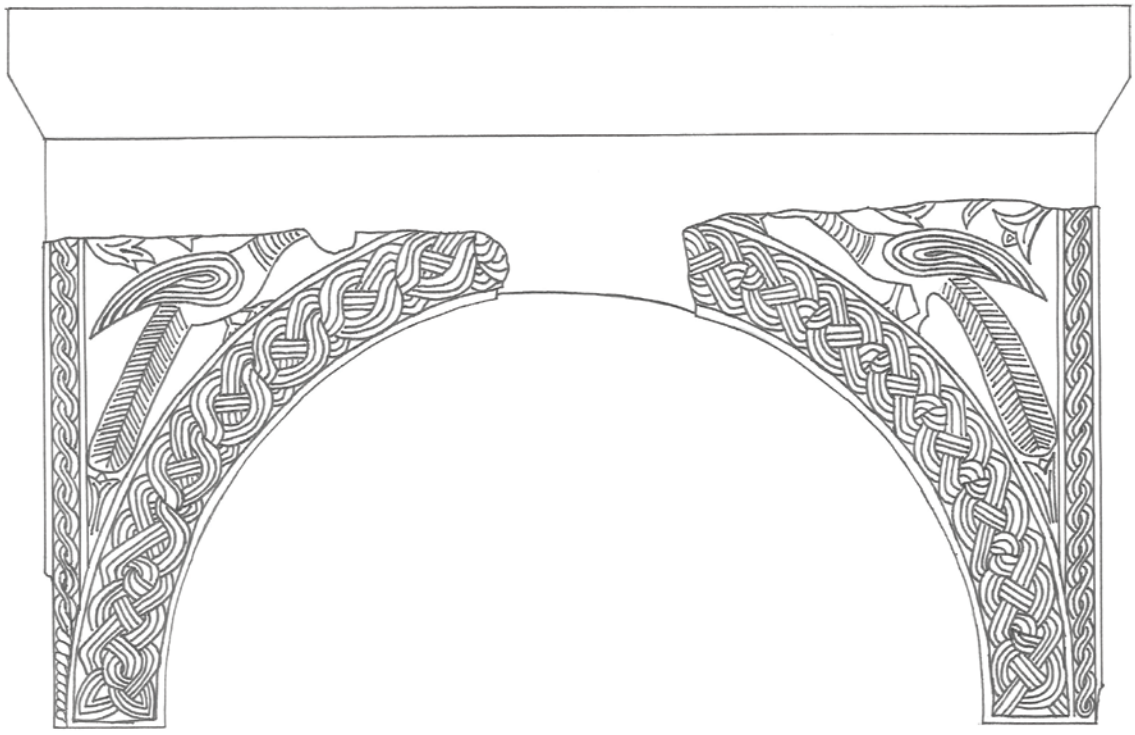
38 Crtež rekonstruirane polikromije na zadarskom reljefu prvi je koji objelodanjuje pretpostavljeni izgled dijela predromaničkog liturgijskog namještaja u njegovu izvornom izdanju, iako autor nije nigdje u tekstu pobliže naveo na osnovi kojih su ostataka i eventualnih kemijskih analiza odabrane baš te boje za računalnu rekonstrukciju. M. Pejaković 1996, 143. M. Pejaković 1996, 134–142; 2007, 532, 537–541.

37 The optimal way of continuing the research would be to take pigment samples in all Early Middle Age churches where traces of polychromy on stone were identified and also to take pigments from frescoes. This way, a database for the analyzed pigments – and polychromy samples – would be created (the samples would be photographed, micro cross-sections would be made and FTIR, IRS and XRF analyses would be carried out). In Arts Academy Lab in Split we currently have some 50 medieval, 20 Antiquity-period and some 30 Modern Age polychromy samples on stone. By comparing the analyzed samples (the results of the pigment composition analysis and the method of making the preparation and polychromy), high-quality conclusions could be made, as well as documentation on the composition of the sampled pigments – a precondition for possible future conservation work on this sort of monument heritage. Creation of a standardized database containing laboratory analysis results would provide high-quality specimens for comparisons, because analyses as such do not say a lot; a real context is obtained only when analyses of other pigments from the same period and those from earlier and later periods are compared.

38 Although the author does not specify in his text based on what traces or chemical analyses, if any, were these particular colors selected for the computer reconstruction, the drawing of the reconstructed polychromy on the Zadar relief is the first one depicting the supposed appearance of this part of the Pre-Romanesque liturgical furnishings as it originally looked. M. Pejaković 1996, 143. M. Pejaković 1996, 134–142; 2007, 532, 537–541.



**Slika 30. Lijeva bočna arkada ciborija, grafička rekonstrukcija pretpostavljenog izgleda**
Figure 30. Graphic reconstruction of supposed appearance of ciborium's left lateral arcade
**crtež** / drawing by: **F. Dragičević**



**Slika 31. Crtež u mjerilu, zatečeno stanje ulomaka koji čine stražnju stranu ciborija**
Figure 31. Drawing to scale of fragments making up ciborium's rear side, as found
**izradila** / made by: **J. Marić**

**Slika 32. Stražnja arkada ciborija, jedina na kojoj mikroskopskim pregledom nisu pronađeni tragovi izvorne polikromije**

Figure 32. Ciborium's rear side – the only one where not even a microscope analysis yielded any traces of the original polychromy

**foto** / photo by: **M. Miliša**

s kamene skulpture i zatim njihovim snimanjem IR spektrom može se dobiti identifikacija pigmenta. Napravljene su grafičke rekonstrukcije pretpostavljenog originalnog izgleda svake stranice ciborija prema rezultatima analiza uzoraka (sl. 25, 28, 30). Multimedijalnom rekonstrukcijom originalne polikromije ciborija s pomoću videoprojektora, posjetitelji Arheološkog muzeja u Zadru mogli su se približiti kako razdoblju srednjeg vijeka tako i sakralnim građevinama kojima su pripadali tako ukrašeni reljefi liturgijskog namještaja (sl. 33a, 33b).

Ispitivanjem uzoraka sačuvane izvorne polikromije s ranosrednjovjekovne pleterne skulpture može se donijeti nekoliko zaključaka. Pigmenti su miješani s vapnenim vezivima. Prevladavaju pigmenti anorganskog podrijetla. Uglavnom su tamnijim i hladnim bojama bojene pozadine reljefa, plohe iza pletera, životinja i sl., a toplim i svjetlijim bojama sam motiv izveden u pleteru.[39] Slova su dodatno naglašavana crnim pigmentom, a u nekim slučajevima i zlatnim obrubom. Kemijskim analizama dokazana je prisutnost sljedećih pigmenata: venecijansko crvene, nekoliko varijacija prirodnog okera, auripigmenta, prirodnog ultramarina (lapis lazuli) i koštano crne u nekoliko crnosivih varijacija; što ne znači da se na stranicama ciborija ne nalaze i neki drugi pigmenti koji su promakli ovom uzrokovanju.

and animals etc., while brighter and warmer colors were used for the interlaced-ribbon motif itself.[39] The letters were additionally emphasized with a black pigment and were sometimes lined with gold. Chemical analyses have proven the presence of the following pigments: Venetian red, a few variations of ocher, orpiment, natural ultramarine blue (lapis lazuli) and bone black in several black-and-gray variations. It is possible, however, that the ciborium's sides contain some other pigments that this sampling has failed to identify.

The traces of a polychrome layer should be consolidated wherever they are preserved. Traces of color on stone reliefs – or polychromed Pre-Romanesque sculptures – are

39 A. Baker 2004, 3.

39 A. Baker 2004, 3.

**Slike 33a i 33b. Ciborij za vrijeme digitalne projekcije na originalnu prednju arkadu**
Figures 33a and 33b. Ciborium with digital projection on its original front arcade

**foto** / photo by: **V. Kundić**

Nužna je konsolidacija ostataka polikromiranog sloja gdje god je on sačuvan. Ostatci boje na kamenim reljefima, odnosno polikromirana predromanička skulptura, zaista su rijetko temeljito obrađeni. U bojama pojedinih motiva leže odgovori o njihovu značenju i simbolici, bojom im je dodatno naglašeno značenje.

indeed rarely analyzed. The color of their particular motifs could tell us what they symbolize and mean. The color underlines this meaning.

Spectrum: M1_1

| Element | Series | unn. C [wt.%] | norm. C [wt.%] | Atom. C [at.%] | Error [%] |
|---|---|---|---|---|---|
| Carbon | K-series | 56.15 | 56.15 | 69.46 | 24.7 |
| Oxygen | K-series | 24.24 | 24.24 | 22.51 | 10.1 |
| Sodium | K-series | 7.41 | 7.41 | 4.79 | 0.9 |
| Silicon | K-series | 0.55 | 0.55 | 0.29 | 0.1 |
| **Sulfur** | **K-series** | **0.09** | **0.09** | **0.04** | **0.1** |
| Chlorine | K-series | 1.87 | 1.87 | 0.78 | 0.1 |
| Potassium | K-series | 2.29 | 2.29 | 0.87 | 0.3 |
| Calcium | K-series | 1.13 | 1.13 | 0.42 | 0.2 |
| Germanium | L-series | 0.87 | 0.87 | 0.18 | 0.1 |
| Bromine | L-series | 1.00 | 1.00 | 0.19 | 0.1 |
| Indium | L-series | 2.49 | 2.49 | 0.32 | 0.5 |
| Thallium | M-series | 1.91 | 1.91 | 0.14 | 0.2 |
| Total: | | 100.00 | 100.00 | 100.00 | |

**Tablica 1. Elementarna analiza uzorka A1**
Table 1. Elemental analysis of Sample A1
**izradio** / made by: **I. Ljubenkov**

Spectrum: M2-1

| Element | Series | unn. C [wt.%] | norm. C [wt.%] | Atom. C [at.%] | Error [%] |
|---|---|---|---|---|---|
| Carbon | K-series | 21.01 | 21.01 | 28.97 | 6.8 |
| Oxygen | K-series | 61.56 | 61.56 | 63.73 | 19.1 |
| Calcium | L-series | 16.61 | 16.61 | 6.86 | 7.2 |
| Silicon | K-series | 0.64 | 0.64 | 0.38 | 0.1 |
| **Arsenic** | **L-series** | **0.08** | **0.08** | **0.02** | **0.0** |
| Zinc | L-series | 0.03 | 0.03 | 0.01 | 0.0 |
| Aluminium | K-series | 0.07 | 0.07 | 0.04 | 0.0 |
| Total: | | 100.00 | 100.00 | 100.00 | |

**Tablica 2. Elementarna analiza uzorka A2**
Table 2. Elemental analysis of Sample A2
**izradio** / made by: **I. Ljubenkov**

Spectrum: M3-1

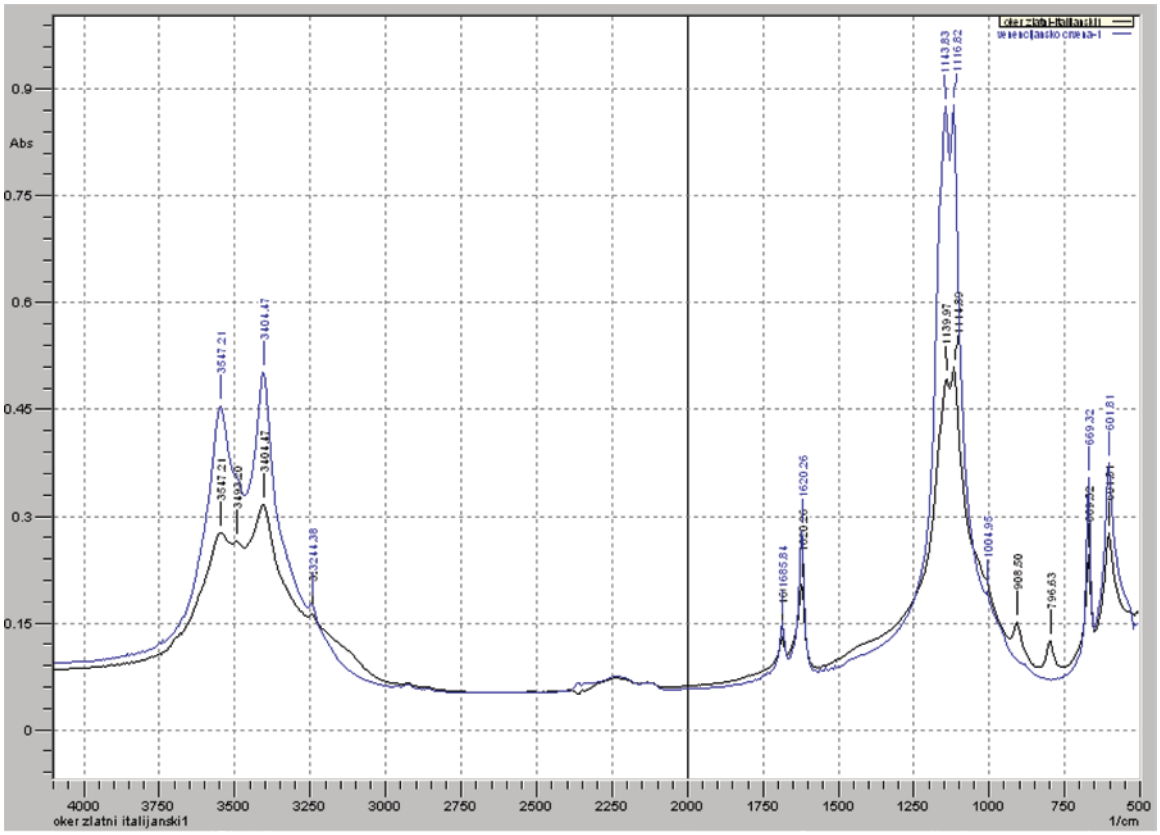
| Element | Series | unn. C [wt.%] | norm. C [wt.%] | Atom. C [at.%] | Error [%] |
|---|---|---|---|---|---|
| Carbon | K-series | 17.08 | 11.76 | 19.28 | 2.3 |
| **Oxygen** | **K-series** | **69.55** | **47.90** | **58.96** | **8.0** |
| Calcium | L-series | 25.97 | 17.89 | 8.79 | 5.7 |
| Magnesium | K-series | 4.73 | 3.26 | 2.64 | 0.3 |
| **Silicon** | **K-series** | **18.84** | **12.98** | **9.10** | **1.3** |
| **Aluminium** | **K-series** | **0.86** | **0.59** | **0.43** | **0.1** |
| **Sodium** | **K-series** | **0.52** | **0.35** | **0.30** | **0.1** |
| Lead | M-series | 7.66 | 5.28 | 0.50 | 0.6 |
| Total: | | 145.20 | 100.00 | 100.00 | |

**Tablica 3. Elementarna analiza uzorka A3**
Table 3. Elemental analysis of Sample A3
**izradio** / made by: **I. Ljubenkov**

Spectrum: M4_1

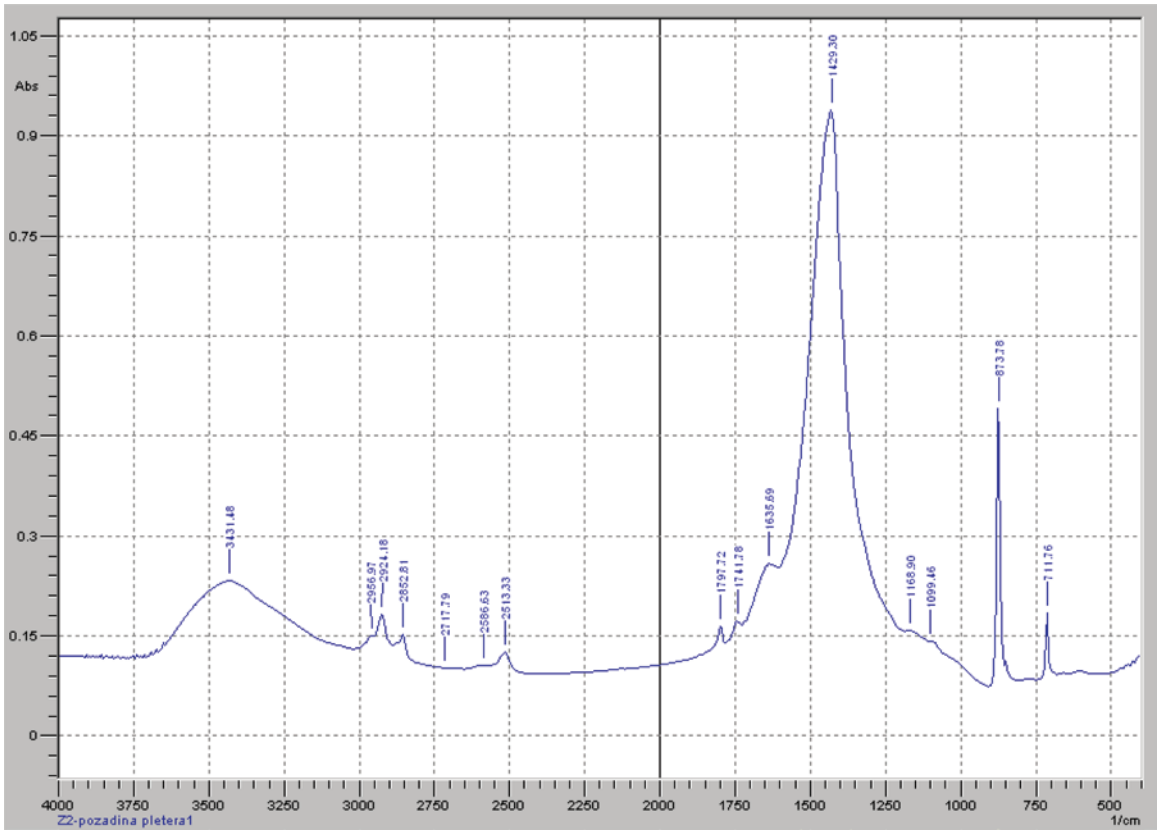
| Element | Series | unn. C [wt.%] | norm. C [wt.%] | Atom. C [at.%] | Error [%] |
|---|---|---|---|---|---|
| Oxygen | K-series | 29.92 | 30.42 | 31.91 | 4.5 |
| Carbon | K-series | 25.83 | 26.26 | 36.70 | 23.1 |
| Calcium | K-series | 8.23 | 8.37 | 3.50 | 0.3 |
| Magnesium | K-series | 1.40 | 1.43 | 0.99 | 0.1 |
| Chlorine | K-series | 4.58 | 4.66 | 2.20 | 0.5 |
| Tantalum | M-series | 0.36 | 0.37 | 0.03 | 0.1 |
| Potassium | K-series | 1.36 | 1.38 | 0.59 | 0.2 |
| **Silicon** | **K-series** | **2.05** | **2.09** | **1.25** | **0.3** |
| **Aluminium** | **K-series** | **0.82** | **0.83** | **0.52** | **0.1** |

**Tablica 4. Elementarna analiza uzorka A4**
Table 4. Elemental analysis of Sample A4
**izradio** / made by: **I. Ljubenkov**



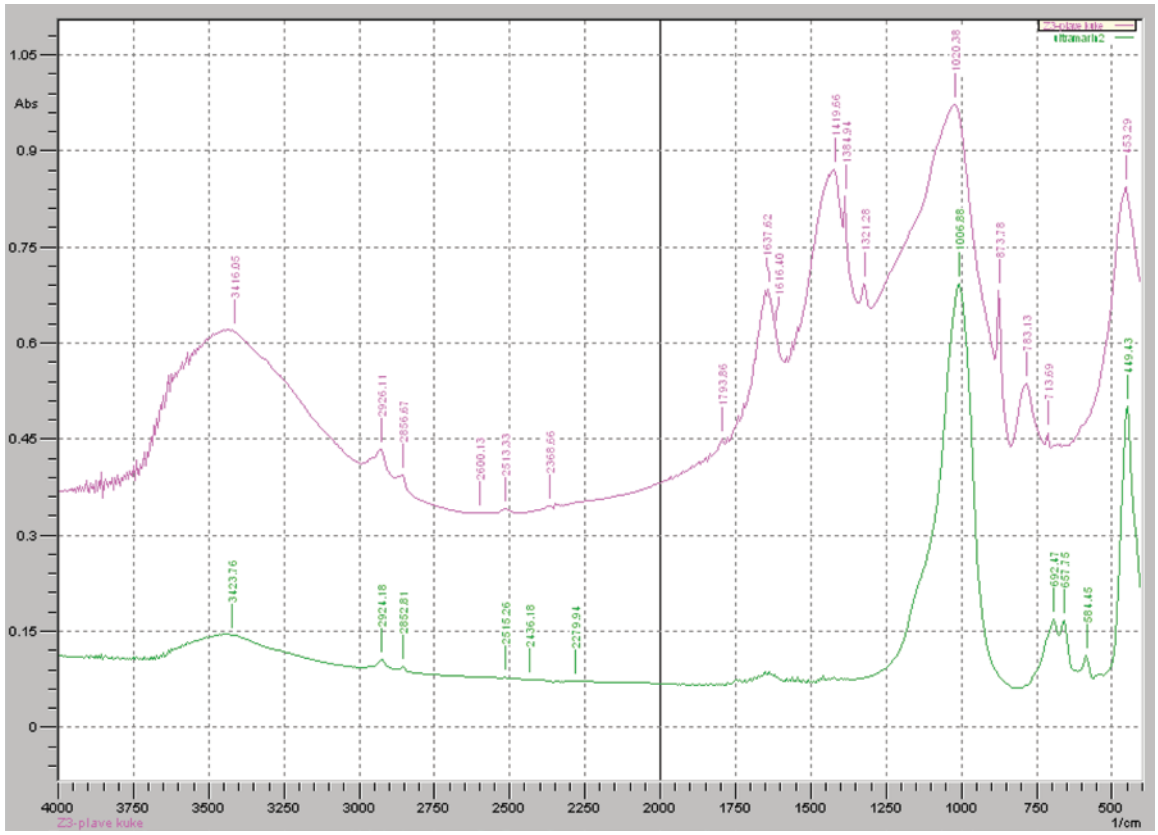

**Prilog 1. Preklopljeni IR spektri uzorka B1, talijanskog zlatnog okera i venecijansko crvene**
Appendix 1. Overlapping IR spectrums of Sample B1, Italian gold ocher and Venetian red

**izradio** / made by: **I. Ljubenkov**




**Prilog 2. IR spektar uzorka A2 – pikovi pigmenta se ne vide**
Appendix 2. IR spectrum of sample A2 – pigment peaks not shown

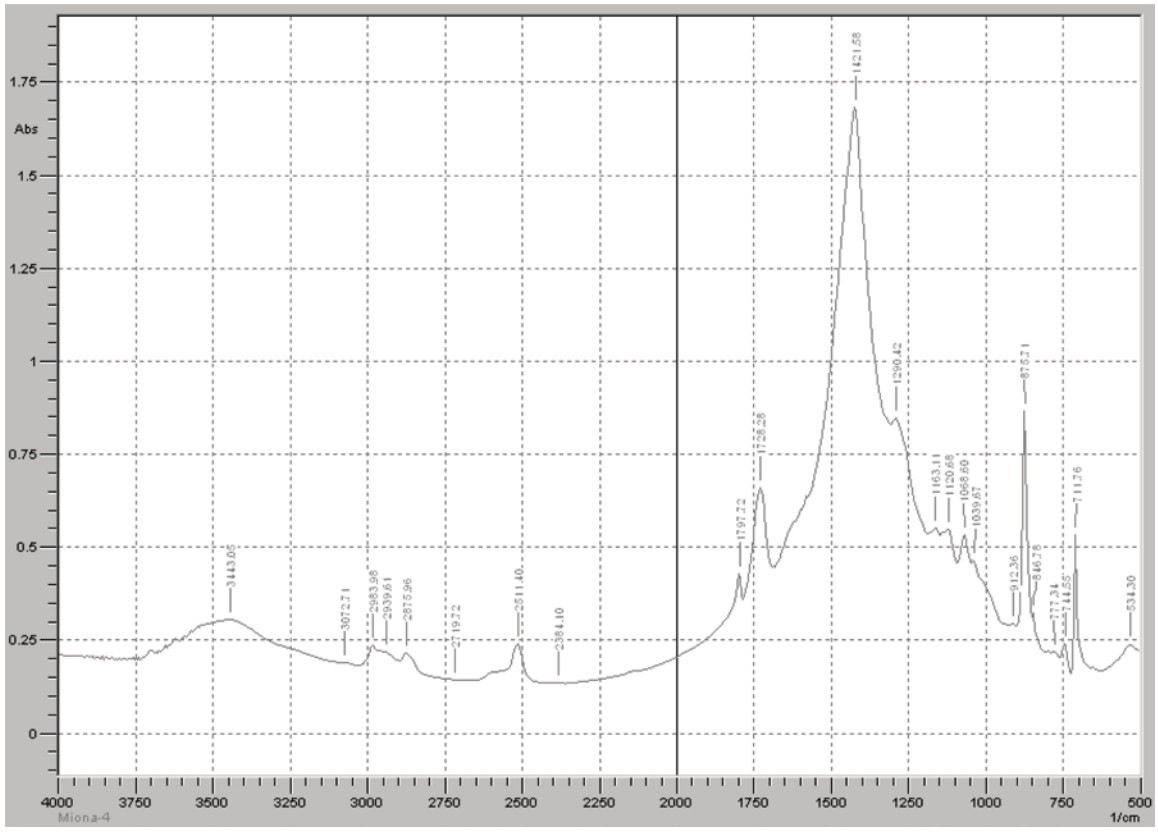
**izradio** / made by: **I. Ljubenkov**




**Prilog 3. Preklopljeni IR spektri uzorka B3 i ultramarina**

Appendix 3. Overlapping IR spectrums of Sample B3 and ultramarine blue

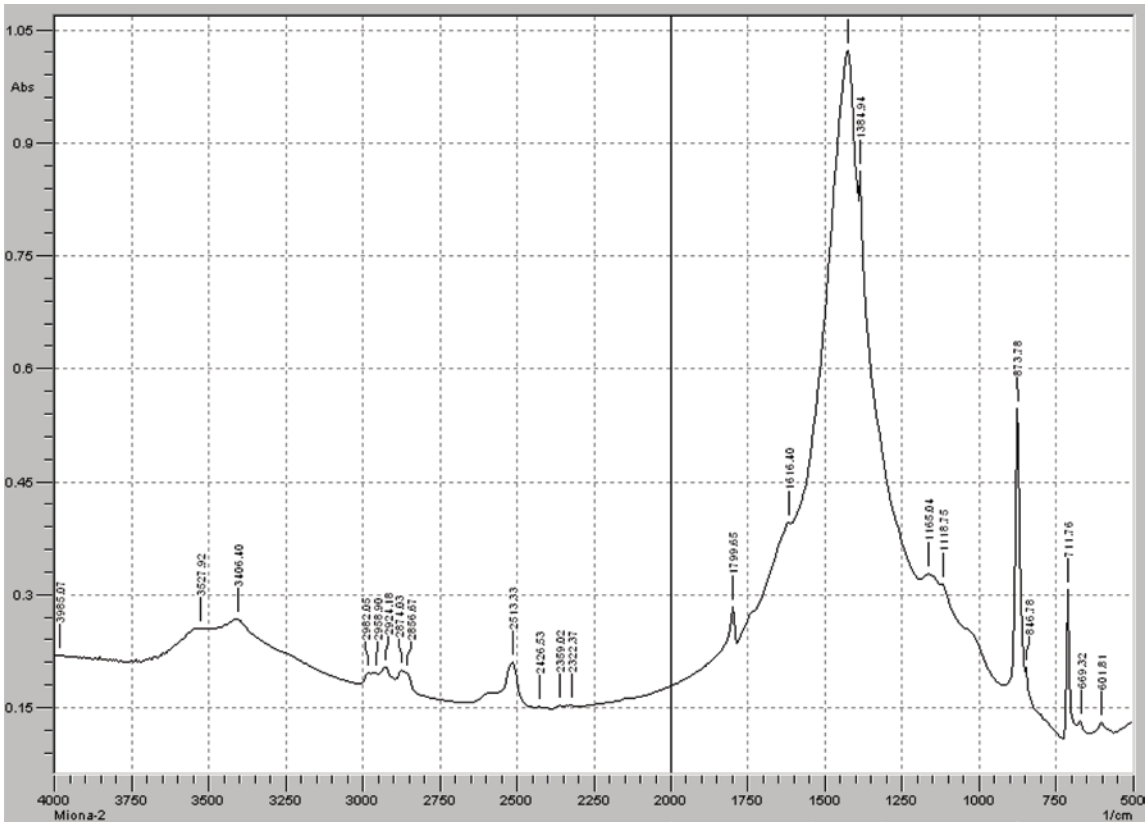
**izradio** / made by: **I. Ljubenkov**



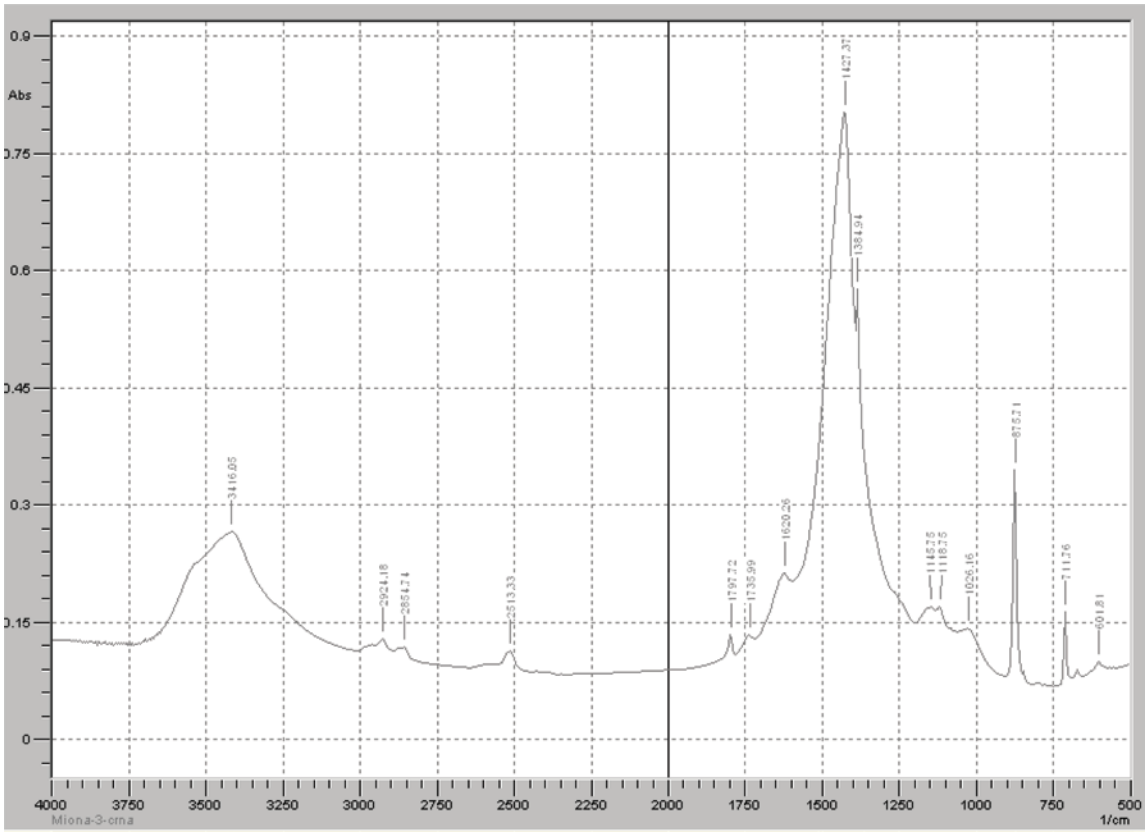

**Prilog 4. IR spektar uzorka A4**

Appendix 4. IR spectrum of sample A4

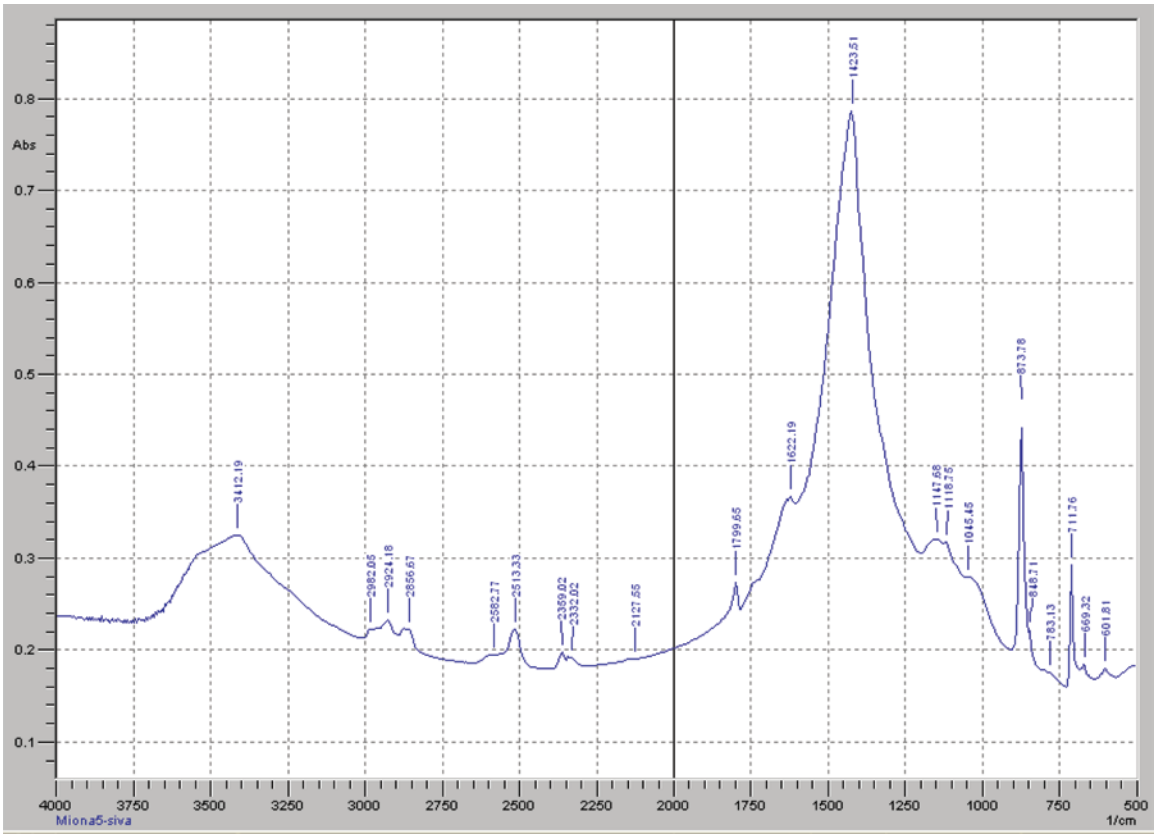
**izradio** / made by: **I. Ljubenkov**



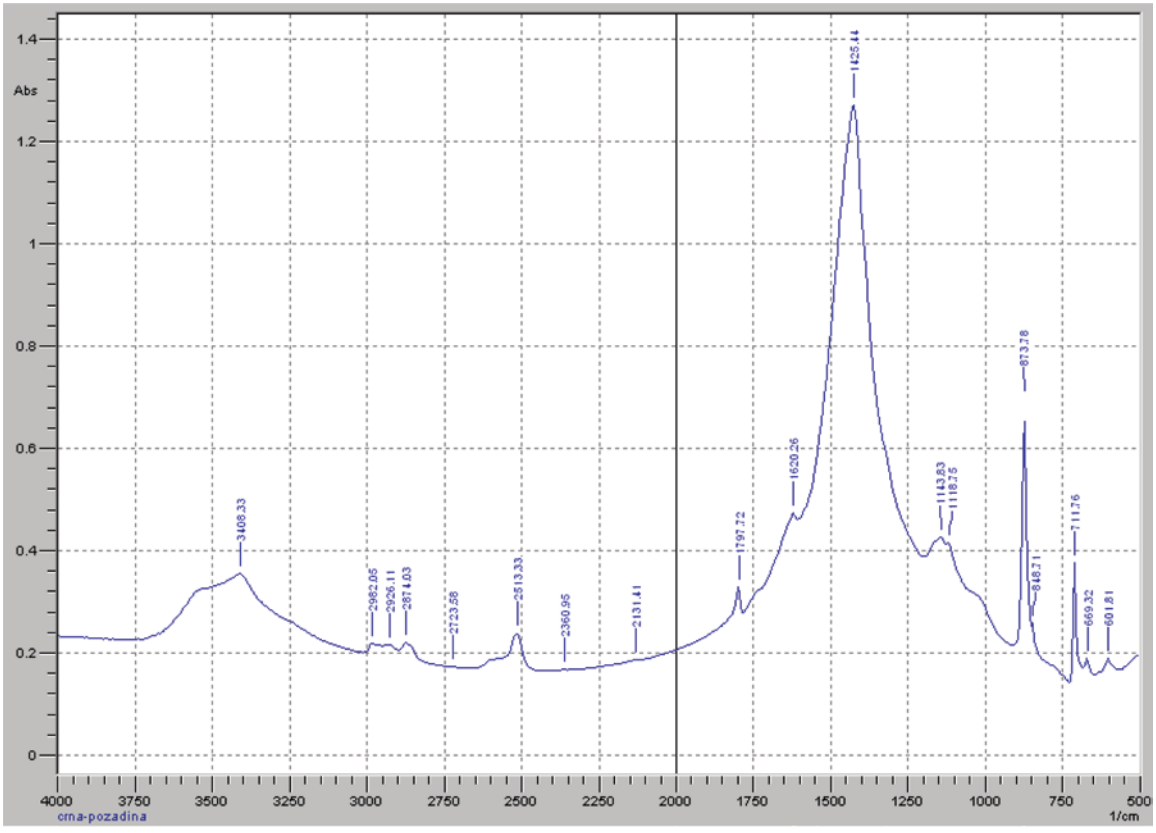

**Prilog 5. IR spektar uzorka B2 koji prikazuje samo prisutnost gipsa**
Appendix 5. IR spectrum of sample B2, showing only presence of gypsum
**izradio** / made by: **I. Ljubenkov**



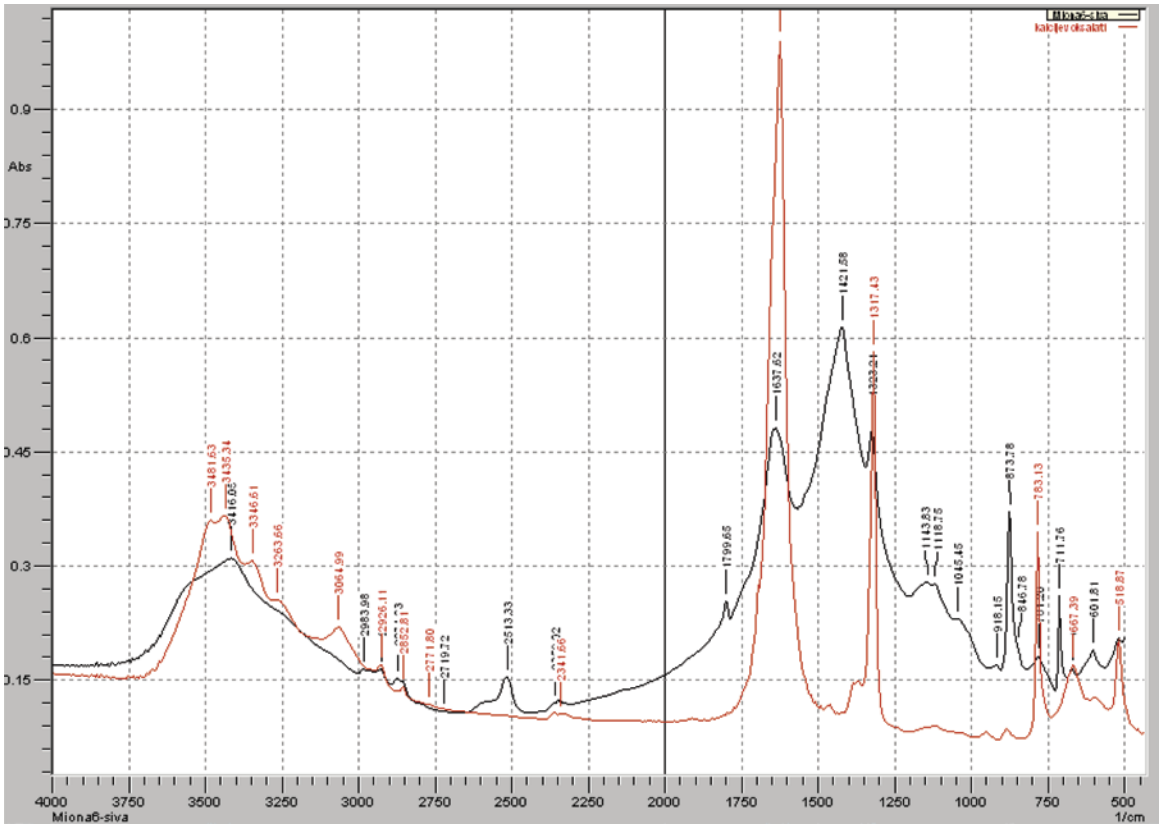

**Prilog 6. IR spektar uzorka B5 koji prikazuje samo prisutnost gipsa**
Appendix 6. IR spectrum of sample B5, showing only presence of gypsum
**izradio** / made by: **I. Ljubenkov**




**Prilog 7. IR spektar uzorka B3 koji prikazuje spektar gipsa s tragovima koštano crne**
Appendix 7. IR spectrum of sample B3, showing spectrum of gypsum with traces of bone black pigment
**izradio** / made by: **I. Ljubenkov**




**Prilog 8. IR spektar uzorka B7 koji prikazuje spektar gipsa s tragovima koštano crne**
Appendix 8. IR spectrum of sample B7, showing spectrum of gypsum with traces of bone black pigment
**izradio** / made by: **I. Ljubenkov**




**Prilog 9. Preklopljeni IR spektri uzorka B6 i kalcijevog oksalata**

Appendix 9. Overlapping IR spectrums of Sample B6 and calcium oxalate

**izradio** / made by: **I. Ljubenkov**

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