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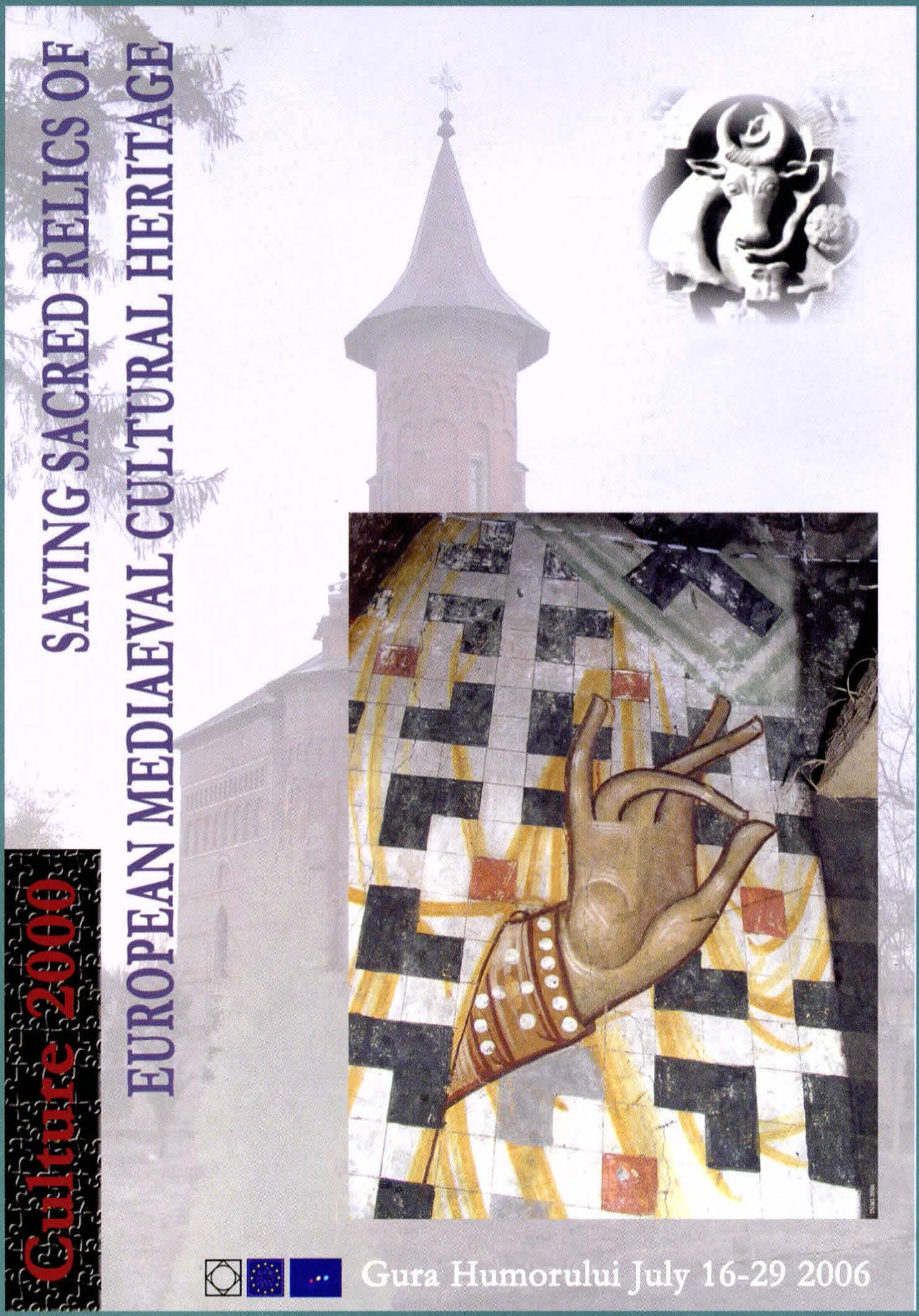

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REVISTA A FOST FINANȚATĂ PRIN PROGRAMUL **CULTURA 2000**, ÎN CADRUL PROIECTULUI *"SAVING SACRED RELICS OF EUROPEAN MEDIEVAL CULTURAL HERITAGE"*, 2005-2006

Coperta 1

Afişul Laboratorului in situ organizat în cadrul Proiectului *"Saving Sacred Relics of European Medieval Cultural Heritage"*

Poster of the Laboratory in situ organized in the frames of the Project *"Saving Sacred Relics of European Medieval Cultural Heritage"*

Coperta 4

Biserica Mănăstirii Suceviţa, una dintre locaţiile Proiectului *"Saving Sacred Relics of European Medieval Cultural Heritage"*

Church of Suceviţa Monastery, one of the sites of the the Project *"Saving Sacred Relics of European Medieval Cultural Heritage"*

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SAVING SACRED RELICS OF EUROPEAN CULTURAL HERITAGE.

A CULTURE 2000 PROJECT IN ROMANIA

Tereza Sinigalia

Within the European Union Programme "CULTURE 2000", during the month of November 2005, two Romanian organizations – the National Institute for Research and Development in the field of Opto-electronics (INOE) in collaboration with the National Institute for Historical Monuments (INMI) – in partnership with a series of prestigious organizations from Italy, Spain, Portugal and Austria were awarded a grant for the project "**Saving Sacred Relics of European Medieval Cultural Heritage**" (**Fig. 1**).

The main goal of the Project was the organization of the Laboratory for the experimentation of new laser technologies, applied to monuments and tangible cultural heritage items from the north of Moldavia, an extremely rich region of Romania, as far as cultural values are concerned

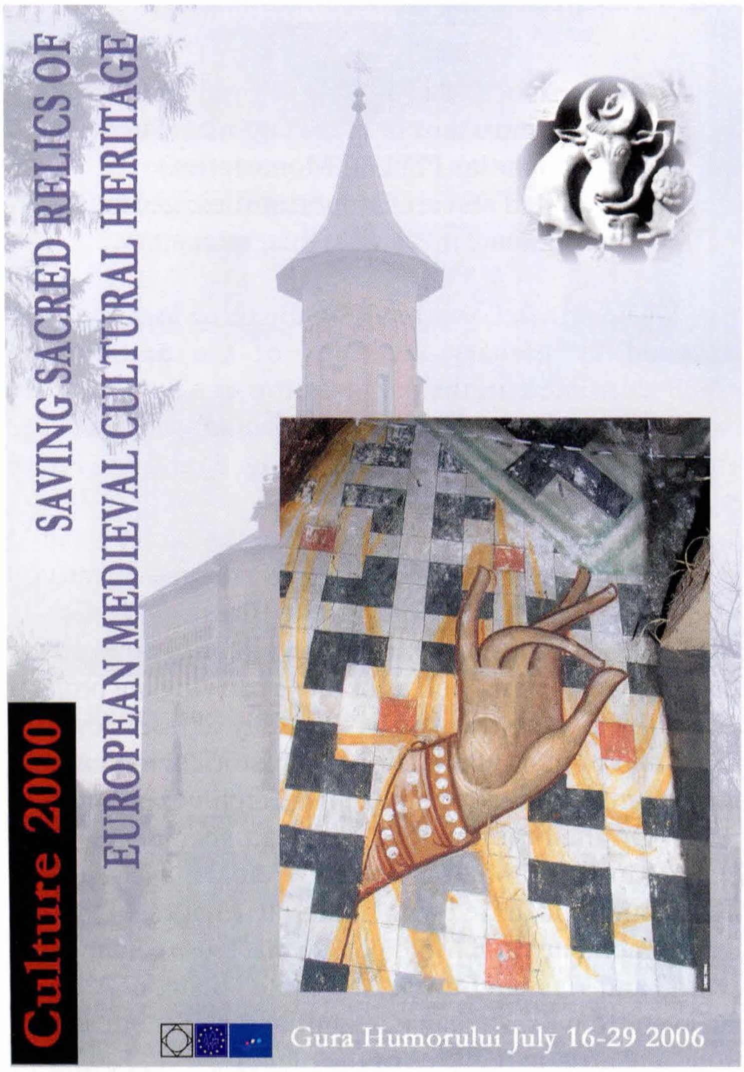

Fig. 1. Poster of the Laboratory in situ

For a two week-period (16^{th} – 29^{th} July 2006) about 100 specialists from Austria, Brazil, Germany, Greece, Italy, Great Britain, The Netherlands, Portugal, Russia, Slovenia, Spain, Unites States of America and Romania met themselves in northern Moldavia for *in situ Laboratory* [See Annex no 2: *List of Participants*].

As far as Romania is concerned, it was represented by the traditional collaborator of INOE from research and development institutes, but also by recognized specialists in the field of historical monuments and tangible heritage (painting restorers, art historians, architects, chemists, physicists). A special opportunity was created for the young Romanian specialists, PhD or master students but also for some students in the terminal years of the Restoration Departments within the Fine Arts Universities of Bucharest, Ia°i and Cluj and of the Sacred Art Departments of the Theological Institutes of Bucharest and Ia°i.

For them, the Laboratory proved to be a very useful workshop training, and the lectures and demonstrations consisted a very first way of disseminating the results of innovative research and applications, thus applying one of the major goals of the CULTURE 2000 Project.

The Laboratory took place in three locations: the monastery of Sucevita (Suceava county), the monastery of St. Nicholas Popãuti in Botosani (Botosani county) and the Church of St. Nicholas in Balinesti village (Suceava county) (**Fig. 2, 3, 4**).

The choice of the three locations above was done taking into account several criteria:

- Artistic importance: All three are very important items of the national and the world cultural heritage especially for their architecture and mural paintings;
- History: All are monuments dated to the 15^{th} century (Balinesti, Botosani) and 16^{th} century (Sucevita)
- State of conservation: it varies at the level of the architectural features (including stone elements), and at the level of the frescoes, respectively
- Before hand existence of a mural painting restoration site

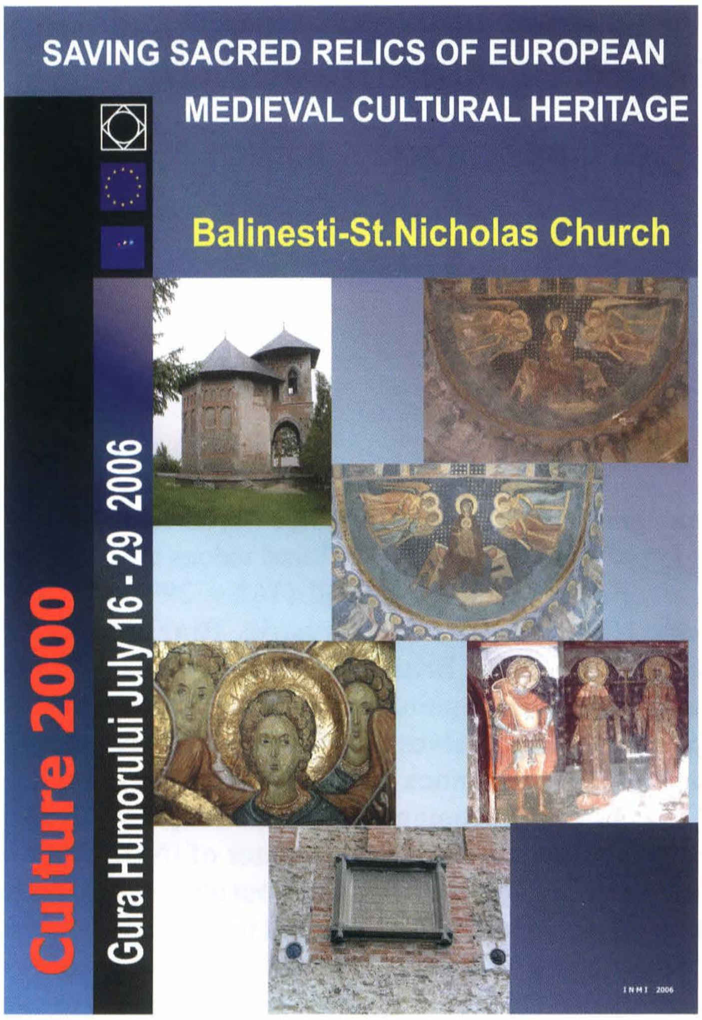

Fig. 2. St Nicholas church, Balinesti

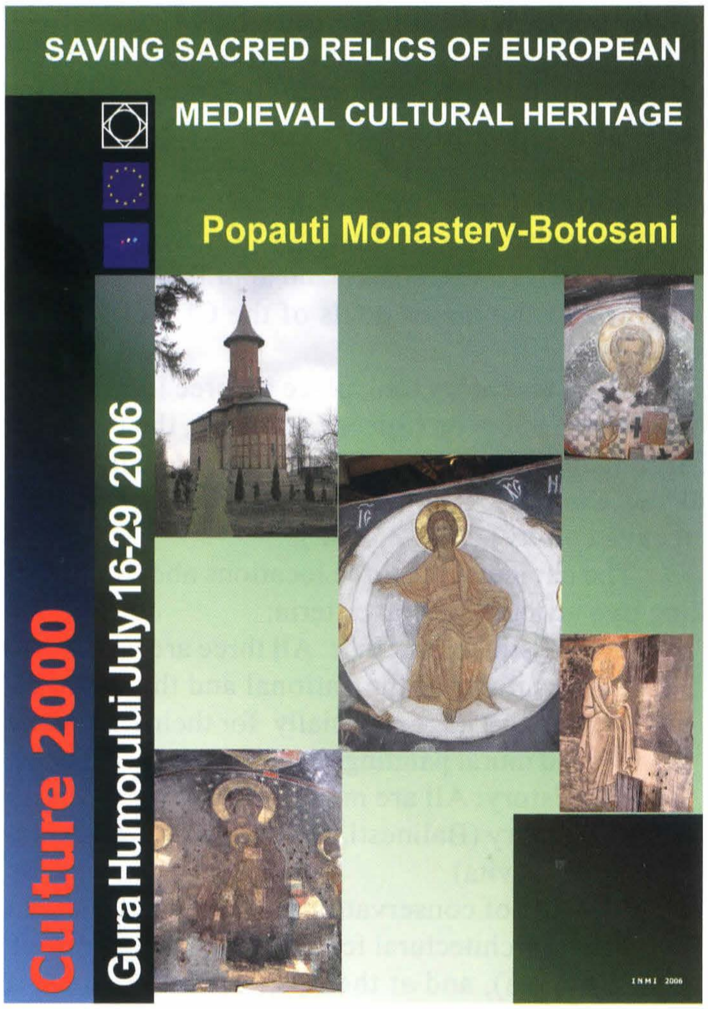

Fig. 3. St Nicholas church, Popãuti Monastery

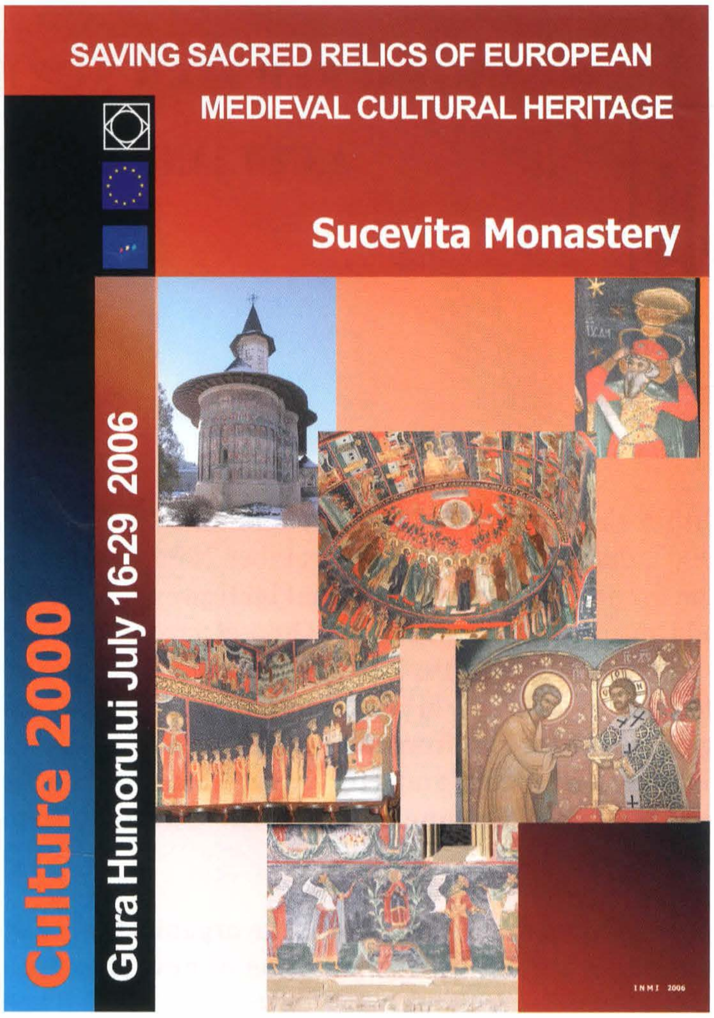

Fig. 4. Resurrection church, Sucevita Monastery

- Existence of a valuable cultural heritage in the local museums or in the deposits (Sucevita and St Nicholas Popauti Monasteries)
- Related research opportunities: georadar, microclimate measurements, art history.

The *in situ* Laboratory on the three locations was preceded by plenary meetings of the participants, which consisted in the presentation of a number of 36 contributions of the foreign and Romanian specialists [See Annex no 1 – List of participants] (**Fig. 5**) and of a Poster session (**Fig. 6**).

Their topics, subordinated to the wider topic of the Laboratory, varied according to the type of activity practiced by each contributor or by the organization to which he/she belonged. Most of the interventions of the foreign specialists as well as of those carrying out projects within INOE were focused on the study of laser developments and of their applications on historical monuments or on tangible heritage in museums , archives or libraries.

On the other hand, Romanian specialists (Prof. Tereza Sinigalia and Eng. Andrei Vretos) made a general presentation illustrated with numerous images, of the mediaeval monuments of Moldavia, so that those coming from Central and Western Europe, the United States of America and even from Brazil, can get familiar with historical, religious and artistic realities of the places.

Mural painting restorers working in the sites of the three monuments specified above (Prof. Oliviu Boldura

Fig. 5.

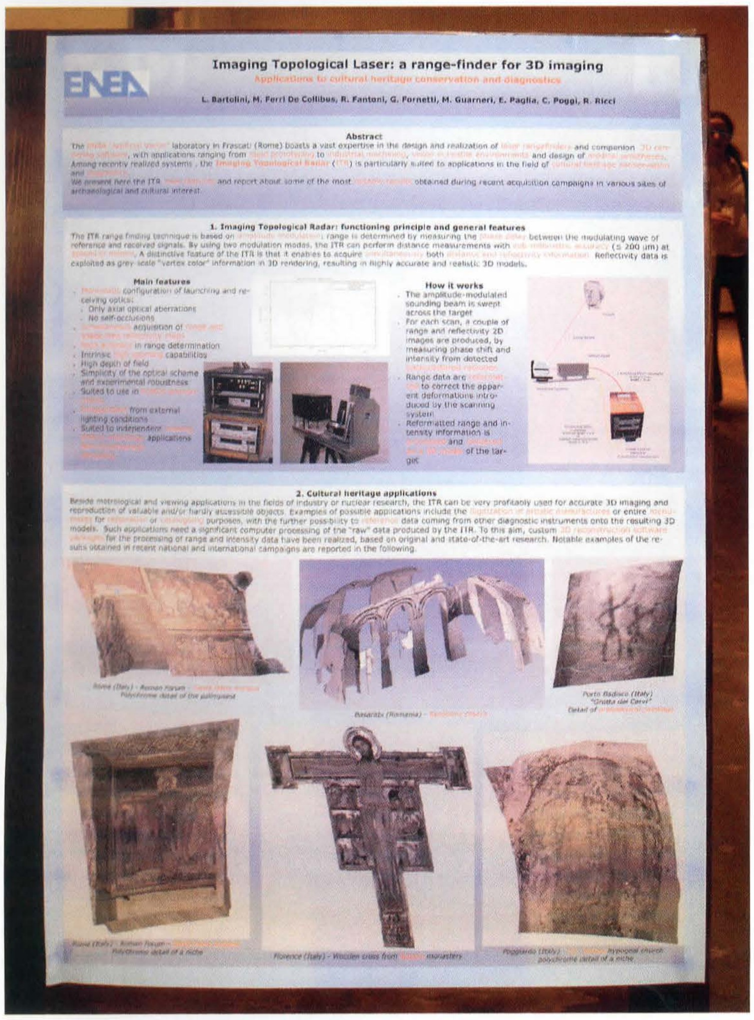

Fig. 6. Poster presented by ENEA, Italy

for Sucevita, Carmen Solomonea for Botosani and Geanina Rosu for Balinesti) prepared ample presentations of their works. Starting from the state of conservation of the wall paintings, the physical-chemical and biological investigations, as well as from the observations on the microclimate, they presented the classical restoration methodology, which consists in the following procedures: cleaning, consolidation of the support layers (masonry, *arriccio, intonaco*) and of the paint layer as well, removal of the biological growth and of its consequences, chromatic integration [See *Presentations* in this paper]. The techniques were discussed in details, with the thoroughness of the practitioner, but also with the opening of the researcher toward the experimentation of new materials proposed during the last decade by restorers from Occidental restoration institutes and then, with the due prudence establishing their adequacy to the local realities - which are different from those known by the initiators and users of such new materials, successfully applied for instance in Italy, where they are currently used – for the restoration of the painted monuments of Moldavia.

Complementary to the theoretical presentations, the Romanian restorers also provided on the spot, punctually, for each objective of the project, additional explanations and even demonstrations as for the application of some of the techniques. .

The rotation of the groups in each of the three locations gave the possibility to all the participants to follow both the application of the traditional techniques and of the innovating ones, as well as a mutually fruitful dialogue (**Fig. 7**).

The practical part of the *in situ* Laboratory – developed on 5 days applications - raised the interests of Romanian specialists and of the foreign ones as well. If the former ones got acquainted with the possibilities of application of laser techniques in cleaning murals (**Fig.**

Fig. 7. Participants to the Laboratory in Popauti Monastery

8, 9, 10, 11), stone surfaces (**Fig. 12**), metal items (**Fig. 13**), textile items (**Fig.14,15,16**) or paper documents (**Fig. 17,18, 19**), in 3D scanning (**Fig.20**) the latter showed their interest in the richness, variety and state of conservation of the heritage of these churches, monasteries and collections. The exchange of information, the practical demonstrations (**Fig. 21, 22, 23, 24, 25**), the colloquial atmosphere (**Fig. 26**) dominated the 5 days of the *in situ* Laboratory (**Fig. 27, 28**).

The three goals of the Project were not the only aspects the participants were interested in. In order to complete the information and assure a best possible approach of the cultural heritage of Moldavia, the organizers of the Laboratory also proposed visits to the monasteries of Voronet, Humor and Probota, all three in-

Fig. 8. Laboratory in Gura Humorului. Final photo

Fig. 9.St Nicholas church, Popauti Monastery.
Laser cleaning tests

Fig. 10.St Nicholas church, Popauþi Monastery.
Laser cleaning tests

Fig. 11.St Nicholas church, Popauti Monastery.
Laser cleaning tests

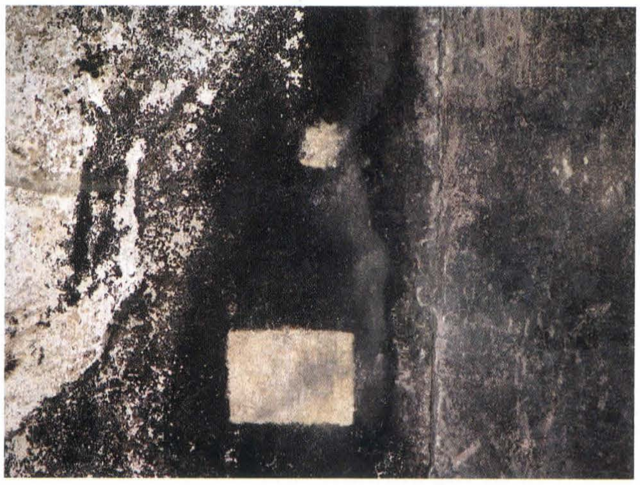

Fig. 12. Nicholas church, Popauti Monastery.
Laser cleaning tests - stone

Fig. 13. Popauti Monastery. Metal cleaning

Fig. 14. Sucevita Monastery. Metal examination

Fig. 15. Sucevita Monastery. Textile examination

cluded in the World Heritage List. In the case of the first two monuments, the murals are still in the process of restoration, while in the case of the last monument, the restoration process was completed in 2001, as the monastic

Fig. 16. Sucevita Monastery. Textile examination

Fig. 17. Sucevita Monastery. Paper examination

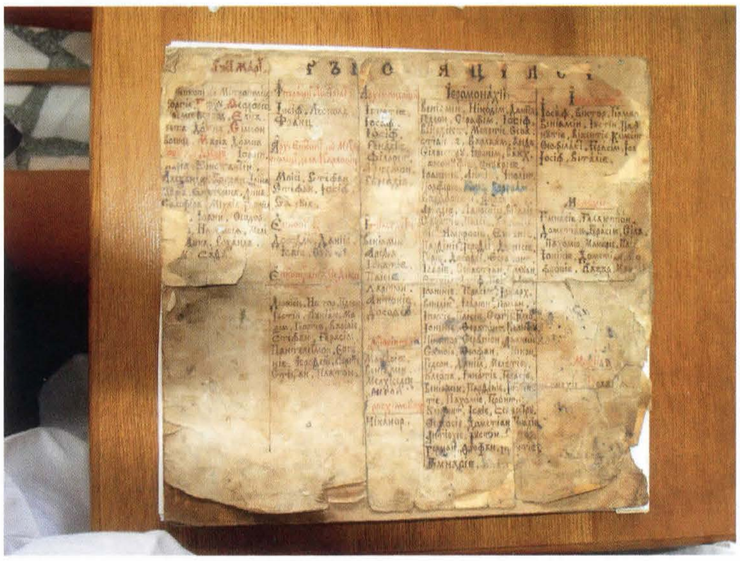

Fig. 18. Sucevita Monastery. Paper examination

compound, founded by Prince Petru Rares, was subject to a wide programme of research, exhaustive restoration and presentation, carried out by UNESCO and financed by the Japan Trust Fund for World Heritage and

Fig. 19. Sucevita Monastery. Paper examination

Fig. 20.Sucevita church. 3D scanning

Fig. 21. Sucevita church. Hiperspectral lidar fluorosensor scanning

Fig. 22. Popauti Monastery. Geo-radar

Fig. 23. Laboratory aspect

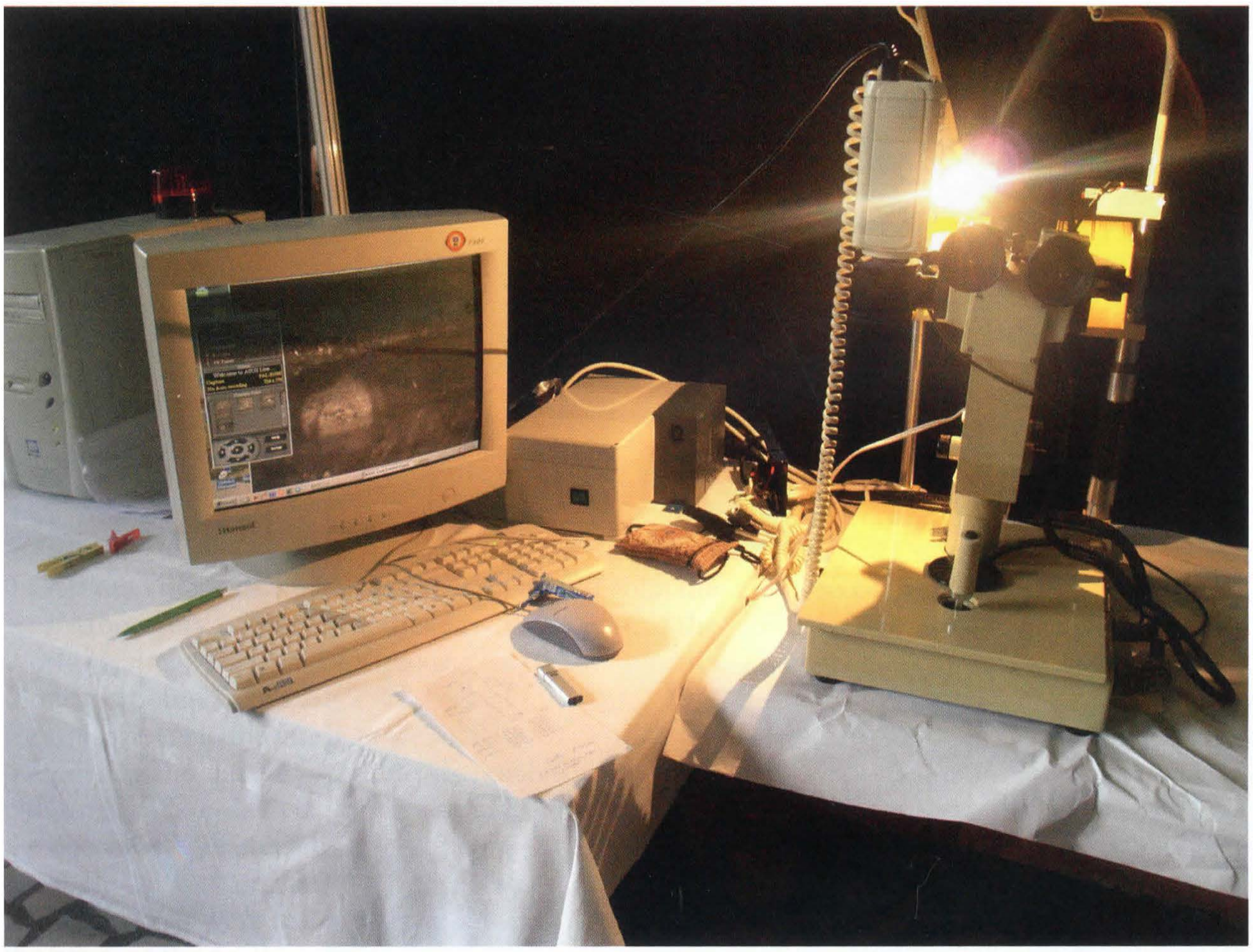

Fig. 24. Laboratory aspect

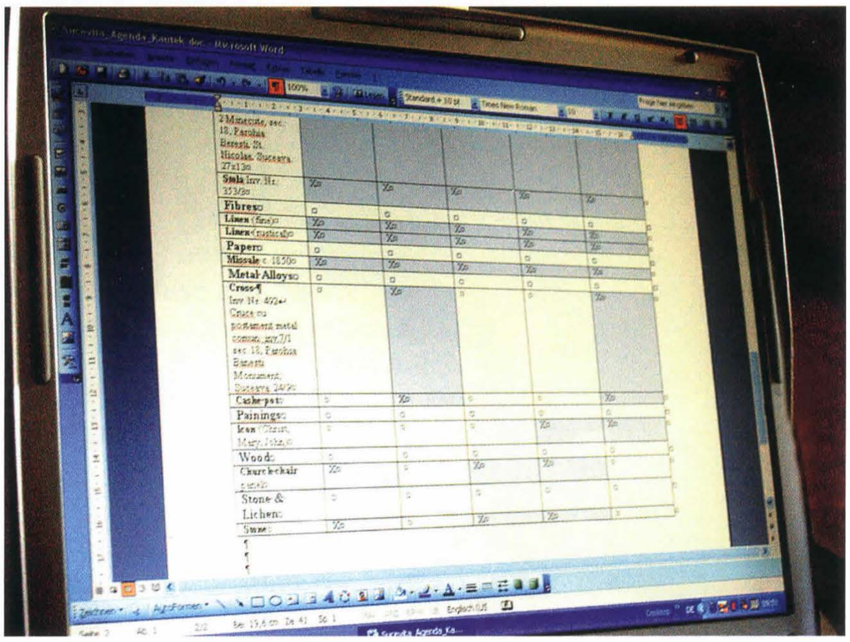

Fig. 25. Programme of the applications on sites

Fig. 26. Sucevita laboratory on site

Fig.27. Sucevita laboratory on site

Fig. 28. Sucevita laboratory on site

the Government of Romania.

Other restoration processes are going on the church of the Arbore village as well as in the church of St John the New Monastery of Suceava, these two also part of the World Heritage List. In the monasteries of Dragomirna (Suceava county) and Bistrita (Neamt county), visits were also made to the museums inside the monastic compounds. In the case of Agapia, the recently restored paintings of Nicolae Grigorescu could be admired. In the church of Neamt Monastery, only paintings of the chancel, the western part of the nave and the former burial chamber were restored, the frescoes in the rest of the nave, of the narthex and porch still waiting for restorers.

The National Institute for Historical Monuments actively involved in the preparation and implementation of the Project from the elaboration phase to the one of the application submitted for obtaining the grant and later on to the selection of the most significant locations for carrying out the Laboratory, the selection of the Romanian specialists and of the young graduates and postgraduates.The Institute prepared the documentation for the general presentation of the monuments in Moldavia, the CD-rom with the sheets of the three major objectives of the Project, together with tens of images, posters for the special demonstration session, which raised the interest of the participants. It was also the Institute who took care of the logistic aspects related to the event, administrating both the funds from the European Union and the funds received from the Ministry of Culture and Religious Affairs for the implementation of the Project.

*

Unwritten, but permanently present, the guiding principle of the reunion could have been: "Cross-disciplinary. Communication".

Already at the beginning of the Laboratory, the Greek researcher Vassili Zafiropulos remarked, while speaking of the laser-based techniques, that these are an instrument; they are not the process of conservation in itself, conservation which is the aim of the intervention, in view of preserving the works of cultural heritage and forward them to the future generations. As the laser procedures concern for the most the process of cleaning architectural or art works (for instance the marbles of the Parthenon or mural paintings), Zafiropulos considered their use as a challenge, whose success can be ensured only by the understanding of the phenomenon and by the cross-disciplinary communication, and the use of a mix of procedures (application from case to case of the UV or IR irradiation).

The implementation of experiments within such Laboratories is as important as the transfer of technology, the *khow-how* of a methodology, which although used for decades in other fields, finds in the protection of cultural

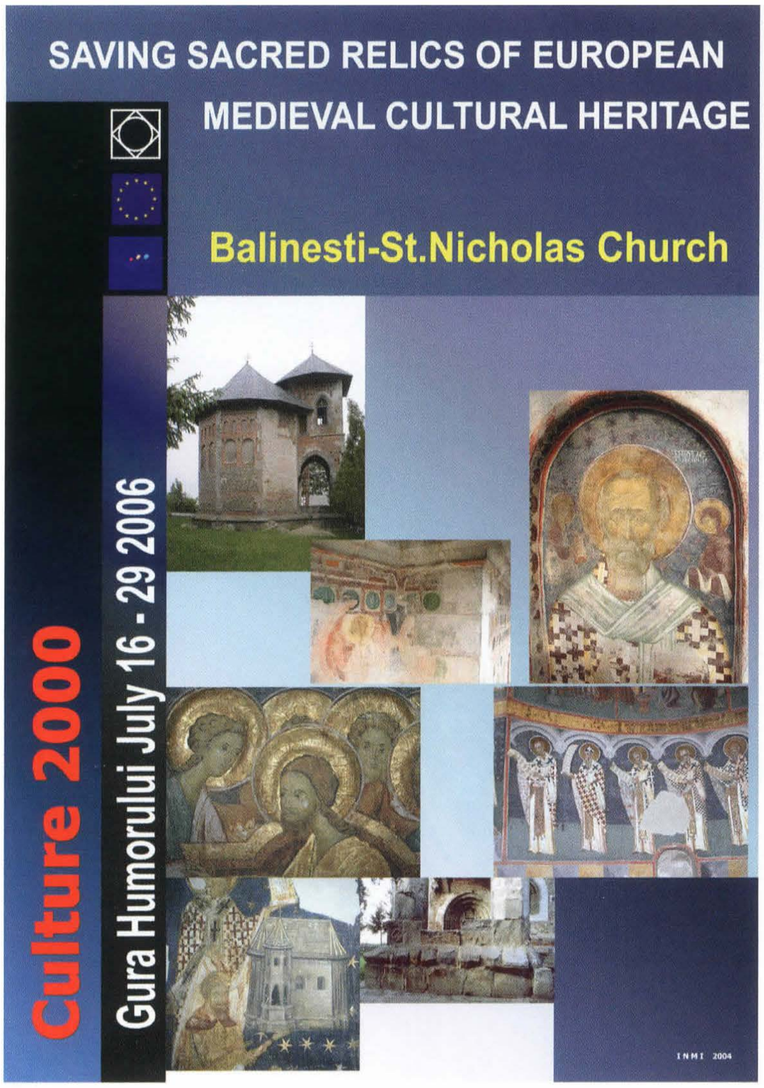

Fig. 29. St. Nicholas church Balinesti. Poster

heritage a new area of application and therefore a new utility (**Fig. 29**).

The introduction on a large scale in Romania of this technology within the restoration of the cultural heritage, combined with the "traditional" methods, specific to each field and type of items, is a wish and a challenge at the same time for all those who participated in the Laboratory, who will moreover forward what they learnt within this framework to those who believe that past may have its future.

*

The *In situ* Laboratory in northern Moldavia was not the final point of the Project. Restoration works at mural paintings in the churches of Sucevita and Popauti Monasteries and in Balinesti continued with the traditional methodology, already approved by the National Commission of Monuments of Romania, in August and September. The results of this work is presented in the next pages of the present paper.

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European Union, Ministry of Culture and Religious Affairs of Romania, foreign Institutes involved in the Project, Archbishopric of Suceava and Radauti, especially Archbishop Pimen, monastic communities of Suceviþa (Superior Mother Mihaela Cozmei) and Popauti – Botosani (Superior Father Luca Diaconu), parish church Baline°ti (Father Gheorghe Lupu), all the participants taking part to the Laboratory.

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DAVIDE **SANSONE**	Conservator	ITALY, Accademia di Belle Arti, Palermo
DAN **SAVASTRU**	Engineer	ROMANIA, National Institute for Research for Optoelectronics /INOE 2000
ROXANA **SAVASTRU**	Engineer	ROMANIA, National Institute for Research for Optoelectronics /INOE 2000
CORNELIA **SĂVESCU**	Restorer	ROMANIA, National University of Arts, Bucharest
BLAZ **SEME**	Restorer	SLOVENIA
SALVATORE **SIANO**	Researcher	ITALY, IFAC-CNR, Sesto Fiorentino
MONICA **SIMILEANU**	Engineer	ROMANIA, National Institute for Research for Optoelectronics /INOE 2000
VLADIMIR **SIMON**	Consultant	ROMANIA, Consultancy Centre for European Cultural Programmes, Buch.
TEREZA **SINIGALIA**	Art Historian	ROMANIA, National Institute for Historical Monuments, Bucharest
CARMEN CECILIA **SOLOMONEA**	Restorer	ROMANIA, University of Arts "G. Enescu", Iaşi
JOAKIM **STRIBER**	Engineer	ROMANIA, National Institute for Research for Optoelectronics /INOE 2000
MATIJA **STRLIC**	Researcher	SLOVENIJA, University of Ljubljana, Ljubljana
GABRIELA **STRNAD**	Professor	ROMANIA, University "Petru Maior", Tg. Mures
PAUL **TOCANIE**	Researcher	ROMANIA, Institute for Eco-Museal Research, Tulcea
BOGDAN **UNGUREAN**	Doctor student	ROMANIA, University of Arts "G. Enescu", Iaşi
PAULA **VARTOLOMEI**	Restorer	ROMÂNIA,CERECS ART, Bucharest
ANA-MARIA **VLAD**	Physics research. ROMANIA, National Research Laboratory for Conservation, Bucharest	
L.F. van **VRIJBERGHE de CONINGH** Restorer		NETHERLANDS, Restauratie Atelier SCHILDERIJEN, Muiden
ANDREI **VRETOS**	Engineer IT	ROMANIA, National Institute for Historical Monuments, Bucharest
JOHANNES **WEBER**	Engineer	AUSTRIA, Technical University, Vienna
VASSILIS **ZAFIROPOULOS**	Engineer	GREECE,Technological Educational Institute of Crete, Sita, Crete
MIRELA **ZAMFIRESCU**	Architect	ROMANIA, National Institute for Historical Monuments, Bucharest

Program Overview | Official language: English

Time	July 16, 2006 - Sunday	Location
12.00	Registration Opens /Workshop Secretariat	Hotel Best Western
	July 17, 2006 - Monday	
8.00	Workshop Secretariat Opens	Hotel Best Western
9.30	Opening Ceremony	Hotel Best Western
	Welcome messages from local authorities and organizers	Tisa Hall
	Vladimir Simon (Romania) – CULTURE 2000 Program's Results and Perspectives	
10.30	**Session 1 / ART- Advanced Research Techniques (Part I)** Chair: Roxana Savastru (Romania) Raporteur: Roxana Radvan (Romania)	
10.30	Vassilis Zafiropulos (Greece) *Lasers in Art Conservation: A cross-disciplinary scientific field*	
11.00	John Asmus (USA) *Radiation Science in the Service of Art*	
11.30	Coffee Break	
12.00	**Session 1 / ART- Advanced Research Techniques (Part II)** Chair: Jose Goncalves (Portugal) Raporteur: Paul Tocanie (Romania)	Hotel Best Western Tisa Hall
12.00	Renzo Salimbeni (Italy) *COST Actions for Cultural Heritage: Crossing Borders*	
12.30	Gheorghe Niculescu (Romania) *National Research Laboratory for Conservation and Restoration of Movable National Cultural Heritage. State of the Art*	
13.00	Roxana Radvan (Romania) *Centre for Restoration by Optoelectronical Techniques*	
13.30	Lunch	Hotel Best Western Restaurant
15.00	**Session 2 / Environment Control Techniques and Methods (Part I)** Chair: Wolfgang Kautek (Austria) Raporteur : Theo Mureşan (Romania)	Hotel Best Western Tisa Hall
15.00	Dario Camuffo (Italy) *Investigations performed to point out the interactions between artworks and microclimate variability within the European Project Friendly-Heating*	
15.30	Marta Castillejo (CSIC, Spain) *Thin films, nanostructures and new optical devices for environmental sensing*	
16.00	Francesco Colao (Italy) *Compact scanning LIDAR fluorosensor for investigations of biodegradation on ancient painted surfaces*	
16.30	Coffee Break	
17.00	**Session 2 / Environment Control Techniques and Methods (Part II)** Chair: Wolfgang Kautek (Austria) Raporteur : Theo Mureşan (Romania)	
17.00	Jose Gonsalves (Portugal) *Humidity Analysis and Control*	
17.30	Vasco Fassina (Italy)	

	Surface protection of wall paintings: laboratory test methods for the evaluation of the performance of water repellent product		
18.00	Anabela Hipolito (Portugal) *Archaeology & Patrimony*		
19.30	Welcome Reception		Hotel Best Western Restaurant

July 18, 2006 - Tuesday

9.00	**Session 3 / Laser Cleaning Techniques**	Chair: John Asmus (USA) Raporteur : W. Hesterman (Netherlands)	Hotel Best Western Tisa Hall
9.00	Wolfgang Kautek (Univ. Vienna –Austria) *Laser cleaning of organic materials*		
9.30	Nimmrichter Johann (Federal Office for Care of Monuments of Vienna, Austria) *The use of lasers in the field of conservation in Austria*		
10.00	Salvatore Siano (IFAC, Italy) *Laser cleaning optimization through suitable selections of the laser pulse duration: brief discussion of several case studies*		
10.30	W. Hesterman (Restauratie Atelier SCHILDERIJEN- The Netherlands) *Laser Cleaning on easel paintings*		
11.00	Coffee break		Hotel Best Western
11.30	**Session 4 / Diagnosis Techniques**	Chair: Vassilis Zafiropulos (Greece) Raporteur : : Johann Nimmrichter (Austria)	Hotel Best Western Tisa Hall
11.30	Roberta Fantoni (ENEA, Italy) *Amplitude-modulated Laser Range Finder (LRF) for 3D imaging with multi-sensor data integration capabilities during field operation*		
12.00	Marta Castillejo (CSIC, Spain) *Laser in Conservation: Analysis and Diagnosis with Laser Induced Breakdown Spectroscopy and Laser Induced Fluorescence*		
12.30	Daniela Ferro (Italy) *Advantage and limits of the use of surface analysis in the individuation of ancient working processes*		
13.00	Monica Simileanu (Romania) *Laser Cleaning Strategies spring up Historical Buildings - Laser Cleaning Applications in Romania*		
13.30	Lunch		Hotel Best Western
15.00	**Session 5 - Interferometry and Image Techniques (Part I)**	Chair: Panos Liatsis (UK) Raporteur : Andrej Demsar (Slovenia)	
15.00	Margarida Pires (Portugal) *3D Images of Artworks by Laser Scanning*		
15.30	Laura Baratin (Italy) *Three dimensional imaging of cultural heritage through use of laser scanner technologies as a basis for getting to know cultural assets and bringing out their value*		
16.00	Walter Maracineanu (INOE-Romania) *Multispectral Image Analysis Applications*		
16.30	Cristian Deciu (INOE-Romania) *3D laser scanning of the Stavropoleos Church's Atrium from Bucharest*		
17.00	Coffee Break		Hotel Best Western

	Visit to Gura Humorului Monastery – in restoration	Gura Humorului Monastery
20.00	Dinner	Hotel Best Western Restaurant

July 19, 2006 - Wednesday

9.00	**Session 6 / Case studies (Part I)** Chair: Marta Castillejo (Spain) Raporteur : Vasco Fassina (Italy)	Hotel Best Western Tisa Hall
9.00	Jose Gonsalves (Portugal) *The medieval graphite mural sketches of holy spirit Chapel – Sesimbra. New techniques in monument analysis*	
9.30	Enrico Esposito (Italy) *Non destructive/non invasive advanced and experimental techniques for diagnostics of cultural heritage*	
10.00	Synthia Gonsalves (Brasil) *Infrared thermography applied to works of art diagnostic: implementation methodology, uncertainty of measurement analysis and case studies*	
10.30	Vasco Fassina (Italy) *Experimental results on the protection of outdoor mural paintings of Feltre*	
11.00	Coffee break	
11.30	**Session 6 / Case studies (Part II)** Chair: Marta Castillejo (Spain) Raporteur : Vasco Fassina (Italy)	Hotel Best Western Tisa Hall
11.30	W. Hesterman (The Netherlands) *Controlled laser cleaning of fire-damaged paintings*	
12.00	Teresa Bispo (Portugal)	
12.30	Franco Fazzio (Italy) *Il restauro dei mosaici della Cappella Palatina in Palermo- nuova metodologia nella reintegrazione delle lacune*	
13.00	Bogdan Iacob (Romania) *The University of Art and Design in Cluj-Napoca - history, goals and perspectives*	
13.30	Lunch	
15.00	POSTER SESSION and case studies presentations (movies and power point projections)	
18.00	Chair: Margarida Pires (Portugal)	Poster Hall
19.00	Dinner	

July 20, 2006 - Thursday

9.00	**Session 4 - Site Presentations** Chair: Tereza Irene Sinigalia (INMI-Romania) Raporteur : Octaviana Marincas (Univ.Iasi-Romania)	Hotel Best Western Tisa Hall
	Art Historians Perspective North Moldavian Presentation	
	Tereza Irene Sinigalia (INMI-Romania) *Churches in Moldavia - an European heritage*	
11.00	Coffee Break	
11.30	Oliviu Boldura (CERECS ART-Romania) Restorers Perspective on Sucevita Casuistry	

12.30	Carmen Solomonea (University of Iasi-Romania) Restorers Perspective on Popauti Casuistry	
13.00	Lunch	
14.30	Oliviu Boldura (CERECS ART-Romania) Restorers Perspective on Balinesti Casuistry	
16.30	Coffee Break	
17.00	**Round Table** – Experimental set-up and working places organization Experiments Program	Hotel Best Western Tisa Hall
18.00	Visit to Voronet Monastery – in restoration	
19.30	Dinner	
	July 21-26, 2006	
9.00 -17.00	Parallel activities in the three important sites: Working point 1 - Balinesti Church (Balinesti village) Coordinators: Oliviu Boldura & Roxana Radvan Working point 2 – Popauti Monastery – Botosani city Coordinators: Carmen Solomonea & Joakim Striber Working point 3 - Sucevita Monastery – Church Coordinator: Oliviu Boldura & Cristian Deciu Working point 4 - Sucevita Monastery – Library Coordinator: Tereza Sinigalia & Walter Maracineanu Visits to *Saint John* Church – Suceava (restoration yard)	Balinesti, Popauti, Sucevita
	July 23- Sunday, 2006	
	Trip to several restoration yards	
	Lunch and Dinner in various places nearby visited places	
	July 27, 2006 – Thursday	
09:45	Seminar – "*Results Reporting and Data Interpretation*" – **Balinesti Church** Chair: Roxana Radvan Raporteur : Gianina Rosu **Introduction** – Gianina Rosu – 5' **Laser Induced Fluorescence** – Francesco Colao – 15' **Vibrometry** – Enrico Esposito – 15' **Ground Penetration Radar** – Enrico Esposito – 10' **3D Scanning** – Cristian Deciu – 10' **Microclimate monitoring** – Joakim Striber – 10' **Discussion** – 10'	Hotel Best Western Tisa Hall
11.00	Coffee Break	
11:30	Seminar – "*Results Reporting and Data Interpretation*" – **Popauti Monastery** Chair: Oliviu Boldura Raporteur : Carmen Solomonea **Introduction** – Carmen Solomonea – 10' **Laser Induced Fluorescence** – Francesco Colao – 15'	Hotel Best Western Tisa Hall

	Vibrometry – Enrico Esposito – 15' **Ground Penetration Radar** – Enrico Esposito 20' **Microclimate monitoring** – Joakim Striber – 10' **Laser Cleaning** – Johann Nimmrichter & Francesco Grazzi – 20' **Discussion** - 30'	
13.30	Lunch	
	Seminar – "*Results Reporting and Data Interpretation*" – **Sucevița Laboratory** Chair: Wolfgang Kautek Raporteur : Daniela Ferro **Introduction** – Wolfgang Kautek – 10' **Colorimetry** – Jens Hildenhagen – 10' **Metals** – Daniela Ferro & Mohamed Oujja – 20' **Icon & Chair** – W. Hesterman – 15' **Paper** – Matija Strilic – 15' **Textile** – Goijka Pajagic – 20' **Discussion** – 15'	Hotel Best Western Tisa Hall
16.45	Coffee Break	
17:00	Seminar – "*Results Reporting and Data Interpretation*" – **Sucevița Church** Chair: Tereza Sinigalia Raporteur : Oliviu Boldura **Introduction** – Oliviu Boldura -10' **Laser Induced Fluorescence** – Francesco Colao – 10' **Laser Range Finder** – Massimiliano Guarneri – 15' **Vibrometry** – Enrico Esposito – 15' **Ground Penetration Radar** – Enrico Esposito – 15' **3D Scanning** – Cristian Deciu – 10' **Microclimate monitoring** – Joakim Striber – 10' **Discussion** – 15'	Hotel Best Western Tisa Hall
20.00	Dinner	
	July 28, 2006 - Friday	
10.00	**John Asmus** **Science in the Service of Art**	Hotel Best Western Tisa Hall
13.30	Lunch	
15.00	Visits to Probota Monastery (Former UNESCO Restoration chantier)	
20.00	Dinner	
	July 29, 2006 - Saturday	
10.00	Second visit to Humor Monastery	

TRENDS ON PHOTONICS FOR RESTORATION AND CONSERVATION OF CULTURAL HERITAGE. ROMANIAN EXPERIENCE

Walter Maracineanu, Monica Simileanu, Dragos Ene, Cristain Deciu, Joakim Striber, Roxana Radvan, Roxana Savastru

Introduction

Nowadays when technology allows for complex investigations, many people, mainly restorers and researchers, know that restoration is a genuine science accompanied by artistic knowledge. This is no longer a mere craft. Any action performed on an artwork must come along with diagnoses and very accurate interpretations. Optoelectronics brings with it the benefit of such techniques and has become a very useful restoration and preservation instrument.

SAVING SACRED RELICS OF EUROPEAN MEDIEVAL CULTURAL HERITAGE – project under auspices of CULTURE 2000 Programme – developed a new and non-conventional form of cooperation between muldisciplinary teams from all over the Europe and with participation of non-European well-known specialists. The project envisages creation of the professional approach for a pertinent solving of an acute aspect in restoration process for pieces with artistic and historic value in the same time. The project focused attention on the advanced restoration and conservation strategy implemented on an ensemble of three religious sites from North of Moldavia - historical region of Romania, with contribution of the advanced investigation techniques results.

The admirable contribution and hospitality on selected locations have been offered by monasteries and churches and by CERECS ART S.R.L, mainly from prof. Oliviu Boldura – chief restorer.

This project was created with a contribution of a National Institute of Research and Development for Optoelectronics (INOE)– Centre for Restoration by Optoelectronical Techniques, National Institute of Historical Monuments (INMI) both from Bucharest-Romania, ENEA from Frascati - Italy, Institute of Applied Physics "N.Carrara", from Florence- Italy, Institute of Physical-Chemistry Rocasolano, from Madrid-Spain.

The selected monuments are: *Sucevita Monastery, Balinesti Church, Popauti Monastery.* These three locations of the important marks of the historical events that are strongly correlated with European history have strong links to *Stephan the Great* kingship and have been documented and presented by specialist of INMI, mainly by Prof. Tereza Sinigalia. Objectives' significance in the Romanian people history, in European people history, and – particularly in religious history are largely sustained by the contribution of Prof. Sinigalia.

Because of the unfriendly environmental conditions over centuries, the fabulous paintings and important collections (books, documents, textiles) are permanently stressed and exposed to accelerated degradation process. In such conditions, modern conservation strategy could benefits by modern investigation & diagnostic methods and techniques.

The project – organized as restoration *laboratory* - was started on 1st of November 2005 and had a core that brought the participants in situ in the same time and supported the good-practice demonstrations and advanced results implementation. This *laboratory* had a secondary effect, too: it strongly entrusted all categories of participants in the high quality of multidisciplinary work.

The l*aboratory* benefited by a number of advanced techniques and modern methods of investigation, diagnosis, restoration. Involved techniques generated qualitative – RH&T monitoring networks (PC compatible), laser induced breakdown spectrometery for on site pigment analysis and stratigraphy, and for polluted encrustation characterisation, laser induced fluorescence for non-contact control of surface contamination, laser range finder techniques for deteriorated surfaces.

This on-site laboratory – an atypical project - was intended as an introductory event for students and end-users interested in knowing more about the less known important pieces of the European cultural heritage, about exciting developments in this advanced high-tech area of conservation and conservation science. The project's description is available on dedicated website (http://inoe.inoe.ro/moldavia). The project was an initiative of networking to promote advanced photonics, mainly laser techniques, in conservation of artworks. These innovative instruments are considered as well-recognised tools for solving a variety of problems in conservation, such as investigation and diagnosis of artworks, statues, monuments and historical buildings, cleaning, detection of defects, in-situ analysis of composition and 3D documentation.

The on site laboratory had in view to cover simultaneously several purposes: restoration interventions presentation, monitoring of the deterioration; harmonization of the advanced knowledge and methodology developed by appreciated teams, training of a large number of participants with the aim to establish a proper knowledge and use of optoelectronical instruments and innovative methods for diagnostics, and given a high priority by the specialists of the European members of the thematic network, by Romanian specialists, , members of PRO RESTAURO – Romanian National Thematic Network (http://inoe.inoe.ro/prorestauro) and invited members of LACONA group (LASER IN CONSERVATION of ARTWORK) from Europe, USA, Brazil [1].

Photonics in Restoration – State of art

Laser techniques have demonstrated very promising applications for diagnostic and restoration purposes in art conservation. During last decade a growing interest in Europe has brought this innovative approach to be tested and validated on various important tasks: structural laser diagnostics of frescoes and art objects; compositional laser diagnostics of materials; environmental laser monitoring, laser cleaning of stone, metals, paintings, paper etc. Presently the CULTURE 2000 is giving the frame of promoting the advancements achieved in the development of new instrumentation, accumulating validation of laser based techniques with case studies, extending the use of laser for conservation throughout Europe.

Today laser techniques are being successfully employed in the conservation of a number of masterpieces in many European countries, featuring the advantage of preserving historical layers otherwise impossible, especially for stone and metals. Because of this, the general acceptance on laser methodologies by the conservation institutions appears continuously and convincingly growing. Technology transfer has been also pursued and many laser systems producers could make products out of these research projects. A permanent increasing number of professional restorers are being acquainted with these new instruments and methods [2, 3, 4].

Having in view the large and constant activities of the last years, Romanian specialists accumulated an important experience. INOE is prepared to be involved in dissemination and technological transfer activities for such innovative methods towards the conservation community. Under the light of these results, the priorities of INOE are focused on case studies and complex collaborative projects. INOE is part of European consortium concerned on still open issues and which will propose new and more advanced technologies.

Last decades an increasing interest among art historians, archaeologists conservators and scientists was shown in exploring and applying laser-based methods for Cultural Heritage. This interest generated a very active and interdisciplinary community all over the Europe, involved in research on and actual use of advanced laser techniques in a wide variety of diagnostic and conservation problems. The fundamental research is greatly devoted to the investigation of the potential of laser spectroscopic techniques (laser-induced fluorescence, LIF; laser-inducedbreakdown spectroscopy, LIBS; Raman and IR spectroscopy) as tools for characterizing the materials (e.g. LIF for pigments, binding media, varnishes; LIBS for pigments, stratigraphic analysis, on-line monitoring etc).

Advanced laser-based techniques, like 3-D scanning, holography, holographic interferometry, Doppler vibrometry, offer accurate data about the defects' distribution on surface or – even – under the superficial layer. Also, fluorescence imaging, multispectral imaging (UV-VIS-IR) and colorimetry demonstrated their success to detect underlying drawings and pigments composition in paintings.

Laser cleaning can be a tool for restorers to remove deteriorated layers that cannot be removed by conventional methods, with renowned features like: no chemical solvents, selective removal of deteriorated layers or materials due to differential optical absorption, accurate control of amount of material removed.

Lasers have significant applications in monitoring of environment effects of deterioration. The atmospheric pollutants affect the artwork in different ways and speed under different humidity and temperature conditions.

NO_x, SO_2 and some VOC are main pollutant species, responsible for the degradation of artwork objects and their recommended limits are now recommended, given by the artwork environment authorities of galleries and museums, are well below those specified for the outdoor environment acceptable for the human protection. To protect the artwork object, the indoor parameters have to be controlled and consequently they need to be monitored. In this respect, INOE installed a microclimate monitoring network in each location of the project and the dynamic of the microclimate will be study after a long term monitoring.

Optoelectronical facilities on site

The selected methods and instruments used on site - all employed in INOE's laboratory [5, 6]- are highly technical, perfected mostly in the last decade at European level. The main ones, shown in next block-scheme (**Fig.1**) and described below, are extremely versatile, addressing a wide range of materials.

Microscopic laser cleaning systems assure a high cleaning precision, but they can be coupled with other monitoring systems, starting from photo-video recordings, to *thermovision* analysis or *UV-VIS-NIR multispectral analysis*. To go with these, there are results of the latest researches: qualitative evaluation

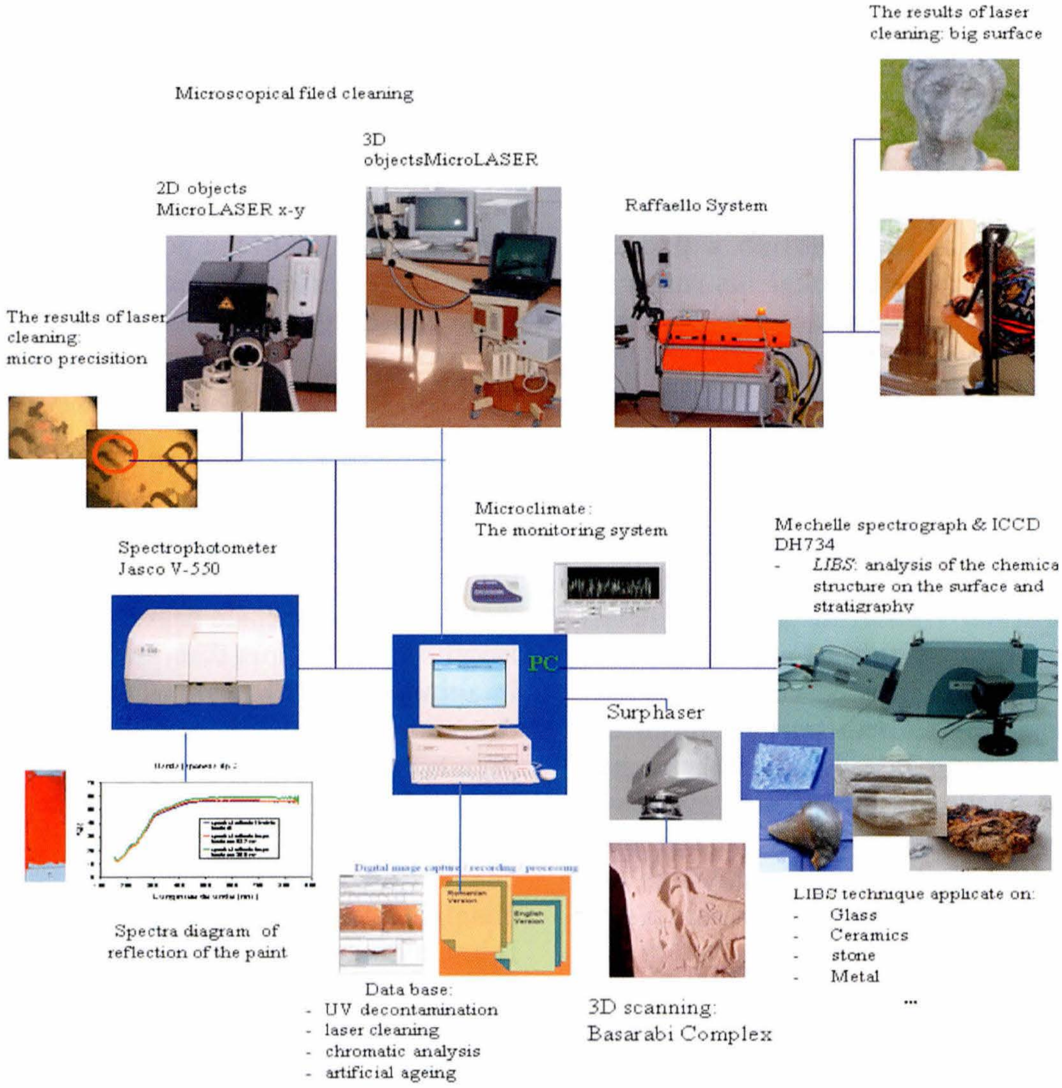


Fig.1. INOE-CERTO current activities

techniques using LIF, LIBS, LRF and 3D Scanning of large objects – including historical buildings. *UV-VIS Spectroscopy* concerning transmission and reflection spectra measurements, as well as CIELab chromatic system *Colorimetry* can also provide information helpful for artworks *composite materials and degradations characterization. These techniques that directly envisage cultural objects, together with microclimate conditions and environmental pollutant agents monitoring* establish the way our patrimony is affected. *Large surfaces laser cleaning system* is also integrated to the other operations and systems presented.

It is based on the Nd:YAG laser working at four harmonics (1064nm, 532nm, 355nm and 266nm) and it has numerous applications in diagnosis, analysis, evaluation, conservation and restoration, being adaptable to the previously mentioned techniques, too.

We must underline that optimization of the functional structure, as well as the operating precision of the techniques are established in direct corroboration with important case studies. For some of them, some examples are presented bellow.

Examples of case studies. During this project - at Sucevita Monastery's museum - *an in situ restoration/*

Table 1.

	Technique / ***Object***	**Laser Cleaning**	**LIBS**	**Multispectral images**	**Optical Microscopy**	**Colorimetry**
Textile	***Maniple***	x	x	x	x	x
	Stole	x	x	x	x	x
Paper	***Obituary***	x	x	x	x	x
Metal	***Cross***		x		x	
	Cash pot		x		x	
Wood	***Icon***			x		
	Throne			x		
Stone	***Foundation stone***	x			x	x

conservation workshop using optoelectronical techniques took place, corroborating numerous parallel activities, strongly entrusting all categories of participants in the high quality of multidisciplinary work.
In the table below are presented the artifacts provided, as well as the techniques that were applied to each one of them (**Table 1**).

Textile
Maniple

Inv. Nr. 586 / III, 18th century, provenience from Church St. Nicholas, Beresti Parish, it is kept in storage at Sucevita Monastery Museum. Manipel is a textile artefact that was worn during sacral ceremonies. It has a trapezoidal shape. It is made from white brocade, bordered with yellow gallons. In the middle it presents a cross also made from yellow gallons.

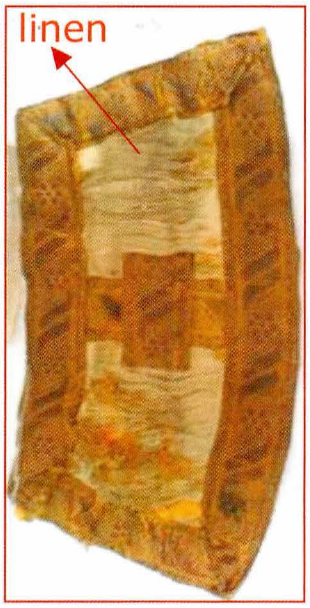


Fig. 1.1

Conservation Status: On the whole averse the textile artefact is destroyed and all it is left is the warp. We can suppose that the fibers are from linen or cotton. Beneath the warp we can actually see the textile support layer, made of linen or hemp.
Investigations:
1. PH Determinations (thanks to dr.Matija Strlic)
PH values were determined on four different spots on the averse of the maniple, and one on its reverse (i.e. white linen - 5.5, yellow threat – 5.7, support textile – 7, yellow gallons – 5.5, cotton (reverse) – 6.7)
2. Microscopic documentation – yellow gallon for conservation status of the metallic threads
Stole
Inv. Nr. 353 / III, 18th century, provenience from Church St. Nicholas, Beresti Parish, it is kept in storage at Sucevita Monastery Museum.

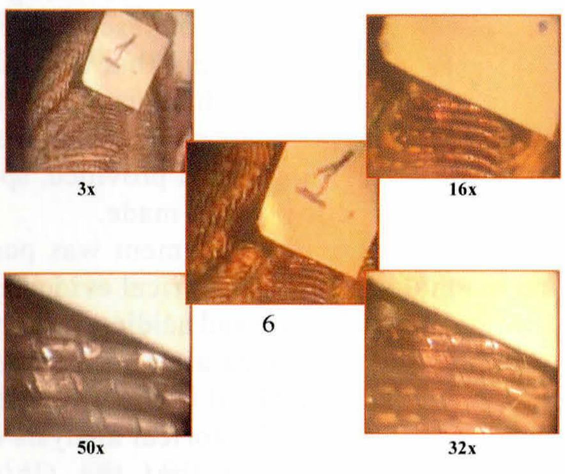


Fig. 1.2

Dimensions: - length 139 cm, width 26 cm
Avers: The stole was made of red silk or cotton brocade with metal silver thread; the technique used was *bucle k*not. The motif consists in beautiful floral ornaments. The stole is bordered by yellow gallons and the neck holder is made of red cotton.
Reverse: The textile is made of linen covered with another layer of cotton. The cotton layer is preserved only on the upper part of the stole. The whole reverse of the stole was bordered with red cotton.

Conservation Status: In the upper part of the stole the textile materials present severe deteriorations mostly from human grease. The gallon is broken in some areas. All over the stole the metal threads present disruptions. The metal threads were made from silk with silver metal foil.

Laser cleaning tests:
A series of laser cleaning tests were accomplished, at different working regimes in order to evaluate the way the laser interacts with old textile threads. Used wavelength and number pulses are mentioned for each example. The searched laser regime (laser fluence particularly) was deeply studied by co-workers in all their previous works [5]. The results were promising, as you can see in the following microscopic images:
Paper
19th century Obituary (Pomelnic)

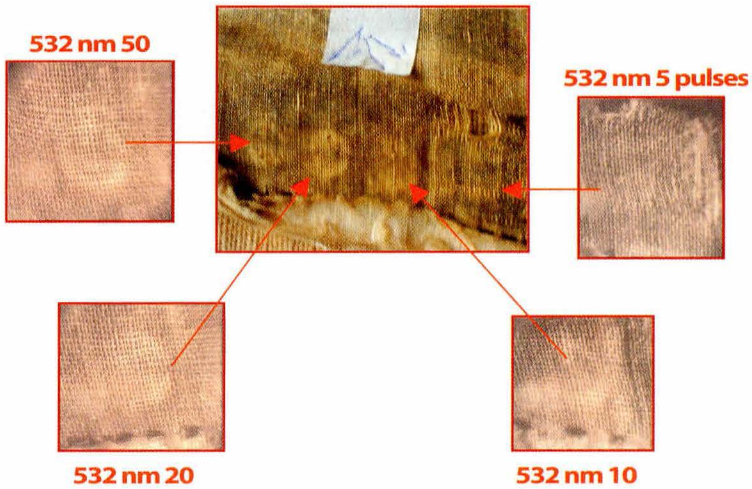


Fig. 1.3

Provenience: Sucevita Monastery, Suceava county

The document - an *Obituary* (*Pomelnic)*, inv. no. 25 - was particularly fragile, which was obviously due to very intensive use. The object was glued on a support, that was also very badly preserved, both of them being loosely glued onto a cardboard support. Immediately after the first examination, a protective envelope was made to prevent information and material loss due to handling during the workshop. Upon visual inspection it was immediately evident that several different inks were

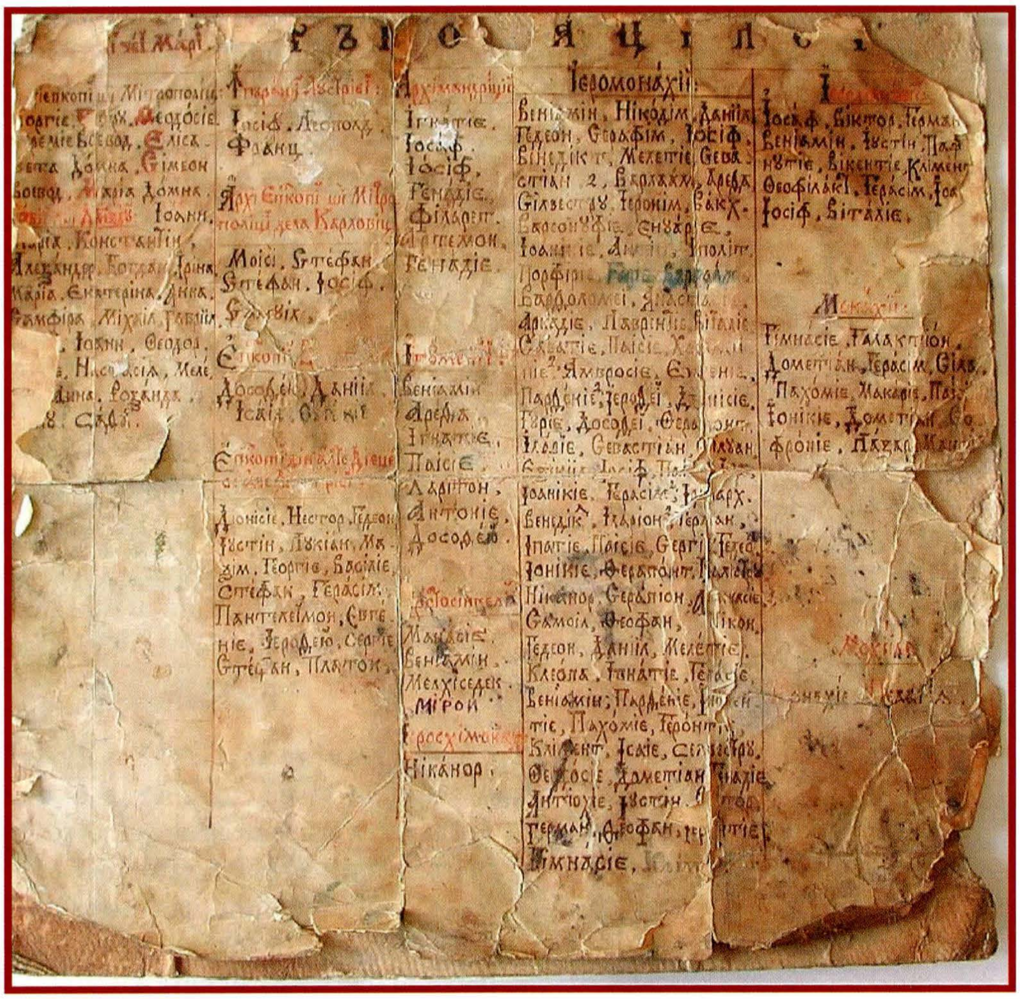


Fig. 1.4

used. They could be examined using colorimetry – thanks to Dr. Jens Hildenhagen - it was established that at least four inks were on the sheet of paper.

Multispectral Investigations:

Analyses using the imaging camera indicated that at particular places (especially where loss of material took place) in the manuscript; there is evidence of biological attack.

The presence of hyphae was indicated by very thin threads, which only became visible as they fluoresce. In this way, however, it is not possible to determine whether the microorganisms are active or not. In fact, their presence could be due to a past mistreatment.

In any case, thorough cleaning of the document would be recommended.

LIBS Investigations:

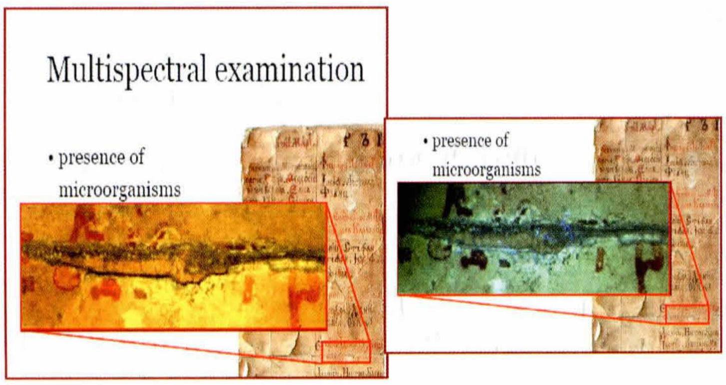


Fig. 1.5

The LIBS tests, as well as the laser cleaning ones were accomplished in collaboration with some of our international partners Marta Castillejo, Mohamed Ouija, Wolfgang Kautek and Vassilis Zafiropulos. The composition of the black ink was of particular interest, as it could be composed of iron ions and extracts of galls. The iron gall inks are infamous for their corrosion, so that it needed to be established whether the ink in question in fact contains a large amount of iron. The analyses done using laser induced breakdown spectroscopy showed that the peaks for iron were only slightly higher when inks were examined than when paper was examined. The LIBS technique was characterized as micro destructive by the conservators, as there is no noticeable damage on the artifact. Additional analyses using iron-indicator paper strips indicated no presence of Fe(II), which means that it is very likely that the ink used was a carbon-based ink, which is usually safe for paper. Also, using a portable colorimeter that our collaborator dr. Jens Hildenhagen provided, specific colorimetry determinations were made.

Approximate dating of the document was possible basing on technological and historical evidence. The paper itself is machine-made and acidic, which means that it was probably produced after 1850, when the production technology changed in the way that such paper became widespread. Historical analysis of the document made it evident that the *Obituary (Pomelnic)* was used during ceremonies and that it

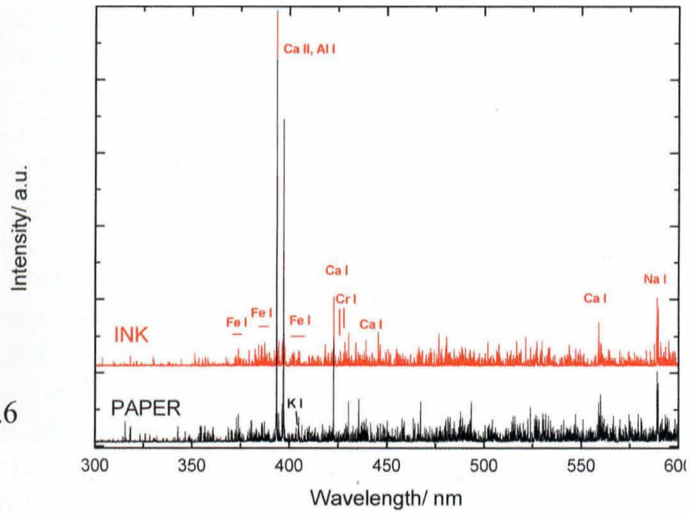
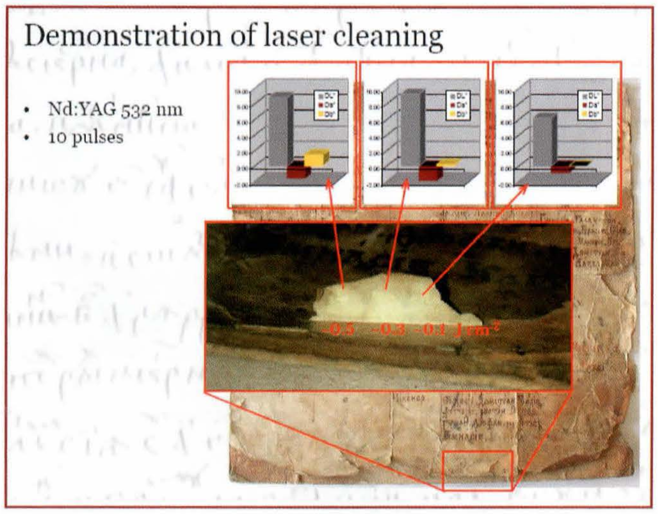


Fig. 1.6



contained names of dignitaries, who were already deceased at the time of its making. Close inspection of the text revealed that the names of three Austrian emperors appeared, i.e. *Iosif, Leopold, Frant*. As they were probably successors, they were Joseph II (1741-1790), Leopold II (1747-1792), Francisc II (1768-1835), while the successor Ferdinand I (1793-1875) was not mentioned. This means that the document was

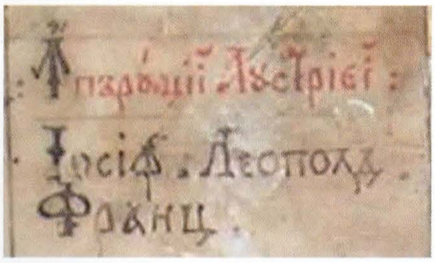


Fig. 1.7 Names of Austrian emperors mentioned in the *Obituary*

probably produced before 1875. In conclusion, the document was produced between 1850 and 1875.

Sp1	Sp2	Sp3
Cu	Cu	Cu
Ag	Ag	Ag
Ca	Ca	Ca
Na	Na	Na
	Au	Au
		Ni
		S

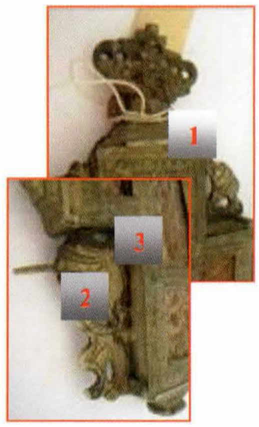


Fig. 1.9

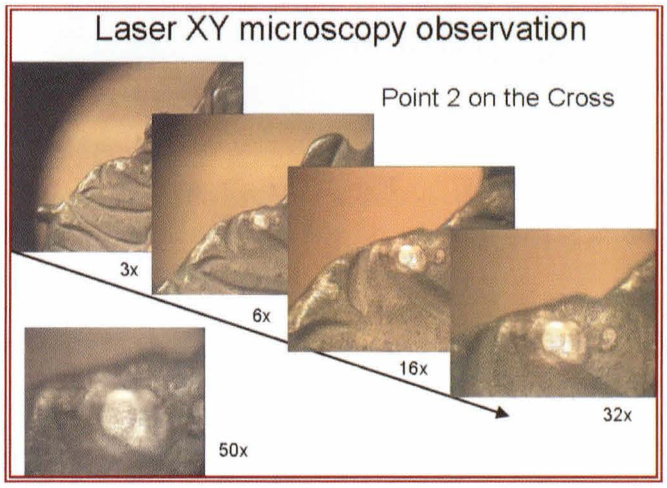


Fig. 1.10

Metal Cross

- The cross is made from common metal – 18th century;

Provenience: Banesti Parish church, Suceava

Fig. 1.8

Cash Pot

- Metal boll – yellow copper

Provenience: Zvoristea Parish church, Suceava

Example of multispectral imaging applied on valuable artwork objects from Sucevita Monastery :
Multispectral image analysis is a technique based on simple principles. Considering the observation that different materials absorb the light in different way, it is possible to measure the amount of light absorbed and reflected and to establish precise spectra of

Fig. 1.11

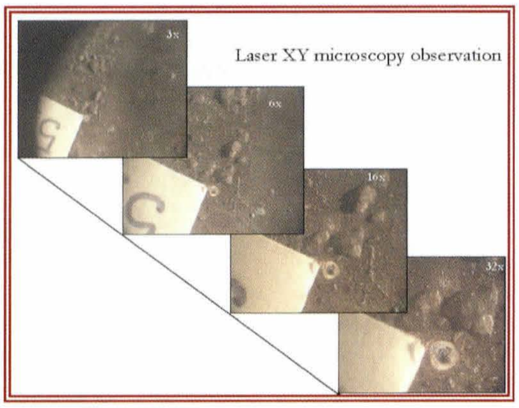


Fig. 1.12

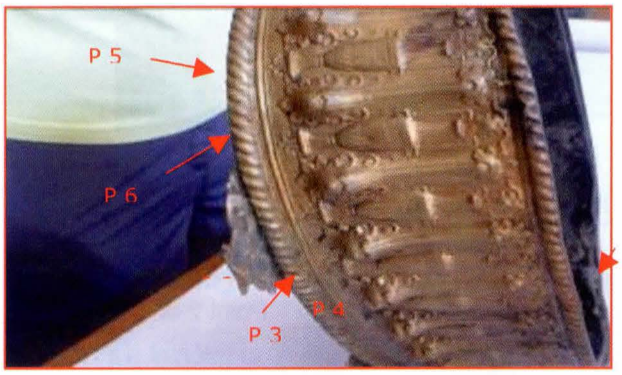


Fig. 1.13

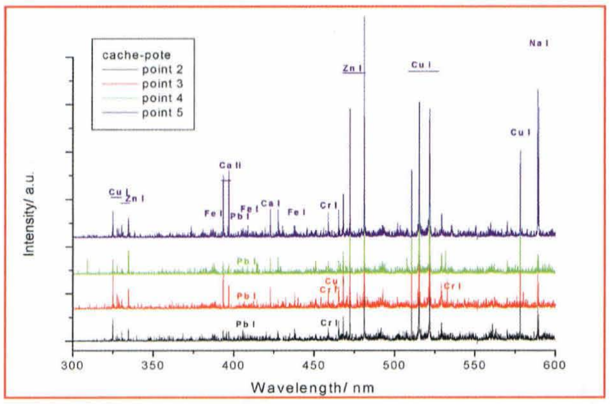


Fig.1.14

absorbance or of reflection for substances that compose art objects. It is also possible to record these spectra not for visible waves, but also for UV and NIR waves. Approaching this idea from a different angle we can consider that electromagnetic waves from UV range to NIR range, including of course visible spectra, go through artwork materials in different ways. If it is possible to analyze the way that materials behave at electromagnetic radiation exposure with a handy mobile device a lot of valuable data will be available to art evaluation, conservation or restoration specialists without support from specialized laboratories.

Such device consists in a high resolution digital camera which can record in separate modes images in UV, visible and NIR spectra. These images are processed, compared and stored using dedicated software. Certain databases offer electronic version of classic conservation-restoration documentation.

Another aspect regarding artwork materials behavior at different ranges o UV-VIS-NIR spectra is related to identification of differences between almost the same colored materials. If the most trained human eye can hardly see any difference between two materials and these materials are chemically different somewhere from UV spectra to NIR spectra these materials will look different on computer screen due to selective mode operation of digital camera. Varying dependant on working mode selection it is possible to identify a complex range of degradations and modifications that art work materials suffered in time. During scientific investigations activities at Sucevita Monastery different sorts of art objects were investigated with this technique. In the following lines we shall present a part of the results which were used next to other analyzing techniques for a proper characterization of artifacts conservation status.

STOLE:

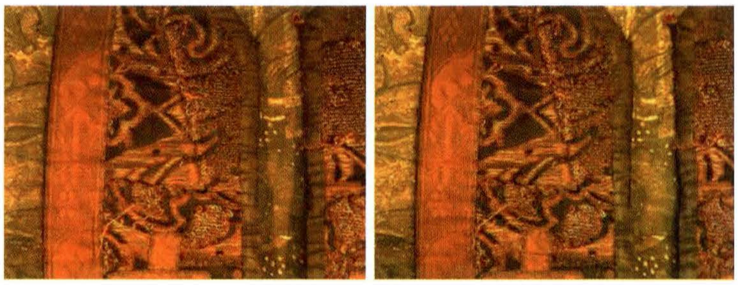


Fig. 1.15. Visible color image (left) compared with fluorescent UV illuminated image (right) showing no difference. The investigation in UV light is usually employed to detect microorganisms' presence on the surface of the art objects. In this case there were no detectable signs of fluorescence fact that proves the good conservation status of the object.

Fig, 1.16a

Fig. 1.16b

Fig. 1.17. Color visible image (up), false colored NIR image (middle) and UV image (down) indicating the areas where laser cleaning was tested in green (532nm) wavelength. The UV image proves that the surface of original material is not damaged by the laser beam.

3D laser scanning

3D scanning offers a three-dimensional image of the scanned object(s). The 3D scanner (optical surface digitizer) used is Surphaser 25HS is a 3D scanner that uses laser technology to produce high-resolution geometric models of three-dimensional objects. This scanner combines high accuracy with top performance, and is suitable for a large variety of applications, ranging from reproducing art objects for museum catalogs to reverse - engineering and product inspection for quality control 360° - 270° purposes. This Hemispherical scanner is with field of view an is

Fig. 1. 18. Commanding the scanner with a laptop (the workshop at Balinesti Church)

commanded by an notebook or desktop PC.

The accuracy of the scan depends on many factors, for example, the environment conditions, temperature variation in electronic circuits that can result in changes in scanner parameters, specific properties of the object's surface, lighting conditions etc. The processing software uses sophisticated correction methods to minimize the accuracy loss, methods known as filters.

The scanner use a laser radiation, with 690 nm wavelength (red), continum wave, with 15 mW power (less then 100 part then power an usual bulb). Range of the scanner is between 1.5 m and 22m. Laser spot size at 10 meters is 5 mm and at 20m is 10 mm. Depending by the variance of relief and interest to capture the finest details, the resolution it may be modify from 17 up to 180 lines per grade (this correspond a distance between two near details by 170 microm, and the distance scanner and object 1.5m.

By scanning the object repeatedly from different angles and by software merging, it cans registry two (or more) different scans to obtain a 3D image, and we obtained a 3D construction with high resolution and without shadows (**Fig. 1.19**).

For combining two (or more) different scans the files must have common points, to identify 3 different details. The final file is called *project* and the scans are named *subprojects*.

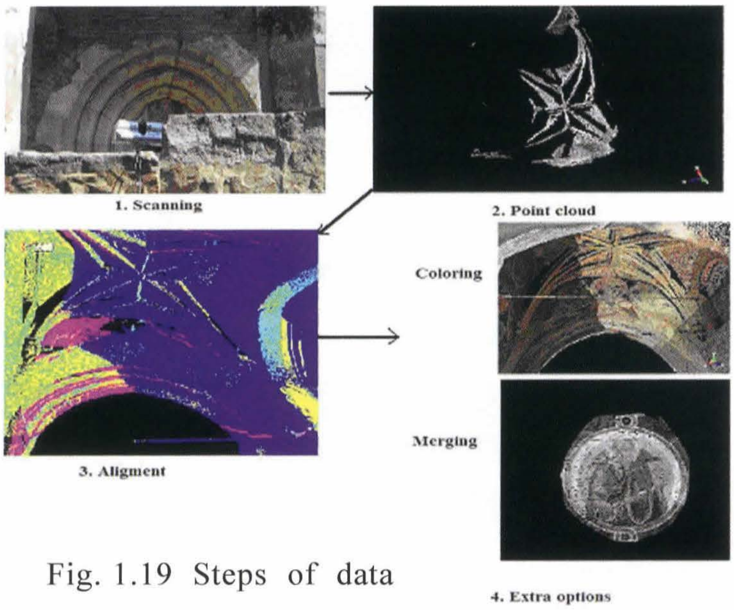


Fig. 1.19 Steps of data

One of the scanner advantages is its handiness: the physical dimensions and weight: 510 mm L x 170 mm W x 285 mm H, Weight 11 kg.

Fig. 1.20 Scanner situated on a tripod
(the workshop at Balinesti Church)

The 3D scanning at *Sucevita* was based by digital reconstruction of the narthex *iconostasis* and funeral tombstones. Because of the variety of the relief, the 3D scanning of the iconostasis need different reposition of the scanner. It takes 4 scans of every half part and then one scan on top of the entrance in the Church. It needed 9 different scans that were over 20 GB of data. The resolution used was 40 lines per degree (approximately 0.6 mm) (**Fig. 2.1**).

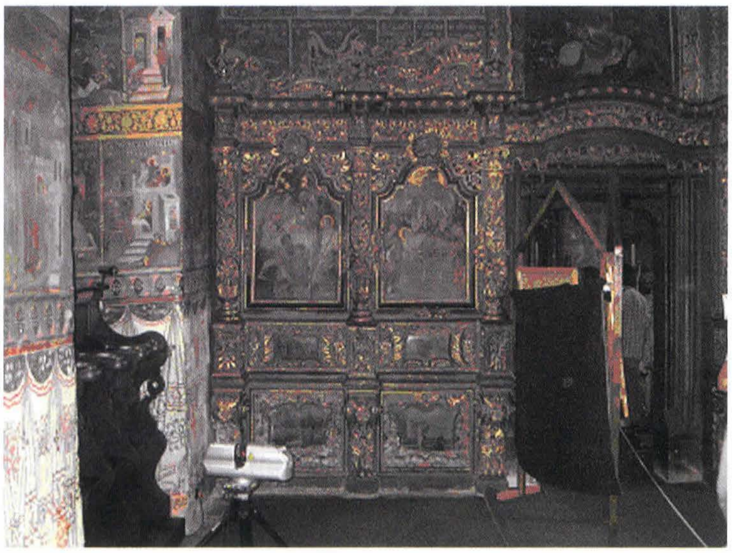


Fig. 2.1 Scanning the narthex iconostasis
(Sucevita Monastery)

The work at *Balinesti* Church was divided by two:

a) Scanning of *Dedicatory inscription*

The first scan was with 65 lines per degree resolution,

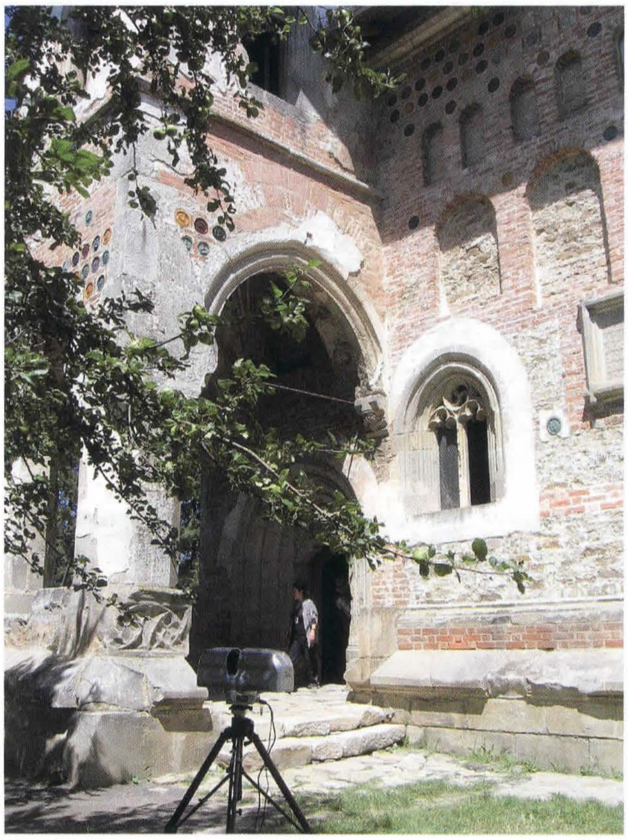


Fig 2.2 Scanning of *inscription*, on site arrangement

with the scanner at 5m distance from the *inscription*. This resolution was chosen because the inscription it's about

Fig 2.3 Scanner situated on a scaffold

4.5m above the ground. After the first results came over, there were a lot of areas shadowed so the scanner was apply on a scaffold so the scanner were perpendicular on the face on the inscription, at the distance of 2m. The resolution was 160 lines per degree and the final result was represented by 45 mil points (**Fig. 2.3**).

This porch is one of the most famous of Romania's Churches, the final result needed to capture all the details and all the faces of the stoop. For this there were 5 different scans, 3 scans that capture 3 faces of the porch and 2 scans of the interior of the porch, to see the details with no shadows.

Fig 2.4 Scanning the interior of the porch

Post processing time is equal with the time for scanning (maximum 2 hours/scanning), but for proper uploading time, it can be working with smaller project, or just with some details. Here there are some details from *Sucevita's iconostasis* (**Fig. 3.1**).

The software used for processing can display the results bought by mesh or by points and it can load a 2D image to obtain the colors of the scanned object (it may colors points and mesh). On the left part of the iconostasis it was a cutting out and with the software it was measured the

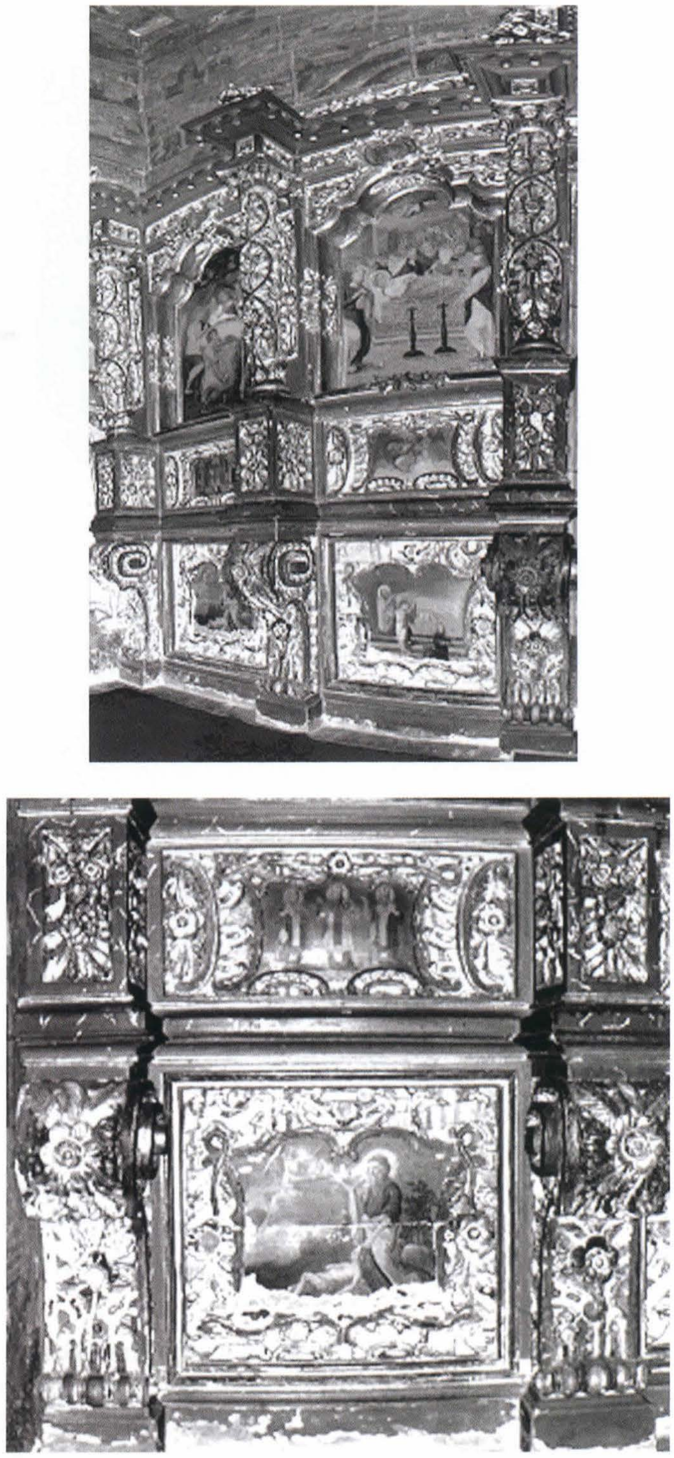


Fig 3.1 Different captures of some details

slit (**Fig. 3.2 a, b, c**).

Fig. 3.2 a

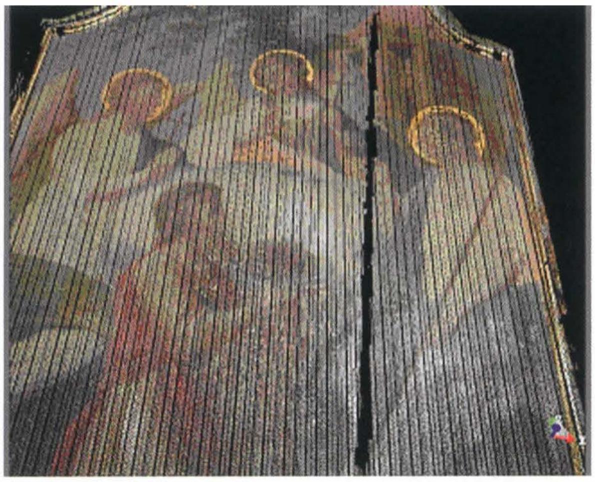


Fig. 3.2 b

Fig. 3.2 c

Fig 3.2. Same details represented by: a) points; b) colored points and c) mesh. The slit distance variable from 0.8 up to 2.3 mm

The image bellow in made from 46 mil points, contains 5 different files and the software may represent an image with the intensity of absorbed radiation (**Fig. 3.3 a, b, c**)

Fig. 3.3 a

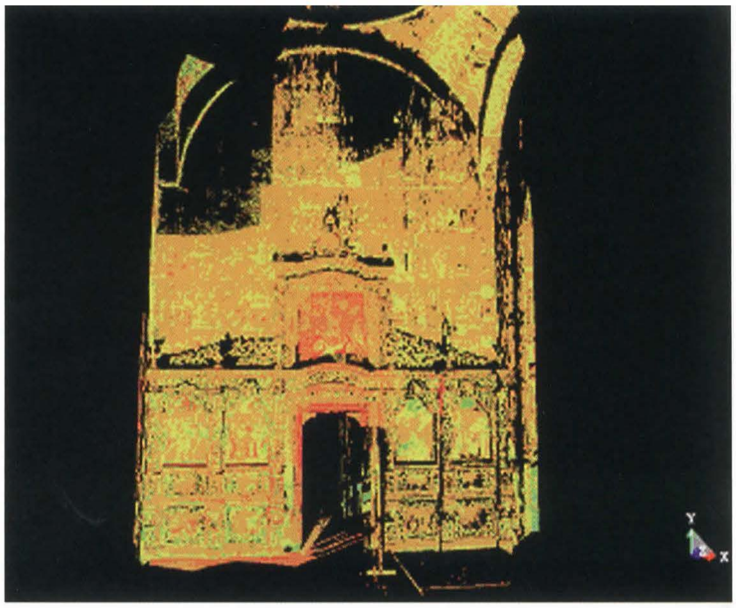


Fig. 3.3 b

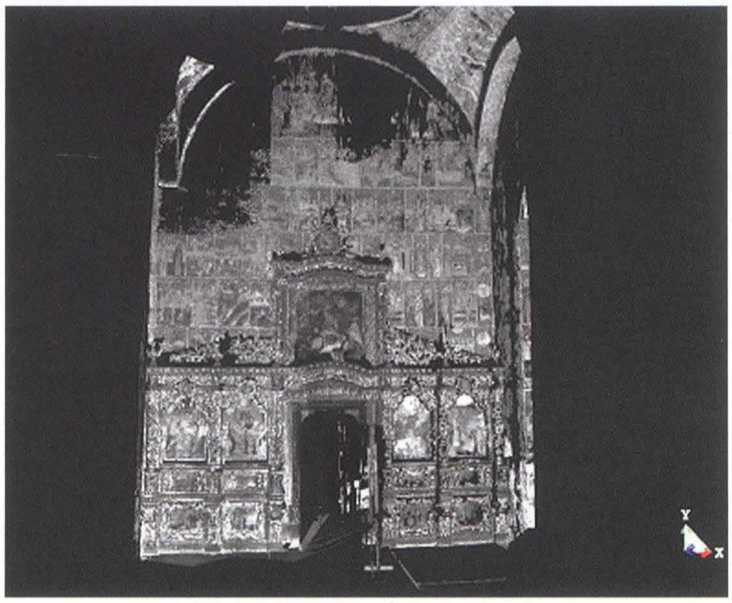


Fig. 3.3.c

Fig 3.3 The final result of iconostasis, represented by a) up-load files; b) intensity of absorbed radiation and c) in grey scale.

With software aid it can measure distance between points or details, which can determine profile of a letter from tombstone (**Fig. 3.4 a, b, c**).
The advantage of mesh representation is that the detail

Fig. 3.4 a

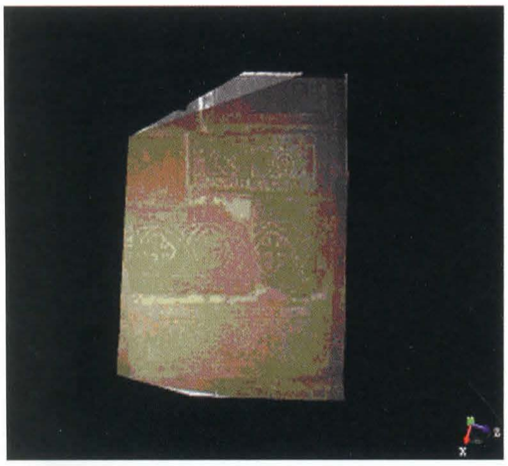


Fig. 3.4 b

Fig. 3.4 c

Fig 3.4 Different capture of tomb scans: a) grey scale points; b) colored points; c) letter profile

is observe better than by points representation, but is harden to work with this kind of files, because ask for more resource from the computer. In *Balinesti's inscription* this kind on representation is better then points representation because the writing were scanned only from front and from bellow, so the up side of the letters wooden be scanned, but the software used can interpolate that part using same representation like the bellow part of the letters (**Fig. 3.5 a, b, c**).

And the resolution of mesh is better then the point's representation, but the points represent the true information meanwhile mesh contains interpolation data (**Fig. 3.6 a, b**).
Representation of the porch was made by 56 mil points,

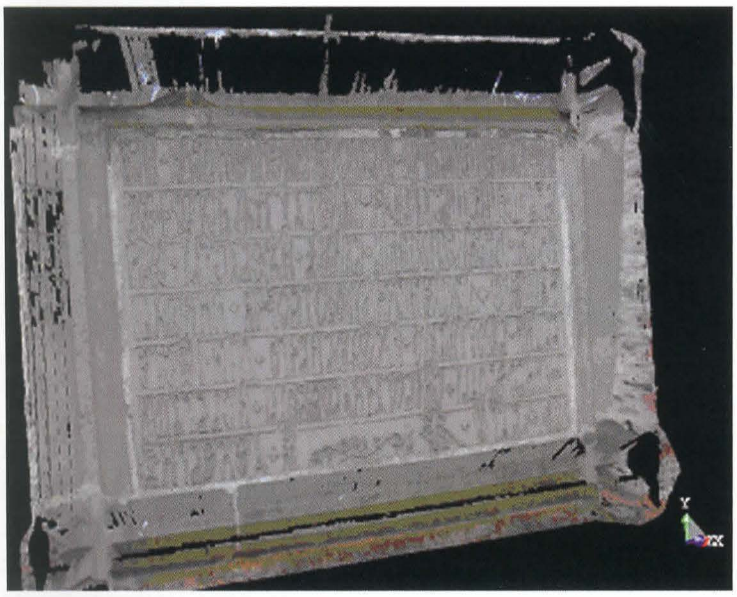


Fig. 3.5 a

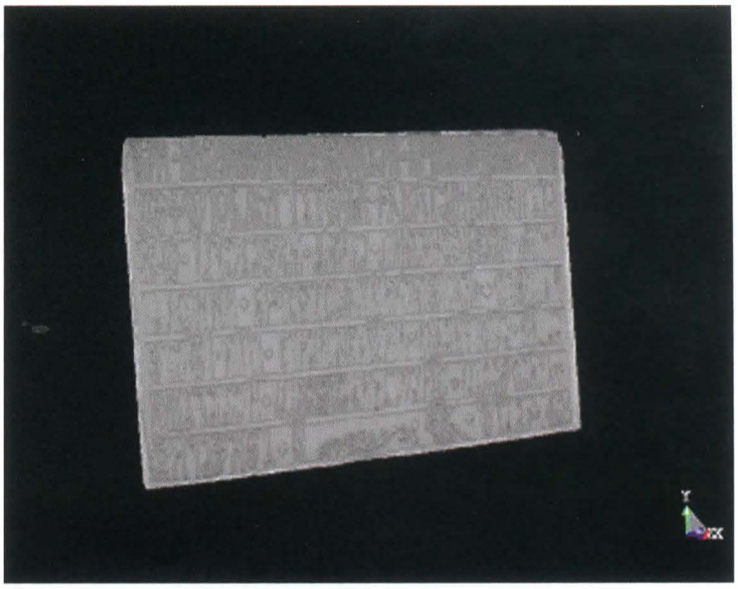


Fig. 3.5 b

Fig. 3.5 c

medium resolution were 0.9 mm and was made by 4

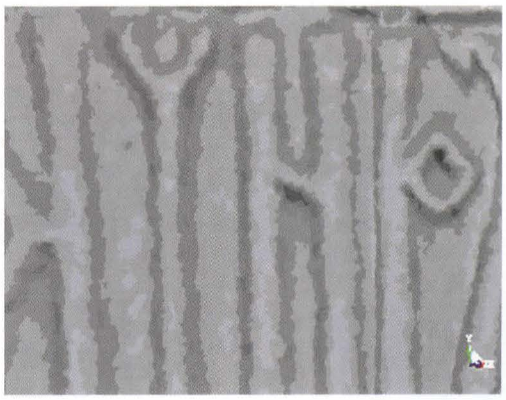


Fig. 3.5 d

Fig 3.5 Inscription represented by: a) color cloud points; b) mesh and a zoom on mesh c) and d).

different scans. The motive of this small resolution is that the interest of this project was to obtain fewer shadowed zones (**Fig. 3.7 a, b, c, d, e**).

Fig. 3. 6 a

Fig. 3. 6 b

Fig 3.6 Resolution of: a) points and b) mesh. The maximal rezolution by points representation is 170 microm and by mesh 100 microm.

By 3D scanning it may obtain high resolution computer model of the scanned object. Laser scanning should not be regarded solely as the means of recording, but it should be widely applied to the development of 3D digital archives. Laser scanning will not only bring efficiency to

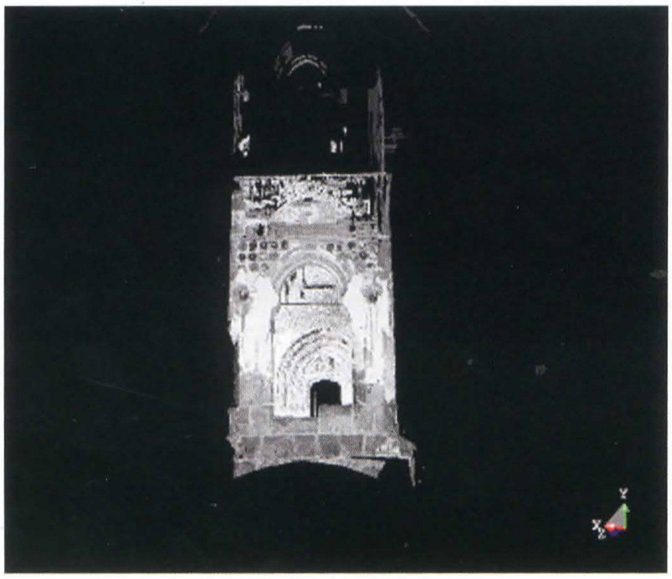


Fig. 3.7 a

Fig. 3.7 b

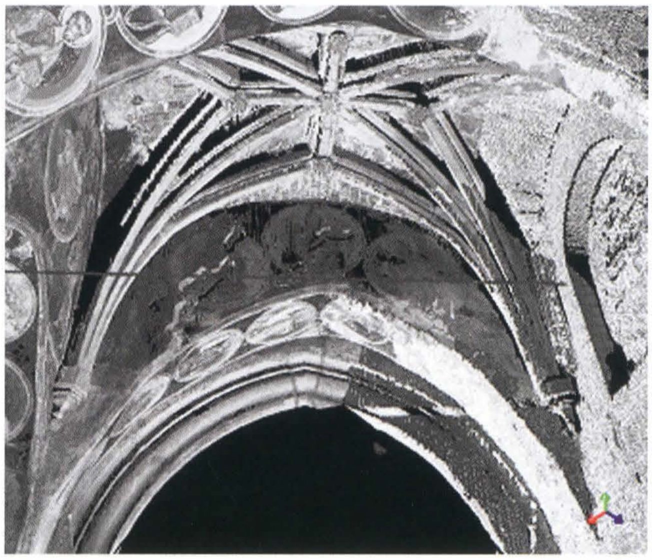


Fig. 3.7 c

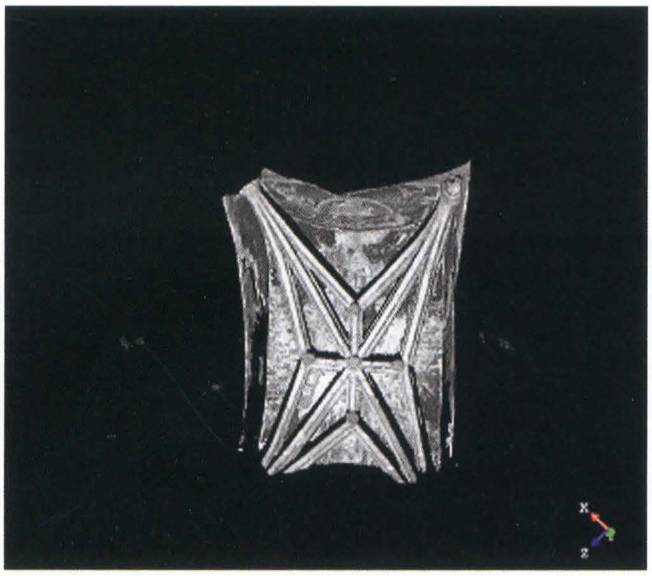


Fig. 3.7 d

conventional works such as making drawings and analyses of structures, but also make the management of whole attribute information such as components, breakage parts and repair parts possible. Moreover, the laser scanning technology indicates various future

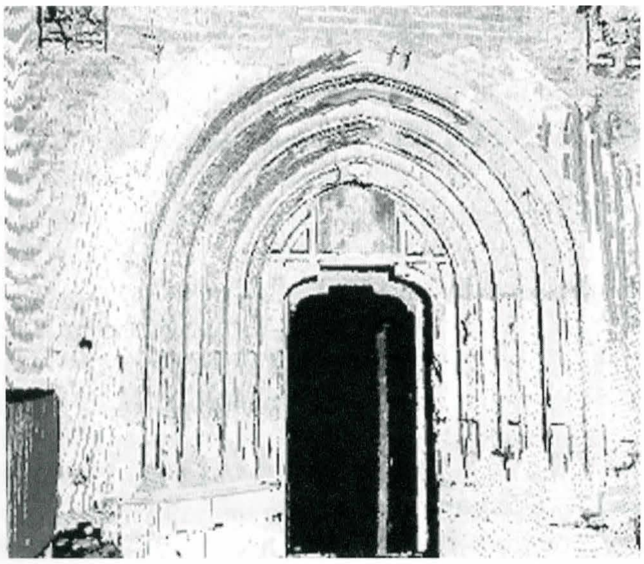


Fig. 3.7 e

Fig 3.7. Different detail of porch's scan

possibilities in the conservation of historic buildings. The simulation of restoration using 3D data obtained by laser scanning will greatly advance the ways of restoration from conventional ones like models and perspective drawings. It will also provide a great visualization method when it is applied to virtual reality that can offer real-time change of views and free movement.

In the exploitation phase of R&D projects and after the phase of the achievement of scientific results and the availability of demonstrators, a well funded strategy we proposed and direct collaboration are established for finding a continuity, with validation trials and technology transfer to end-users.
In this respect, we create a strong collaboration with Prof. Oliviu Boldura from CERECS ART S.R.L, for a long term monitoring of the various stress effects on monuments and for data interpretation, for creation of an advanced workshop hosting good-practice demonstrations.

Today the general acceptance of these physical methods is well acquainted in most of the conservation institutions, universities and research centers.

Acknowledgments
We would like to mention that a very useful support we received from the co-organizers and from invited specialists that sustain our transfer of information and data interpretation.
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LASER CLEANING OF STONE

Johann Nimmrichter

The beginning

Since the early 1970ies, laser technology was successfully applied for cleaning of artefacts. The first cleaning treatment with a laser was done on stone works in Venice by an interdisciplinary team leaded by J. Asmus in 1972 (1). A ruby holographic laser was modified and used for cleaning of the lion portal at Palazzo Ducale in Venice and other pieces of art made in marble. Although the cleaning results were convincing, for a longer time laser was only used seldomly. In some single cases C. Calcagno used the laser technology for cleaning some sculptures or ornaments made in bright marble or limestone.

Up to the middle of the 1980ies the interest for this technique increased in Europe. In France, Italy, Greece, Germany and Great Britain interesting cleaning projects with laser tools started to be carried out. Basic research was done improve the laser tools and to test it on a wide range of applications. Because of these efforts the laser tools became easier to handle and today they are suitable for work on scaffolding. From this moment the possibilities for cleaning have not focused only on stone materials. Laser cleaning technologies were also tested on metals, wood, ceramics, ivory, paintings, textiles and many other inorganic and organic materials.

A hard way to convince

The responsible institutions in the field of care and protection of monuments and artworks are very careful and critical with new conservation techniques and so a lot of preliminary examinations and tests were carried out by scientists and conservator-restorers. In the field of stone conservation the laser cleaning technique is usually compared with other traditional techniques (e.g. micro sandblasting, paper pulp pad impregnated with an aqueous solution of ammonium carbonate and ion exchange resins (2). In many cases laser cleaning showed advantages and therefore some very interesting conservation projects could be done with Nd: YAG- lasers (e.g. Romanesque portal of Cremona (fig.1), the portals of the Cathedral of Amiens (3) and Notre Dame in Paris, etc.). Especially on very delicate surfaces with thin scaling or brittle parts the laser offers the better alternative cleaning method, however problems have been observed in connection with some pigments and some binding media. In some cases the yellowing of some stone surfaces after laser treatment represents an esthetical problem.

Subsequently, a scientific platform was founded in Heraklion, Crete which was called LACONA (Lasers in the Conservation of Artworks), but there are also other national and international associations which are working

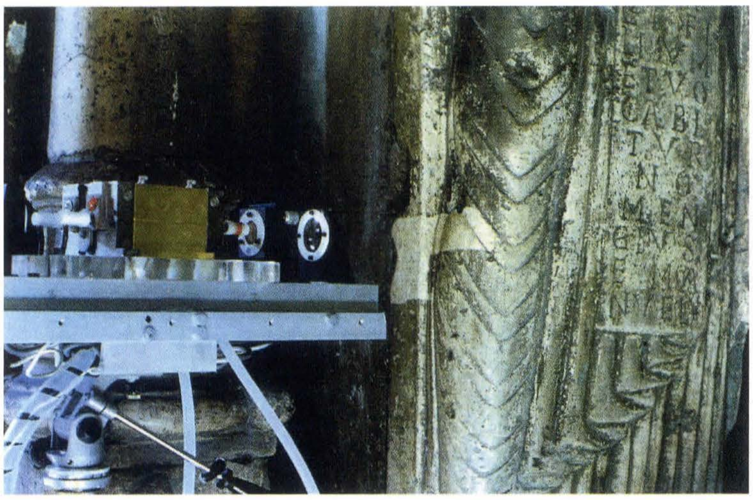


Fig.1. One of the first laser cleaning projects at the beginning of the 1980ies was carried out by J.Asmus and G. Calcagno at the portal of the cathedral of Cremona in Italy

Fig. 2. Example: The inside of the Palladio Laser from Quanta Systems. The small box in the middle includes the artificial YAG crystal, which produces the monochromatic laser light (1064 and 532 nm). The transmission of the laser beam is caused by mirrors. This tool is qualified to the work on the scaffolding.

in the field of laser technology for artworks (e.g. COST G7).

Laser tool and function

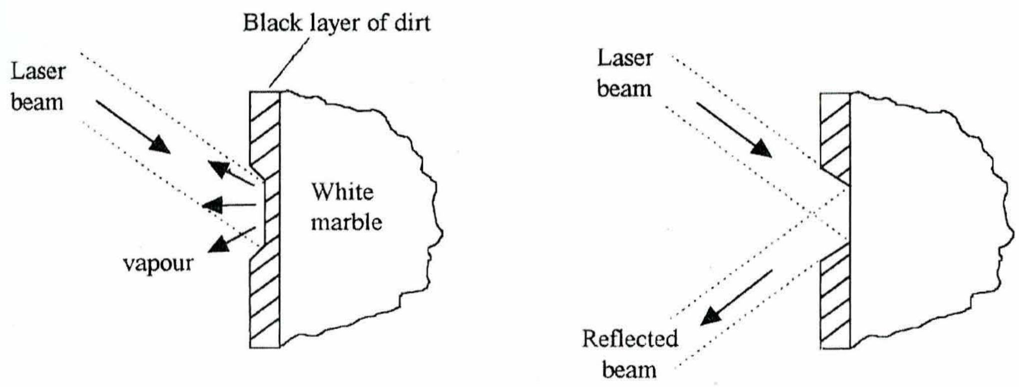
At the moment there is a concentration of producing Nd: YAG lasers for stone conservation, although other laser types could also be successful for special cases. Presently, approximately five companies have YAG-Lasers in their production.

Common parameters of Nd:YAG-lasers are: wavelength (ë): 1064 and 532 nm, energy pulse energy (E): 250 – 1000 mJ and more, pulse width (t1): 6ns and more, repetition frequency (fp): 5 – 20 Hz and more, peak power (Ppk), average power (P) (W), beam diameter (non focused): 2 – 20 mm, different lenses, beam delivery: mirrors or cables made from glass fibre, focusing devices (e.g. zoom optics). Recently the colleagues in Greece developed a modified laser system which combines ultraviolet and infrared laser radiation (4).

The process of cleaning with laser is done by evaporation (photo thermal ablation mechanism) and ablation/spallation (photo mechanical and photo chemical ablation mechanism) effects.

The intensity of absorption or reflection of the laser light, which is manly caused by the shooted substrates (stone, dirt, layers of over paintings, etc) is responsible for the quality of cleaning.

In the simplest case a bright white stone is covered by a black dark crust. After the evaporation of all black crust there is no dark material for absorbing the laser light and the light will be reflected without producing any damage for the white stone. This is also a reason why wet dirt is



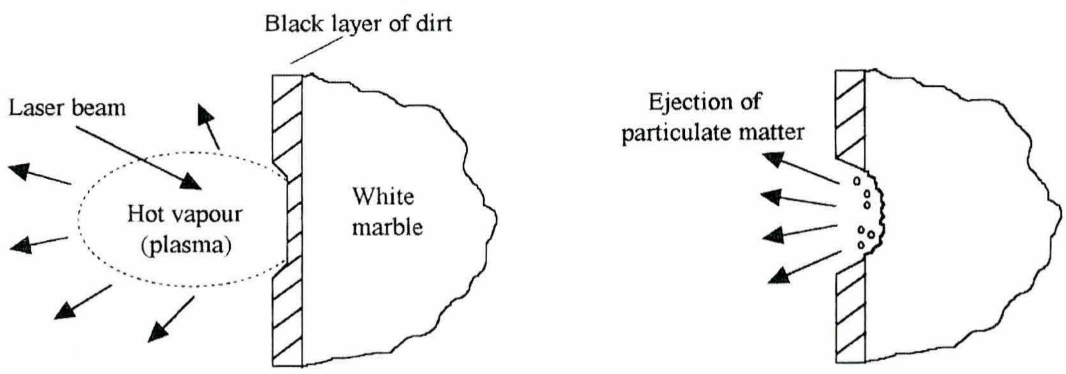
Absorption of laser beam

Reflection of laser beam

Initial interaction of long pulse radiation with a dark encrustation. Strong absorption of energy leads to vaporisation of material.

Final interaction of long pulse radiation with a dark encrustation. Once the encrustation has been removed further pulses are reflected from the weakly absorbing marble surface.

Figure 1.3. *Normal-mode cleaning (Asmus, 1973).*



Beginning of laser pulse

End of same laser pulse

Vaporisation of encrustation occurs early during the pulse, leading to formation of a plasma. The temperature and pressure of the plasma increase rapidly as the incoming laser radiation is absorbed and a microscopic compression is applied to the surface.

As soon as the laser pulse finishes the plasma expands away from the surface. The surface relaxes and a thin layer of material is ejected.

Figure 1.4. *Removal of material by Q-switched laser radiation (Asmus, 1973).*

Fig. 3. - figure 1.3. and 1.4, the laser cleaning process by John Asmus in Martin Cooper, Laser Cleaning in Conservation (5)

Fig. 4. half cleaned marble sculpture

Fig. 5. Sensitive cleaning of scales on a sandstone surface

easier to remove because it is darker. In reality such clear simple cases are rare and difficult situations are making the process of laser cleaning quite complex.

Base for laser cleaning

In the field of conservation (= cleaning) the most important parameters defining the conditions are the stone type and the nature of its surfaces as well as the presence of historical paint layers. The characteristics of the patina layers including black crusts, dust, soot and salts to be removed with the laser device are also important concerning the effect and speed of the cleaning process.

In principle every cleaning has to respect the signs of history and time because they are documenting the periods between creation and today. The task of laser cleaning is also connected with the "value of age" and other aesthetic values (**Table 1**).

Table 1: Principles of conservation and restoration in combination with laser cleaning:

Sandstone, calcareous sandstone, marble, red limestone

conservation report regarding to laser cleaning ↓	aspects of preservation of monuments (e.g. value of age) ↓	natural science report regarding to laser cleaning ↓
	target of the laser cleaning ↓	
	specimen of cleaning ↓	
conservation criticiem regarding to laser cleaning	criticism from the point of preservation of monuments (e.g. esthetical value) ↓	natural science report regarding to laser cleaning
	comparison between rezults and the target ↓	
	forecast/ decision ↓	
laser cleaning done by conservator-restorer ↓	controlling by experts from official agencies of preservation of monuments ↓	controlling by natural scientists ↓
	concept for maintenance	

as well as other bright stone types have shown very successfully excellent results after laser treatments. The risk of undesirable cleaning effects has been reduced through foregoing appropriate cleaning samples and permanent scientific controlling. For special cleaning problems e.g. white marble surfaces with sandy scaling the laser tool can preserve even delicate surface details, which are often identified as last preserved original stone surfaces (**Fig.4 and 5**). A big advantage can also be the possibility to clean without pre-consolidation (e.g. ethyl silicate, acrylic resins, silicon resins and other mixtures). In this case laser cleaning can often be faster than other cleaning techniques.

Stone material where Laser was applied successfully:
- bright marble: Carrara marble, Laaser marble, Penthelicon marble, Carinthian marble,...
- sandstone: Types of quartz sandstone (e.g. Wienerwald-Flyschsandstein), types of calcareous limestone (e.g. Margarethner or Zogelsdorfer stone)
- compact limestone: Istrien stone, Untersberger limestone, Verona red, Adneter red.

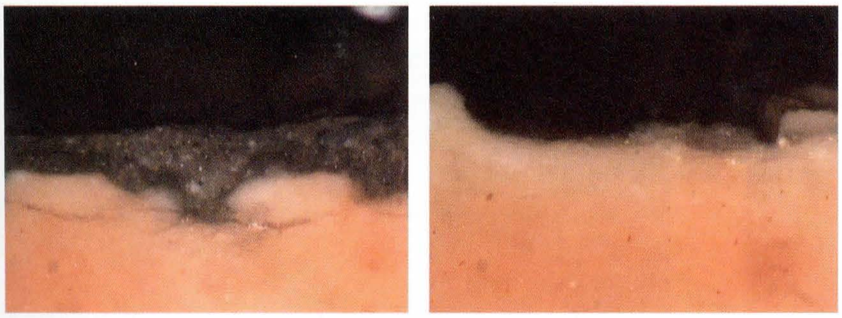


Fig. 6. Photo from a cross section of a red limestone under the light microscope before and after laser cleaning

- Concrete, artificial stone and different types of mortars

Material that could be removed from stone surfaces:
- black crusts
- thin concrete layers
- dust and soot
- old acrylic and epoxy layers from old treatments
- casein layers from former conservation treatments

From the economical point of view the comparison between traditional and high tech cleaning systems is very important. Often the best cleaning result can be achieved by combining three or more cleaning techniques, including also laser treatment for special purposes (**Table 2**). However, if there are monochrome or polychrome layers,

Table 2
Example: Comparison of different methods of cleaning at the Romanesque west portal of St. Stephens Cathedral in Vienna:

tool or material	location	result	time in minutes/dm²
abrasive gums, wish-up and fine brushes	ornamented vault ornaments inside	pre-cleaning	30
vacuum cleaner	all surfaces	before pre-cleaning	1
compresses (9 x) and fine brushes	columns, ornamented vault, flat surface inside	pre-cleaning (only by salty areas)	45
precise whirl blasting (low pressure with dolomite powder)	flat surface outside	pre-cleaning	10
micro sand blasting with different powders	flat surface inside cornices	pre cleaning	15
	flat surface outside	final cleaning	20
laser cleaning with high energy	**sculptures and ornaments outside, flat surface inside**	**final cleaning**	**20**
laser cleaning with low energy	**ornamented vault columns, sculptures tympana (all details**	**final cleaning**	**15**
compresses with ammonium carbonate	figurative consoles outside	additional cleaning	20

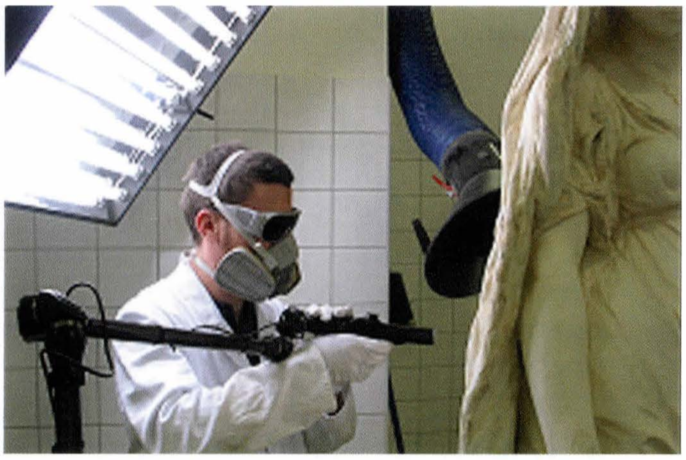


Fig. 7. How do protect yourself during laser cleaning

cleaning with Nd-YAG lasers is possible only in rare cases.

It is also very important for the conservator-restorer to follow safety regulations thoroughly. Protection with special glasses for the eye, gas-mask, appropriate cloths, exhauster and a right isolation with a sign for danger of the working place (studio, scaffolding, work shop) where the laser is used is an absolute mandatory.

Applied to stone conservation the laser technique is not only used for cleaning but also for laser diagnostics (e.g. holography, vibrometry), 3D-measurements for monuments and artworks (documentation tool) and spectroscopy for monitoring and identification (e.g. RAMAN, LIBS, LIF).

Prospects

There is a great attention to side effects caused by laser cleaning (short- and long-term), including the behaviour of pigments and binding media, removal of former conservation layers, fundamentals of laser-artwork interaction (yellowing), recent laser developments for cleaning (e.g. uncommon wavelengths, short/long pulse), laser cleaning stations for practise (in situ/atelier/lab), standardization, safety and health aspects and many other connected contents.

In Austria the use of laser cleaning in the field of conservation was introduced in 1995. During the last 10 years a lot of different stone monuments and historical

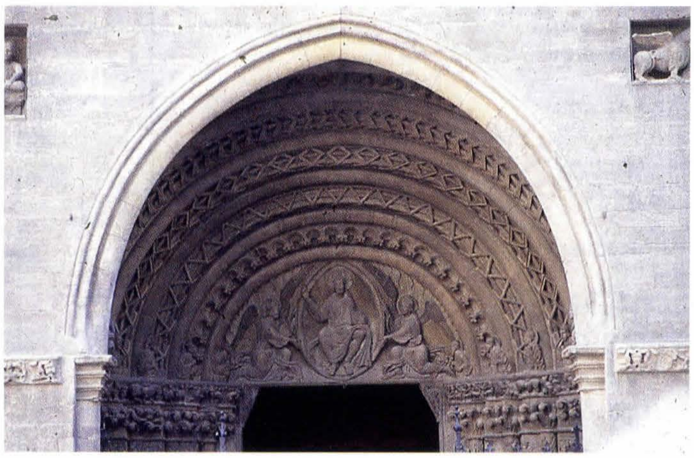


Fig. 8. St. Stephens cathedral, west portal after laser cleaning and conservation

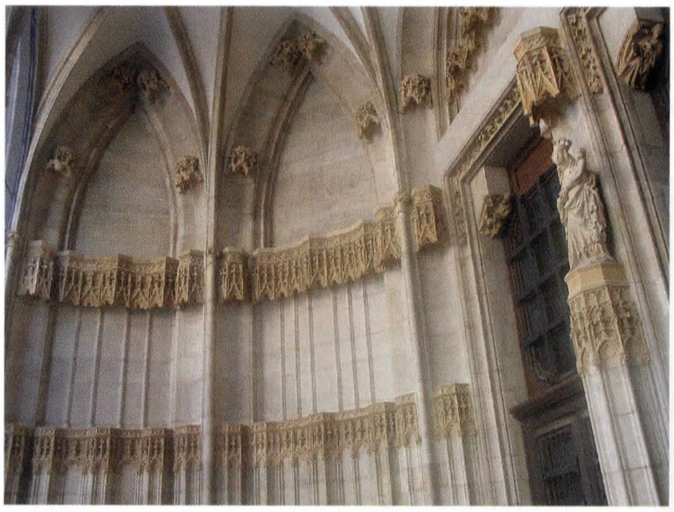


Fig. 9. St. Stephens Cathedral gothic portal under the south dower after laser cleaning

facades were cleaned by laser technique (e.g. Romanesque and Gothic parts from St. Stephens Cathedral (**Fig. 8 and 9**), marble sculptures from the parliament and public gardens, Gothic outdoor sculptures and facades from many other churches and buildings). Four different types of modified Nd:YAG-lasers were used.
The cooperation with Romania started 6 years ago during the Action COST G7 (Lasers for artworks conservation), an European project, which was initiated by a Romanian colleague (Roxana Radvan). Meanwhile the laser is used in Rumania also for very delicate pieces of artworks and monuments.

An example:

The tomb of an Austrian Minnesingers called Neidhart Fuchs is one of 140 other grave monuments outside of St. Stephens cathedral. It was made around 1360 and consists of a rectangular stone tomb, a formal reduced lying sculpture and a relief torso. The sculpture and the relief torso are made out of local calcareous sandstone. Originally these parts of the tomb had a totally polychrome surface. The coloration was very intense and the oil-painting was painted directly on the stone, without first ground. The used pigments are: cooper green for the hat, minium and lead white for the colour of the skin, azurite for the habit and the bolster with an inner-painting in lead-tin-yellow, iron-oxide-red for the hair, cinnabar for the outer-coat, ochre as ground for the gilding of the belt and lead-tin – yellow for the background of the coat of arms. But only traces of these colours can be found on the original surface. Most surface areas of the sculpture are reduced by weathering, black-crust-formations and mechanical damage. The stone shows a lot of cracks, a loss of binder under the black crust and a high amount of chlorides and nitrates. The cleaning, conservation and restoration is based on the results, which was applied at the west portal of St. Stephens Cathedral.
According to the different conditions of the deposits partly first individual pre cleaning has been made with common methods as abrasive gums, compresses with

paper pulp and ammonium carbonate, pneumatic micro tools and micro sandblasting.

But most surface areas were cleaned by laser tool. In some cases sensitive pigments did not allow the laser treatment (e.g. cinnabar) fig.

In the contrary to the other cleaning methods laser was the most sensible. In any case we found important to know where and which colour was left under the black crust because of the specifically reaction from the laser with pigments and the painting media. The laser, which was used was the pulsed Palladio Nd.:YAG laser from ALTECH (parameters of the tool: 1064nm, 6nS, 5-15Hz, 350-650mJ, size of the laser spot 6-10mm, different lenses).

The facade of the cathedral behind the grave was painted under the black crust with ochre and grey lime washes

Fig. 10. The tomb before laser treatment

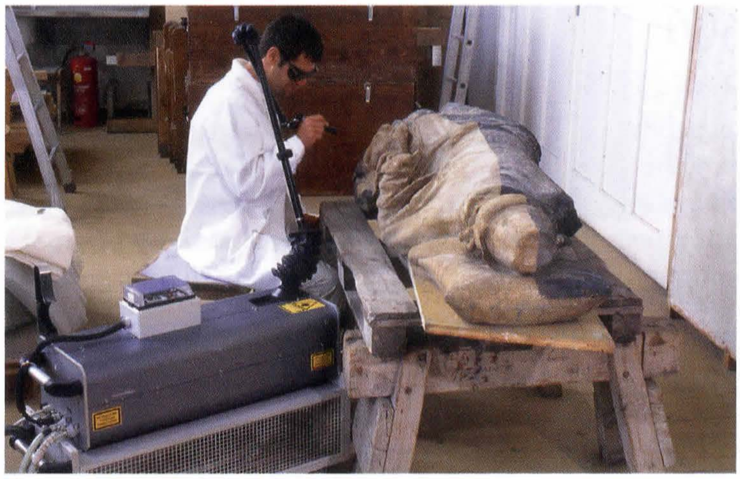


Fig. 11. the sculpture of the Minnesingers during cleaning

Fig, 12. The tomb after laser cleaning and conservation

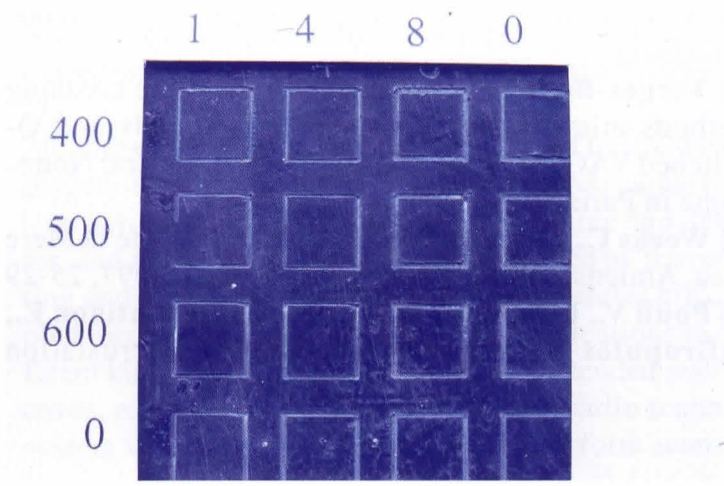


Fig. 13. Ultramarine and azurite shows no changing of the pigments after the laser treatment. 1, 4, 8, 0, are the numbers of laser shots. 400 (ca. 260mJ), 500 (ca. 330mJ), 600 (ca. 400mJ) are the different levels of energy

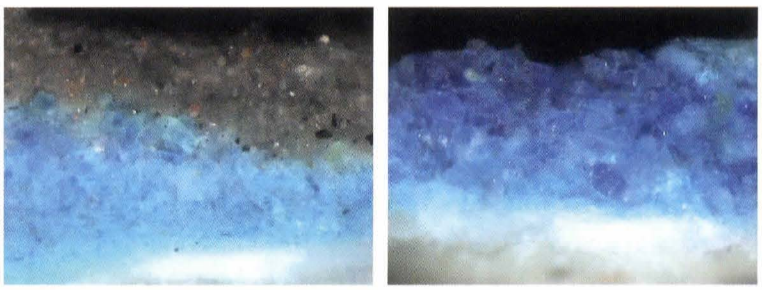


Fig. 14. Photo from a cross section of an azurite layer under the light microscope before and after laser cleaning

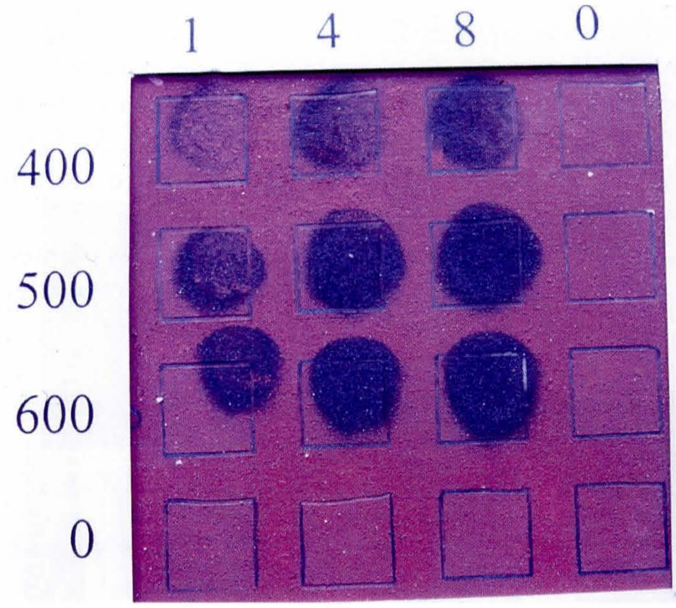


Fig. 15. Cinnabar and lead tin yellow shows total blackening on test areas after the laser treatment

and dark joints. This surface also was cleaned by laser and ammonium carbonate compresses.

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APPLICATION OF AN IMAGING TOPOLOGIC RADAR TO 2D and 3D MODELING OF A FRESCO PAINTED SURFACES IN SUCEVITA MONASTERY DURING THE CULTURE 2000 CAMPAIGN

Massimiliano Guarneri, Luciano Bartolini, Roberta Fantoni, Mario Ferri De Collibus, Giorgio Fornetti, Emiliano Paglia, Claudio Poggi, Roberto Ricc

Abstracts

An Imaging Topologic Radar (ITR), formerly designed to characterize painted surfaces, inside or outside of historical building, has been specifically developed to collect data inside caves, caves churches and chapels. During an international workshop and the related on-site laboratory held on July 2006 in Bucovina (Romania) within the European programme CULTURE 2000, the system has been utilized to make a complete reconstruction of the inside of the Burial Chamber in the Resurrection Church in Sucevita Monastery, and of the outside of a wall surrounding the northern apse. Data have been collected in combination with different imaging techniques, in order to supply a reference frame for their comparative study, in particular as far as fluorescence imaging and acoustic interferograms are concerned, in order to facilitate the restores' work and in view of a successive multimedia conservation and fruition.

Key words: physical diagnostics on cultural heritage, imaging topologic radar, laser range finder, 3D modeling, frescoes.

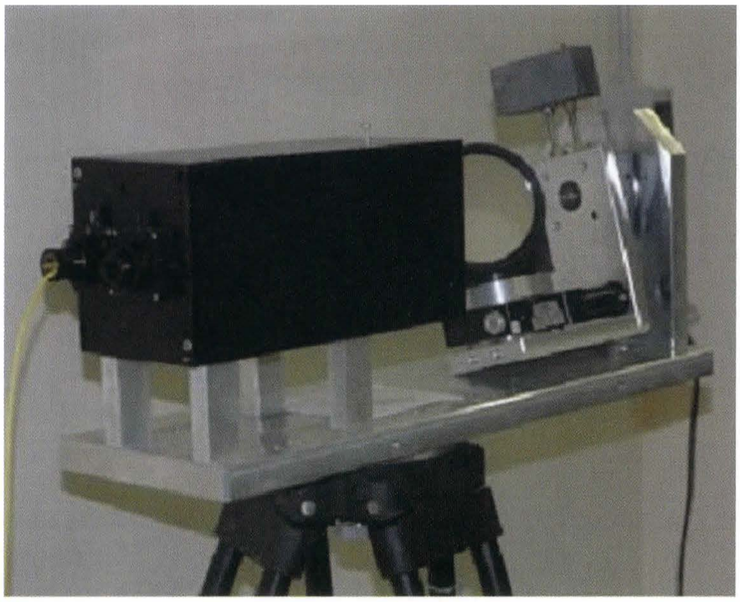
1. Introduction

The Sucevipa Monastery, in particular the Resurrection Church, has been one of the sites selected for on-site activities during the international workshop "Saving Sacred Relics of European Medieval Cultural Heritage", within the corresponding CULTURE 2000 program aimed to supply innovative tools to assist the on going restoration process. In this site the Imaging Topologic Radar (ITR) has been utilized to characterize fresco's inside the church (on the northern apse and in the burial chamber) and on its outer painted wall (norther apse). Selected areas have been scanned in order to test the possibility of data merging with images collected by different techniques (LIF, vibrometry) each one containing different pieces of information valuable to the restores, and to evaluate the instrument performances with respect to those offered by using commercial laser scanners.

2. Experimental set-up

The ITR developed at ENEA Frascati [1] is an optical sensor based on the Amplitude Modulation Laser Radar principle. Its scheme has been detailed described in formers papers [2], so here it is worthwhile to recall only that its operation requires the use of a CW laser whose amplitude is modulated from MHz to GHz. Both intensity and phase--shifting of the back-scattered beam are collected by a telescope and simultaneously detected. A double modulation of the laser beam allows for combined remote use (up to 35 m) and high resolution (to 100 - 200 μ). While the signal intensity gives a clear (shade-free) gray scale photographic picture of the scene scanned by a proper electro-optics device, from the phase shift an accurate metrology of the target can be obtained with a resolution depending on the modulation frequency selected. The 3D rendering of intensity and phase images collected by the ITR allow the precise localization of any feature on the surface and can be further used to reference images collected by other techniques. All the required software is proprietary and covered by copyright [3].

A compact instrument has been developed for field campaigns, in which the system is split into two separate parts – an active module, comprising laser source and detector, and a passive module, basically formed by transmitting and receiving optics [4]. The two modules are coupled through optical fibers. Specific applications to different kind monumental surfaces, from extended walls to caves, required the development of a versatile scanning system which offers the possibility to perform scans on large angles, in order to collect metrological data on the entire environment (310° vertically and 40° horizontally) minimizing in the same time the number of needed scans. The head optical axis, along with both the laser beam and the backscattered signal coaxially propagate, is defined as the horizontal axis. A suitably designed bracket allows to install the optical head in positions rotated of fixed angles with respects to the floor, in order to scan walls including either a vault or the floor itself. The optical head, with the bracket as a detail, is shown in **Fig. 1.** For field operation the ITR is equipped with fast scanning, highly accurate, motor drivers from Newport (mod. M-URM80CCHL) and all its electronic components, including laser, detector, control and data acquisition system are assembled in two small avionics boxes (535x395x790 mm each), in order to facilitate transportation. Main instrumental characteristics and settings during the measurements in Sucevita are summarized in **Table 1**, note that the data acquisition time refers to the model of the entire burial chamber.



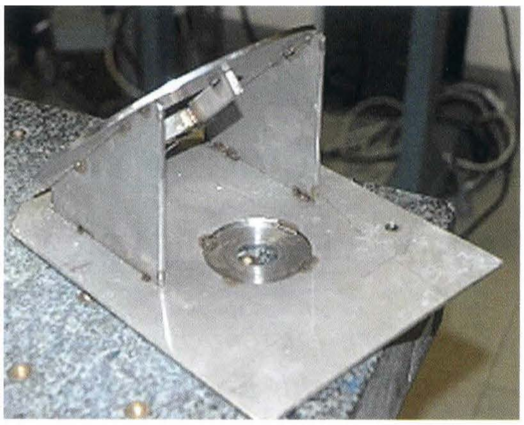


Fig. 1 - Picture of the ITR optical head with the scanning system suitable to closed environment scans. Left: entire head; right: a detail of the holding bracket mounted at 45° in order to optimize the scan on vaults.

As far as the data handling is concerned it is worthwhile to remind that in the case of entire chambers, different section are acquired with a partial overlap, after polar reformatting the entire 3D model is built based on the absolute distances measured (cloud of points). The available black and white 3D image, contemporary acquired with each point of the cloud, allows for a further check of the method on the overlap of the drawings. The 2D images contains a valuable information, also independently on the model, as a remotely acquired high defini-

Optical Wavelength	λ = 830 nm
Transmitted Laser Power	P = 7 mW
Beam Modulation Frequency (low/high)	ν^L = 5/200 MHz
Spot size	d^m= 700 µm – 3 mm
Distance From Target	R = 1 – 15 m
Pixel Sampling Time	τ = 10 ms
Average Range Resolution	200 µm
Time to acquire the burial chamber model	~ 30 hours
Average lateral resolution (10 mdeg)	17 µm – 2.6 mm

Table 1 – Technical data and setting of the ITR system while acquiring the 3D model of the burial chamber in the Resurrection Church at Sucevita monastery.

tion picture which might reveal details of interest, an example is shown in **Fig. 2** where an inscription under a high arch can be easily read. The availability of the intensity images on the 3D model is a great help whenever an overlap with independently acquired 2D images is required, as shown at the end of the next section.

3. Results and discussions

The model of the entire burial chamber has been acquired and reconstructed, complete with the gray-scale images of the frescoes. Two views are shown as examples in **Fig. 3**, due to the large size of the images collected at high resolution, only reduced data are usually shown after a 90% to 99% decimation. Data have been collected during day and night, acquisitions were started from an height of about 1.80 m, in order to avoid problems related to the presence of visitors during day operation. Most of the frescos are located on the 3D model, only a few corners and the lower parts of the walls are missing, however the latter was covered mostly with minor geometrical decorations. The 3D model obtained offers the possibility of studying the chamber at different level of complexity:

1. An overview is possible, using the reduced model to make a movie and examine the chamber from different prospective, as if recorded by a video camera (movies can be released with standard *.avi extension)
2. Metrical images can be obtained relevant either to the precise location of different painted features, architectonic elements or surface damages (bubbles, sketches, discolorations). In **Fig. 4** different projections of the model obtained for the front wall of the chapel (northern apse s) are examined. The front image shows an example of measuring painted features, e.g. one aureole, similar measurements for the three saints gave different diameters: 207.1 mm, 225,9 and 229.4 mm from left to right.
3. Architectonic defects ascribable to the original construction or to progressive degradation can be highlighted once the real model is examined in term of curves of level, or selected sections are compared to the ideal geometrical structure. In **Fig. 5** the image from the front half of the vault is overlayed by isohypses on the model, which highlight details in the construction along with metrical representation. In **Fig. 6** the measured section of a single arch is compared to its mathematical fit with an ellipsis having the same major axis diameter. Discrepancies between the real model and the fit function are in this case related to fresco's irregularities which may suggest the need for a restoration action (suspect detachments).

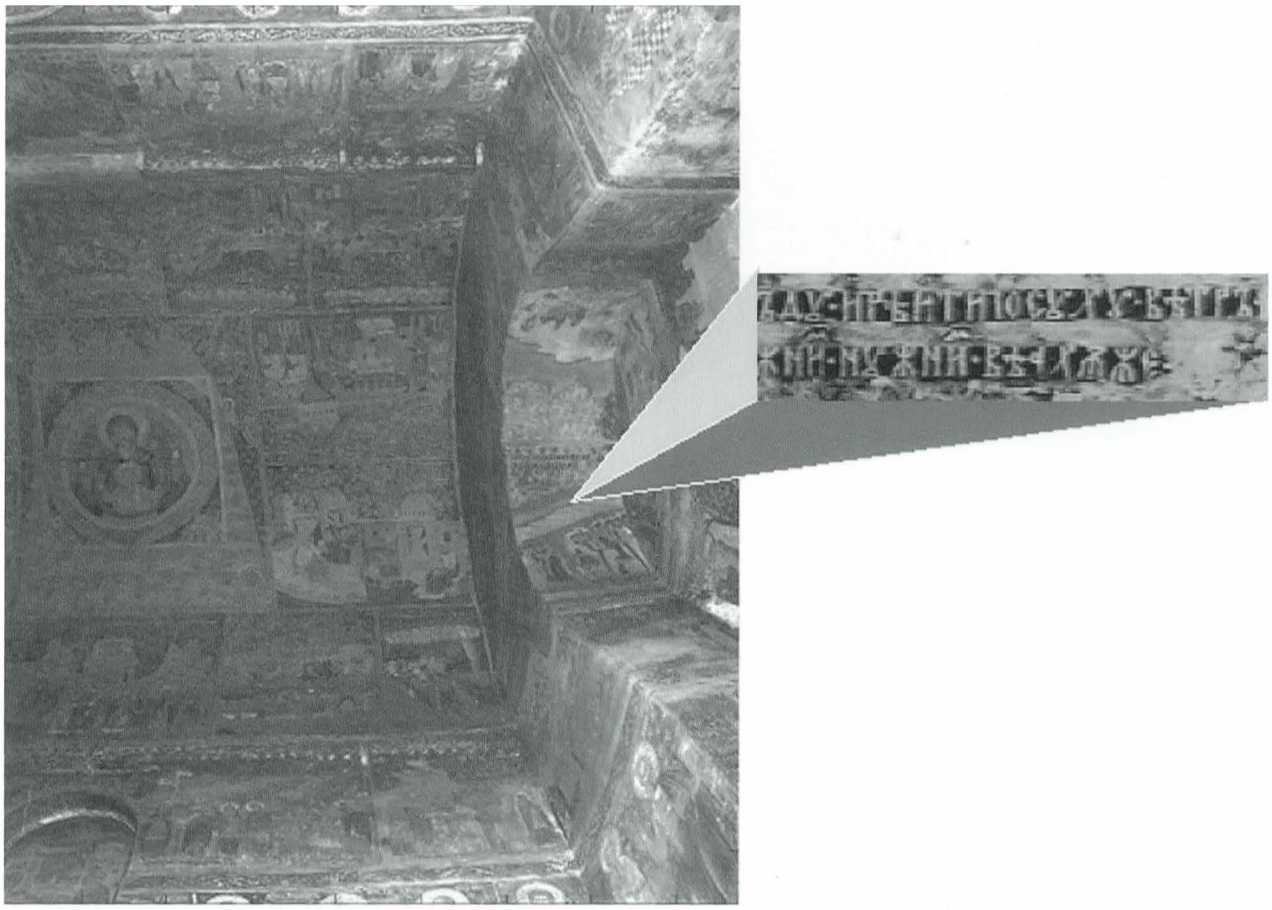


Fig. 2 – Black and White intensity image collected on the right side of the vault in the burial chamber, with a zoomed detail of an inscription found under the arch in the niche near the window.

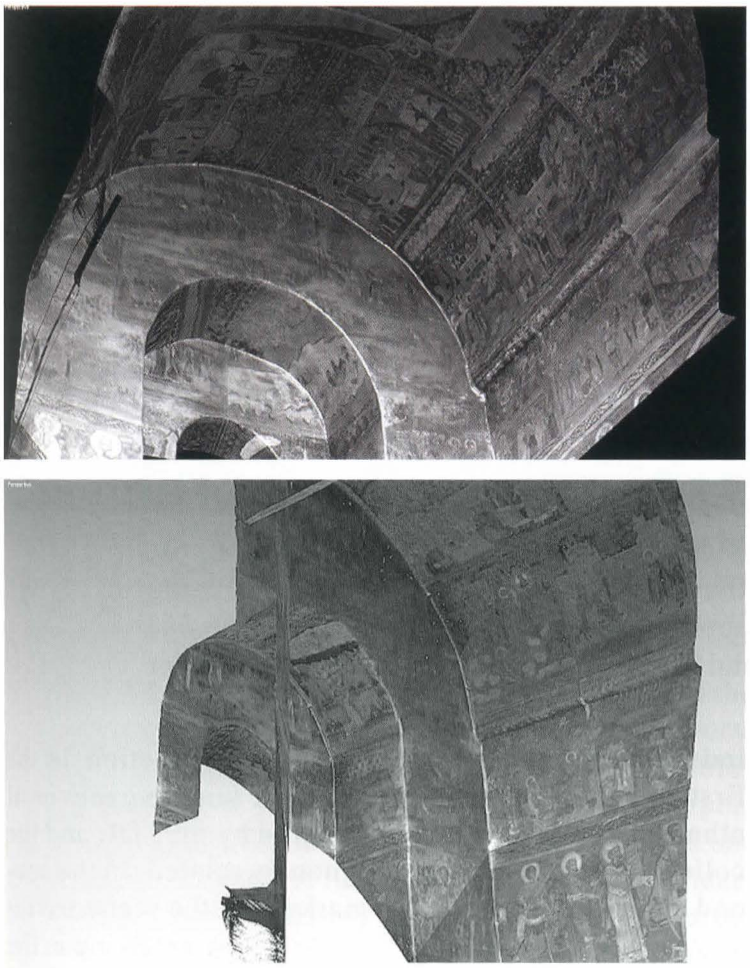


Fig. 3 – Two section of the burial chamber 3D model dressed by the black and white images contemporary collected by the ITR: wall to the right window (upper), wall to the left window (lower).

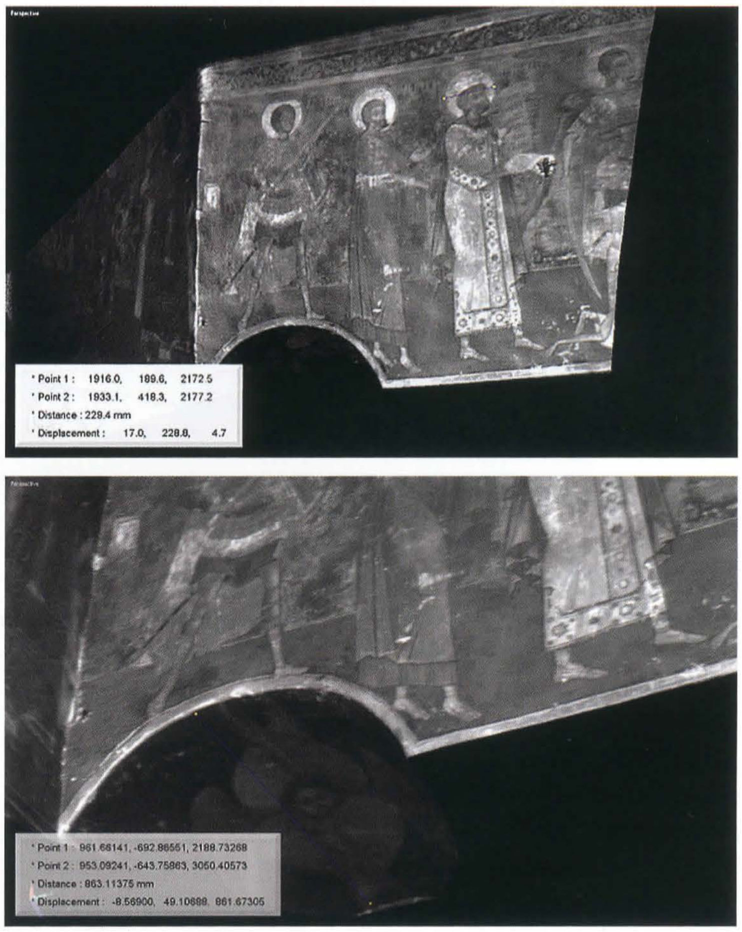


Fig. 4 – Front wall of the burial chamber, going towards the altar. Examples of metrical capabilities of the instrument are shown looking a different projection of the model: in plane as the third aureole diameter (top), out of plane as the door arch thickness (bottom).

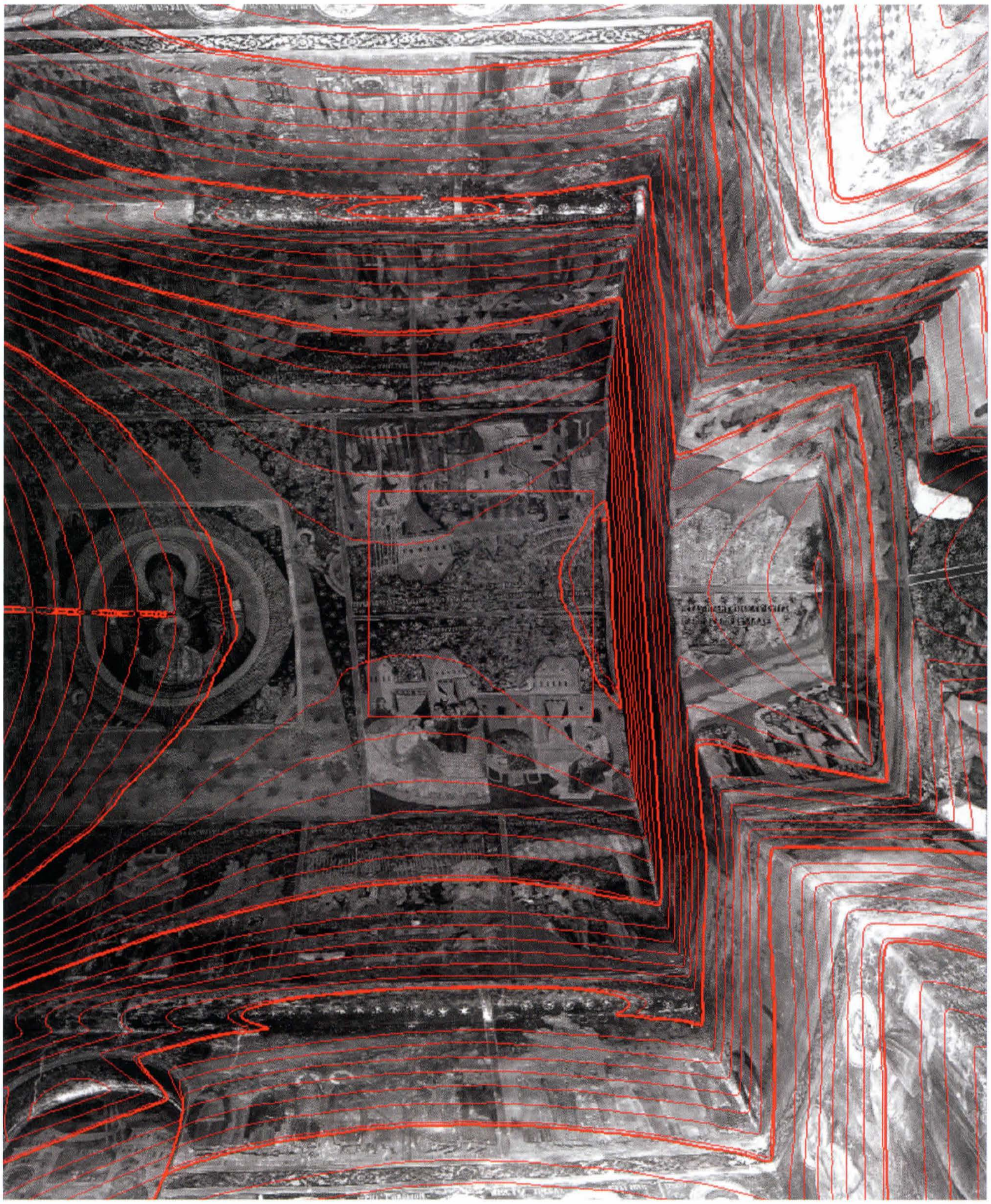


Fig. 5 – A projection of the image of the front side of the burial chamber vault, in red the isohypses obtained from the model. Note that different projection can be obtained by rotating the model and the image is automatically overlapped on each of them, due to the one to one correspondence between the phase (distance) and intensity (reflectivity) data collected for each scanned point.

The reconstructed 3D models, dressed with the corresponding gray-scale image, are suitable to be used as a metric frame where reporting image data collected by different data acquisition systems. In order to merge different layers of digital images on the same model a suitable number of reference points is required. For the present ITR system two different protocols have been developed: one suitable to utilization only in the case of two different scanning systems contemporary present on the same scenario, another of more general use not requiring the presence of both instruments together and independent on the principle of image collection. In the first case the absolute position of the scanning mirror of other system is accurately measured by the ITR, and the collected images are unambiguously related. In the second case easily identifiable markers on the scene are required, which might be difficult to add or annoying in the case of cataloguing artwork. Although the referenced position of the LIF scanning system with respect to the ITR was already demonstrated in a former campaign in Constanþa [4], the area examined in Sucevita by the LIF system looking for biodegradation was framed within scaf-

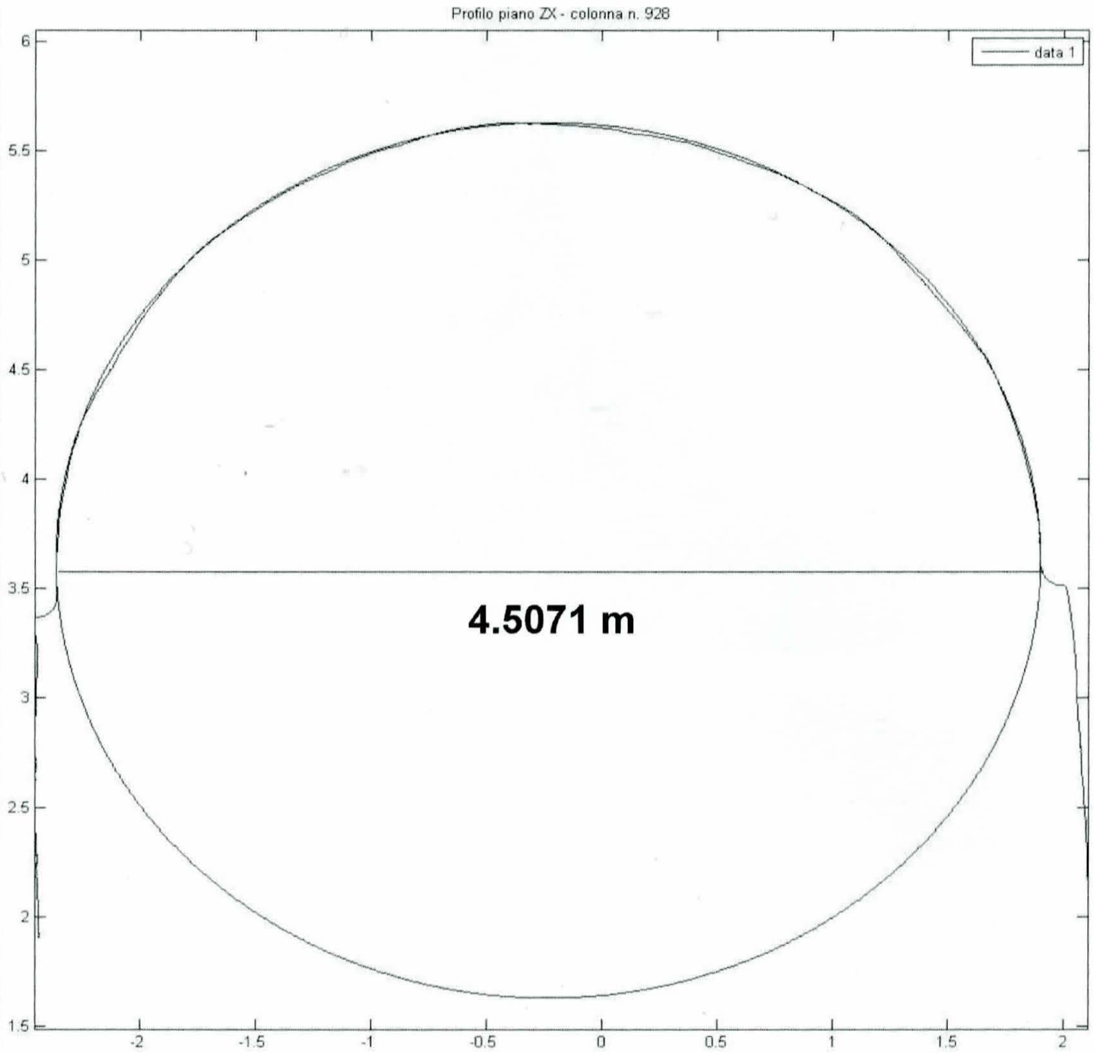


Fig. 6 – A section of one arch on the left wall in the burial chamber as derived from the real model is compared to its mathematical reconstruction corresponding to an ellipsis with the given major axis, the occurrence of discrepancies may be related to the onset of detachment.

folding, built by the restorers involved in the cleaning procedure. So two scanning systems could not be mounted contemporary to look at the same location, and the procedure based on markers had to be adopted both for texturing the color picture and the false color LIF image on the 3D model. However no marker had to be added since the drawing on the gray-scale image collected at high resolution (200 μ) by the ITR served itself as a very large set of reference points. The results are given in **Fig. 7**, where both a color picture and data collected by a LIF scanning system operating at 355 nm and released in false RGB colors [5] are overlapped to the 3D model. Note that the achieved resolution is in both cases limited by the worst instrumental performance, which is 400 μ for the color digital camera and 1 mm for the LIF scanner. The importance of the capability of referenciating different kind images on the 3D model is fully understood when considering that this is often the only way to precise localize areas where a specific restoration action must be undertaken. For instance the LIF images show a spot where a biological attack from fungi is present (on the lower part of Christ dress) not evident in the color picture and not precisely localized in the 2D LIF image alone, which appears distorted due to the angle of collection from the scaffolding.

The ITR system is fully suitable to field operation, its outdoor capabilities during the day (in full sun light) have been checked on an outer painted wall where another group was performing structural tests by means of laser vibrometry [6]. The model of the scanned area, a curves section of the absidis is shown in **Fig. 8**, as collected in a fast scanning (four time faster than in the former case) from the ground. The same area (reaching 5 m of height) was independently investigated by the other group after installing the laser vibrometer head on a scaffolding. Work is in progress to overlap on the model the low resolution interference image collected by the second instrument. Concerning the resolution of the ITR image shown in **Fig. 8**, it is worth mentioning that it is lower than in images collected inside only because of the faster scanning utilized in order to avoid to leave the instrument unattended outside in the night (total data acquisition time was limited to 2 hours).

4 Conclusion and perspectives

The ITR system developed at ENEA Frascati and utilized in its compact version for field operation during

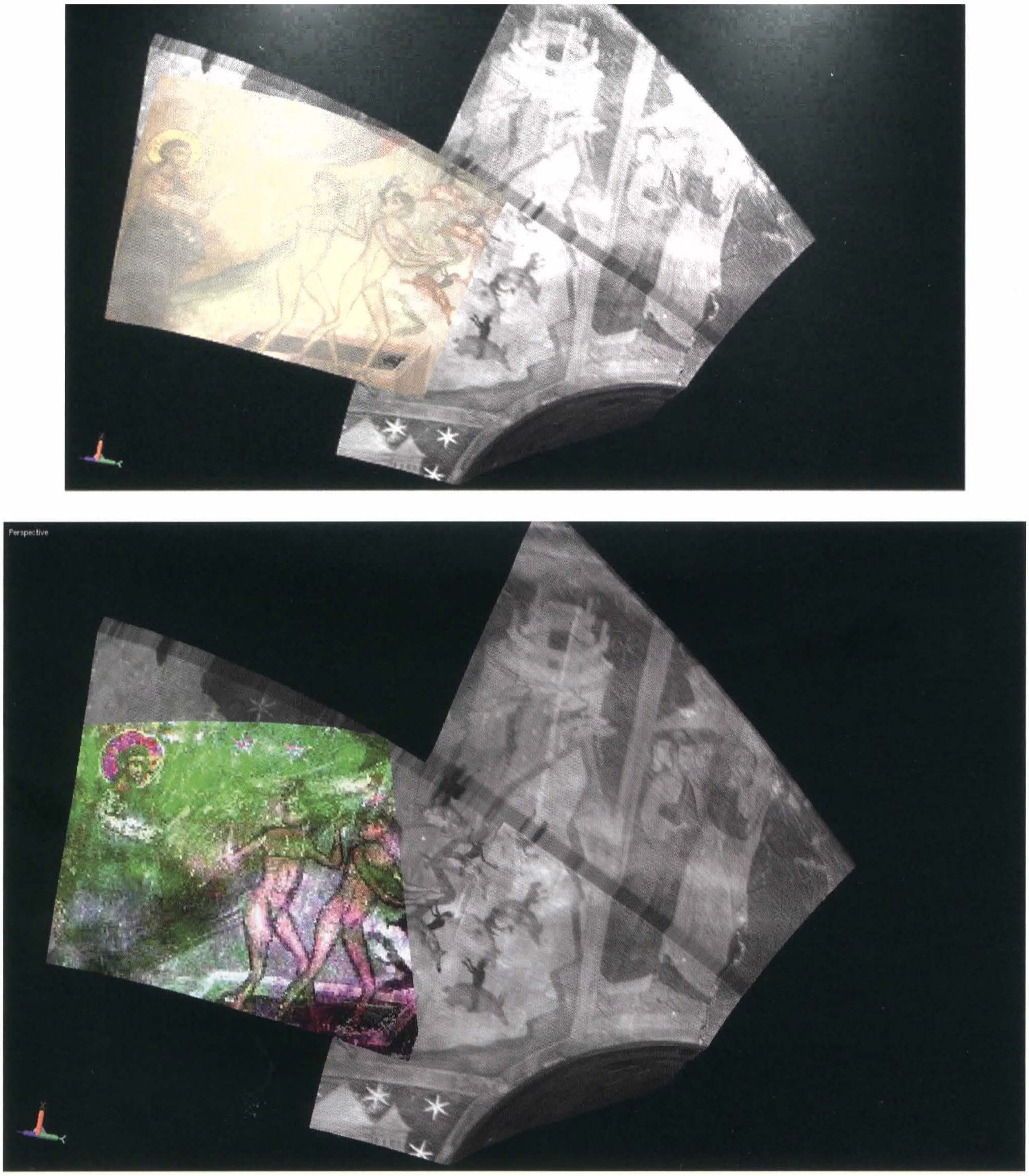


Fig. 7 – 3D model of a section of the left absidis where the fresco "Jesus Heals the Demon-Possessed of Gadarenes" is painted, with the black and white image contemporary acquired by the ITR. Overlap of: a digital color picture on the model (top), a LIF scanner image reproduced in false colors (bottom).

the CULTURE 2000 campaign on painted Moldavian Monastery has shown all its capabilities in:

1. acquiring model of surface painted with the a fresco technique, also in the case of dark surfaces before starting the cleaning restoration procedure,
2. contemporary acquiring gray-scale images of the painted surfaces which can be studied from any orientation of the model and metrically characterized with sub-millimetric resolution,
3. highlighting surface irregularities with respect to a mathematical model, which might be related to the architectonic structure (either original or degraded) or to damages in the outer layers (bubbles in the plaster, thin cracks),
4. supplying a frame with high resolution metrical capabilities for supporting different kind of images collected by other instruments, which examined independently the same painted target.

In general our ITR system showed a higher resolution than commercially available laser scanners (although at the price of longer scanning times), a larger versatility in acquiring data from partially hidden corners and surfaces requiring high degrees of freedom, and the unique possi-

Fig. 8 – 3 D model of portion of the left niche in the outer wall of the absidis. The same area has been scanned by a laser vibrometer [6] looking for structural cracks.

bility of the automatic acquisition of the gray-scale image, which largely facilitates the merging of other images independently collected by different instruments.

Although colorimetric information relevant to the painted surface can be superimposed on the 3D model by digital images independently collected, the realization of a laser remote colorimeter is an objective of the research group. A three color system might be the first step towards this realization and work is in progress in this direction.
Another issue which is pursued by the research group is the design of optical heads suitable to the exploration of hostile environments, which in the case of Cultural Heritage preservation means inaccessible cavities (caves, tombs, etc…). The design of a scanning system based on a motorized prism is at the basis of such a kind of innovative optical probe inspector.
The ITR system is also suitable for underwater use, once the laser wavelength is properly selected. A miniaturized prototype for in water image collection and 3D model reconstruction has been already developed with short range operation (up to 2 m) [7]. Work is in progress to scale up this prototype to higher distances for underwater archeology from unmanned vehicles.

Acknowledgements
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The authors are deeply grateful to the coordinator Roxana Radvan for the outstanding organization of the international workshop and the on-site laboratory in Sucevita. A special thank is addressed to Daniela Ferro for the digital pictures. The precious help of the restorer leader Oliviu Boldura and its group is gratefully acknowledged during all the measurements, together with the co-operation of Enrico Esposito and its group for the on-going work of merging the laser vibrometry results on the ITR model of the selected walls.

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APPLICATION OF A SCANING HYPERSPECTRAL LIDAR FLUOROSENSOR TO FRESCO DIAGNOSTICS DURING THE CULTURE 2000 CAMPAING IN BUCOVINA

Francesco Colao, Roberta Fantoni, Luca Fiorani, Antonio Palucci

Abstract
A hyperspectral system based on laser-induced fluorescence (LIF) has recently been developed for optical characterizations of surfaces relevant to cultural heritage. This paper describes its field application to frescos diagnostics during an international workshop and the related on-site laboratory held on July 2006 in Bucovina (Romania) within the European program CULTURE 2000. The scanning LIF system demonstrated its capability to supply valuable information on the considered frescos, which were under restoration; in particular, results relevant to biological attacks, current and former restoration methods, and realization techniques, were achieved.

Key words: physical diagnostics on cultural heritage, laser-induced fluorescence, scanning laser systems, frescos, biodeterioration.

1 Introduction
A complex of monasteries, included in the UNESCO World Heritage List [1], is located in Bucovina, Romanian region at the borders with Ukraine and Moldova. They have been built as fortresses between the XV and the XVI century and hold, like a coffer, their precious content: the church at the center of the inner garden, decorated with unique frescos. In fact, those paintings are exceptional in size (they cover all the interior and, in the best preserved cases, most exterior walls) and quality (they are rich of details and gildings, as icons on wood). Nevertheless, these admirable works did not cross the centuries unaffected and require diagnostics and restorations.
From July 16th to 29th, 2006, took place in Gura Humurolui, Bucovina (Romania), the international workshop "Saving Sacred Relics of European Medieval Cultural Heritage" that put together more than one hundred delegates from all over the world, which are experts in different fields linked to the topic: from restoration to conservation of works of art, from icon theology to laser physics. The workshop, funded by the European Union in the framework of the "CULTURE 2000" program [2], included a theoretical part, with lectures on the artistic and scientific aspects, and a practical part, with visits to monasteries, on-site activities and instrumental measurements. During the workshop different high technology systems such as ground penetrating radar, thermocamera, laser vibrometer, laser range finder, laser-induced breakdown spectrometer, laser cleaner and laser-induced fluorescence (LIF) spectrometer have been used to demonstrate their capabilities in supporting the restorers' work.
This paper describes the application of laser-induced fluorescence imaging technique to diagnostics of frescos performed during the workshop by researchers of the Physics Technologies and New Materials Department - Laser Applications Section, carried on along a research and development line pursued for years [3, 4, 5, 6] and funded on different Italian and European projects.
In a typical LIF measurement, an ultraviolet laser beam is directed on the surface under study where it excites a fluorescent emission, whose spectrum is collected and detected by an optical system. The target point can be accurately varied, scanning a complete image, by moving the beam with a electrically actuated mirror. A portable computer synchronizes laser and mirror so that the instrument can carry out automatic scans on large surfaces. The information on the material at the scanned surface is contained on the fluorescence spectrum that allows to reveal details hidden in a naked eye analysis, related to pigment composition, biological attack and former restoration techniques. LIF technique has the advantage of being fast (a few minutes are required to acquire a 10×10 cm^2 image), remote (images are recorded at several meter distance) and not invasive (no sample is removed or damaged). The compact instrument realized at ENEA, thanks to its reduced size and weight (see sect. 2) is also suitable to the utilization on scaffoldings whenever high walls or vaults have to be examined.
The sites under study were located in Bucovina. They were:

- the Resurrection Church in the Sucevita Monastery,
- the Saint Nicholas Church in the Popauti Monastery in Botosani,
- the Saint Nicholas Church in Balinesti.

All the sites are currently under restoration.

2 Instrument and method

The compact scanning LIF system used in Bucovina is the natural evolution of a previous instrument developed and tested during former projects [6]. All the mechanical and optical elements (with the exception of the laser – Thomson mod. DIVA and the spectrometer – OceanOptics mod. S2000) have been substituted, thus allowing a size reduction from $101\times54\times45$ cm^3 to $58\times43\times36$ cm^3 (i.e. of more than 63% in volume) and a similar diminution in weight. A picture and the layout of the system are given in **(Fig. 1)**, the specifications for the optical elements are listed in **Table 1.**. The small the laser pulses reach 5 mJ. The maximum energy was too high for the measurements carried out in Bucovina: according to distance and consistency of the fresco, energies ranging from 0.1 to 1 mJ have been used without focusing the laser beam (1 mm diameter) in order to avoid any surface vaporization. M1 is a high reflecting dielectric mirror, due to the specificity of its coating, the element with the appropriate reflectivity is in turn installed according to the wavelength emitted by the laser. The laser beam reaches the mirror M2 through the hole in the mirror M3. The mirror M2 is mounted on a gimbal support actuated by two stepping motors (MICOS mod. DT-80) driven by

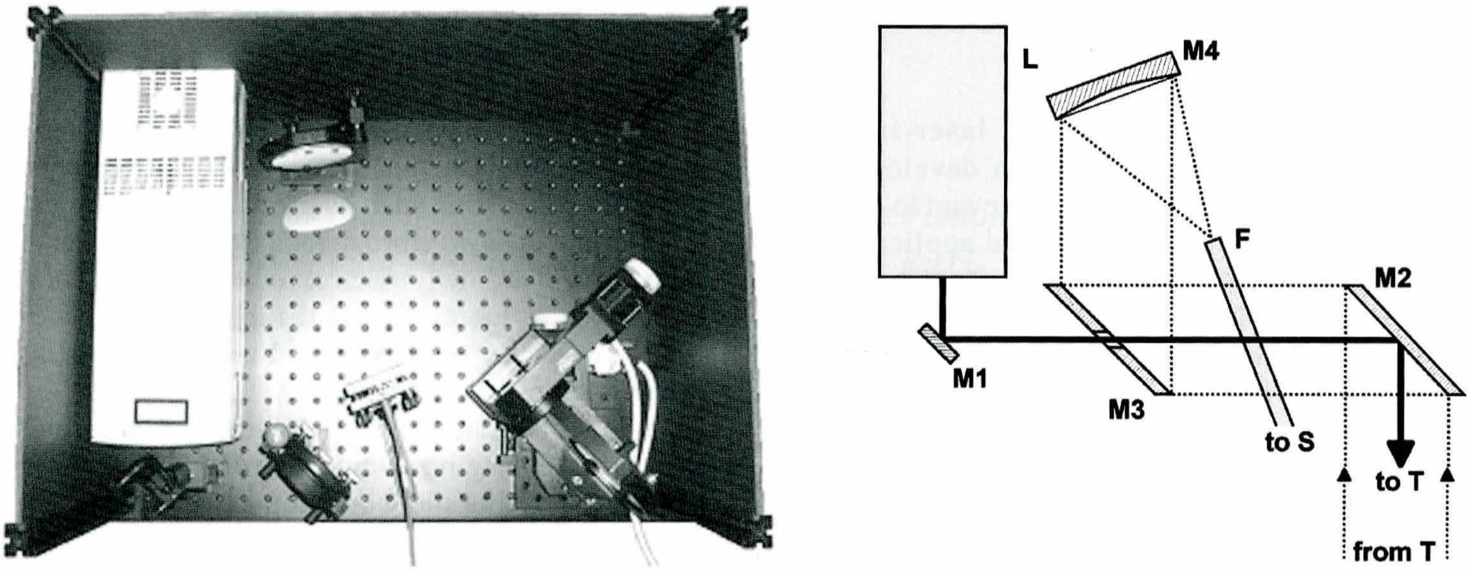

Fig. 1. - Picture from the top (left) and optical layout (right) of the compact scanning LIF system. The optical elements, described in Table 1, are contained in a rigid box (the cover has been removed to take the picture) mounted on a small optical bench.

size and weight allow an easy transport of the system and its operation from scaffolding, in the case of surfaces unreachable within the current maximum range for remote operation (10 m).

After a first doubling crystal (generating the second harmonic at 532 nm starting from the fundamental emission at 1064 nm), either a second doubling crystal or a combining crystal can be mounted alternatively in the same mechanical support inside the laser, generating radiation at 266 or 355 nm, respectively. In both cases the portable computer, so that the azimuthal and polar angles of the laser beam are accurately controlled. In this way, the target point, i.e. the beam footprint on the fresco surface, can be changed allowing the instrument to scan the surface, with the best resolution corresponding to the laser spot size.

The laser-induced fluorescence coming from the fresco is gathered by the mirrors M2 and M3 and focused by the mirror M4 on the fiber optics F. The mirrors M1, M3, M4 and the fiber optics F are mounted on mechanical

Symbol	Element	Description
L	Nd:YAG laser	ë: 266 or 355 nm (changing the crystal), energy: 0.1 – 1 mJ, repetition rate: 20 Hz
M1	Flat mirror	Coating: dielectric, ∅: 25 mm, AOI: 45°, R~99% @ 266 or 355 nm (selecting the mirror)
M2	Motorized flat mirror	Coating: protected Al, ∅: 100 mm, R~90% in ultraviolet and visible light
T	Target	Fresco, painted surfaces at different preservation stages
M3	Flat mirror with hole	Coating: protected Al, ∅: 100 mm, hole ∅: 5 mm, R~90% in ultraviolet and visible light
M4	Concave mirror	Coating: protected Al, ∅: 100 mm, f: 250 mm, R~90% in ultraviolet and visible light
F	Fiber optics	Material: quartz, core ∅: 910 µm, l: 250 mm, NA: 0.22, T~90% in ultraviolet and visible light
S	Spectrometer	Elements: 2048, range: 200 – 1100 nm, sensibility: 86 photon/count, integration time: 3 ms

Table 1 – Optical elements of the compact scanning LIF system. ë: wavelength, ∅: diameter, AOI: angle of incidence, R: reflectance, f: focal length, l: length, NA: numerical aperture, T: transmittance.

supports with micrometric actuators. The light collected by the fiber optics F is sent to the spectrometer S. Finally, the digitized spectrum is transferred from the spectrometer S to the portable computer where a LabView program allows the user to set experimental parameters, to control data acquisition and to perform data analyses.

In the standard protocol selected for operation, the user sets:

- top-left and bottom-right corners of the scanned area,
- azimuthal and polar angle steps,
- number of laser pulses per measurement point,
- shortest and longest wavelength of the spectrum,
- the number of wavelength bands to be acquired.

The wavelength step is a function of the wavelength range, i.e. is derived from the difference between longest and shortest wavelength, divided by the number of wavelength bands. The latter number can be as high as 120, conferring a hyperspectral character to the LIF system.

A first data analysis can be performed on-line thanks to a front-end panel (**Fig. 2**). A black and white image of the scanned area is provided in the panel. The intensity of each pixel is given by the ratio of the signals (background corrected) at two selected wavelengths (510 and 395 nm in **Fig. 2**). On the right of the image, the cumulative histogram of the horizontal rows is shown (it is obtained by summing the intensities of the pixels of each row). Similarly, the cumulative histogram of the vertical rows can be found under the image. At the panel bottom, two spectra are plotted: the yellow one corresponds to the pixel indicated by the two yellow lines on the image, the red one matches to the area inscribed by the four red lines on the image. The user can choose the wavelengths and can move the lines, gaining information on data collected. The yellow and red spectra of **Fig. 2** come from two parts of the aureole, and are characterized by different intensities and, especially, by different spectra: paraloid, a protective substance deposited by restorers on the left part of the aureole, fluoresces strongly at about 310 nm while the yellow pigments of the outer border and on the right of the aureole emit more at 510 nm. This example shows the capability of the LIF system to discriminate among various substances present in different areas of the scanned image. On frescos two important emission bands relevant to biodegradation identification correspond to fungi at about 320 – 360 nm (once excited at 266 nm, see **Fig. 4**) and chlorophyll-a at about 680 nm (once excited at 355 nm [6]).

A more refined data analysis can be performed with a proprietary software (written in MatLab) that produces false color images: R, G and B signal intensities on the screen of the portable computer are proportional to fluorescent emissions at three different wavelengths. A careful selection of these wavelengths allows the user to identify hidden characteristics of the fresco like pigment composition, biological attack and restoration techniques. More details on this procedure can be found elsewhere [6]. During the present data analysis, the

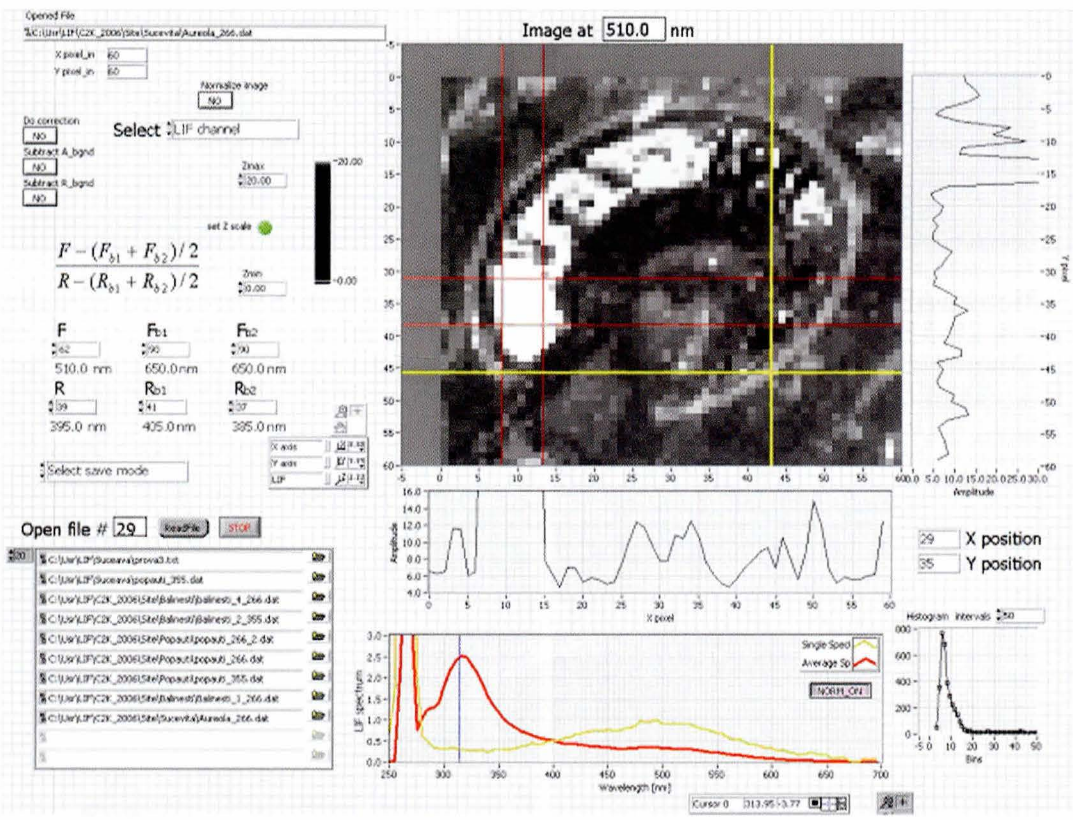

Fig. 2 – Front-end panel for on-line data analyses showing in the top-middle a black and white image of the scan. On the right side of the image, the cumulative histogram of the horizontal rows is displayed. Analogously, under the image, the cumulative histogram of the vertical rows is given. At the bottom of the panel, two spectra are plotted: the yellow one corresponds to the pixel indicated by the two yellow lines crossing on the image, the red one matches to the area delimited by the four red lines crossing on the image.

following bands have been used:

- upon excitation at 266 nm:
  - R: emission at 340 nm, corresponding to fungi or organic compounds,
  - G: emission at 480 nm, corresponding to pigments,
  - B: reflection at 266 nm, corresponding to reflectance/texture;
- upon excitation at 355 nm:
  - R: emission at 680 nm, corresponding to chlorophyll-a,
  - G: emission at 450 nm, corresponding to fungi,
  - B: reflection at 355 nm, corresponding to reflectance/texture.

An example of such analysis is given in **(Fig. 3)**, where the RGB image obtained upon excitation at 266 nm visualizes the use of paraloid on all the remaining aureole gilding during the restoration.

Another example is given in **Fig. 4** where a larger area of the same scene to which **Fig. 3** belongs is reported. In this case, data have been collected upon 355 nm excitation, the aureole fluorescence is mostly related to the pigment utilized for gilding, whereas blue features related to fungi emerge at the bottom of the image on Christ's dress.

The LIF system and the Imaging Topological Radar (ITR) [7], a laser range finder developed by researchers of FIM-FIS-LAS, where both used on the same fresco in Suceviþa. ITR and the LIF system are in some sense complementary: while the first instrument measures range and NIR (near infra red) reflectance, the second one detects LIF upon

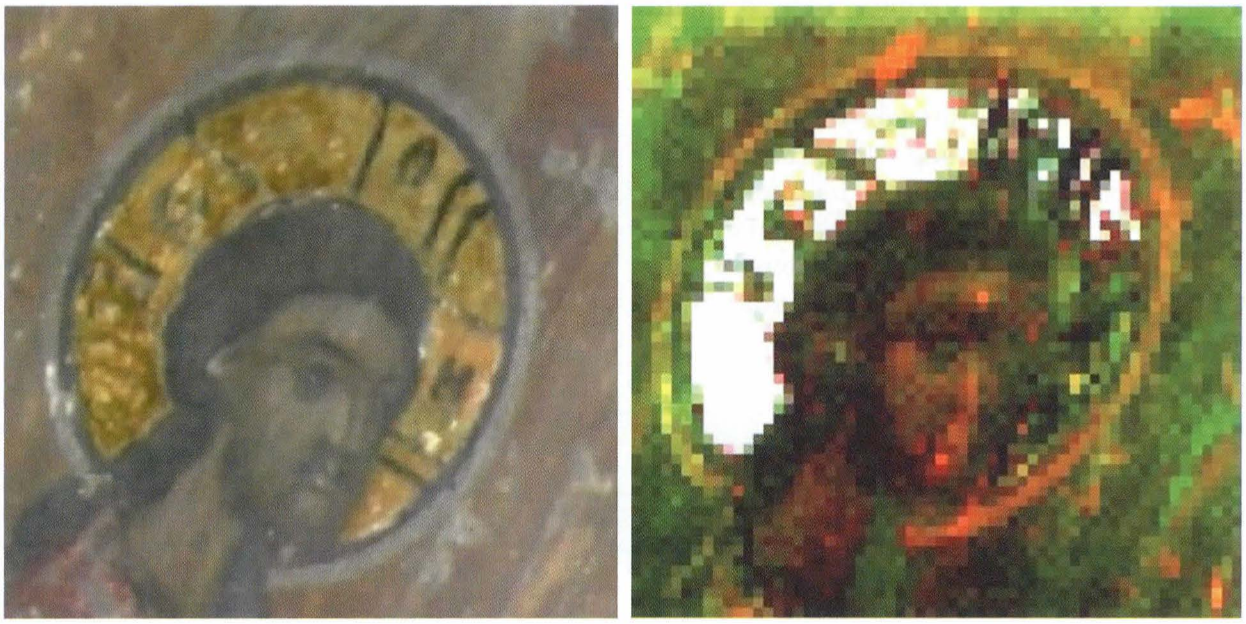

Fig. 3 – Picture of a detail of the fresco "Jesus Heals the Demon-Possessed of Gadarenes" (Matthew 8, 28-33) in Sucevita (left). The corresponding false color image (right), obtained with the scanning LIF system operating at 266 nm, highlights in white the substance deposited on the left part of the aureole (paraloid) to preserve the gilding.

Fig. 4 – Picture of the fresco "Jesus Heals the Demon-Possessed of Gadarenes" (Matthew 8, 28-33) in Sucevita (top). The corresponding false color image (bottom), obtained with the scanning LIF system operating at 266 nm, highlights in dark blue the presence of fungi on the lower part of Christ's dress (circled), conversely the red color of the gilding on the aureole and stars (marked by arrows) does not permit to discriminate the use of paraloid during the restoration.

UV (ultraviolet) excitation. By using the texture collected in both kinds of images or geometrical referenciation of the data acquisition systems [7], the data collected by ITR and the LIF system can be merged in one three-dimensional reconstruction with sub-millimeter accuracy [8]. In this way, damaged areas of a fresco can be localized very accurately by range (revealing the occurrence of plaster detachment) and fluorescence (revealing the presence of biological attack or the use of specific substances for consolidation).

3 Results and discussions

A summary of the data collected by the LIF system during the campaign is given in **Table 2.**. In the following, the most relevant results are reported and discussed. As it will be detailed, biodeterioration is mainly due to fungi: chlorophyll-a, easily detectable by the LIF system [6], has not been found, probably because of the low level of natural light inside the churches under study, preventing the development of photosynthetic microorganisms.

Site	Period	Number of sampled areas	Excitation wavelength
Sucevita Monastery	July 21st – 22nd, 2006	4	266nm and 355 nm
Popauti Monastery	July 24th, 2006	1	266nm and 355 nm
Balineºti Church	July 25th – 26th, 2006	4	266nm and 355 nm

Table 2 – Summary of the data collected by the scanning LIF system during the on-site campaign.

3.1 Sucevita Monastery

The data acquired in Sucevita in sample areas 1 and 2 are given in **(Fig. 5)** and **(Fig. 6).** (note that data acquired in sample areas 4 and 3 were already shown in **Fig. 3** and **Fig. 4**, respectively).

In **Fig. 4**, and especially in **Fig. 5**, the geometry of the LIF image is distorted because the system was installed on a scaffolding located 5 m above the soil and looking at a niche, thus the scanning beam was not perpendicular to the sampled area. In both the figures, relevant to the upper part of the left absidis, four zones are clearly discernible in the false color images:

- green zones, corresponding to the pigments,
- white zones, corresponding to pigments discoloration,
- red zones, corresponding to the gilding,
- purple zones, corresponding to fungi.

Data collected in Sucevipa allowed to demonstrate that paraloid and fungi are clearly distinguishable by their spectra upon 266 nm excitation: their fluorescence peaks are about 30 nm apart (**Fig. 7**). Paraloid spectra are constant throughout the image, while fungi spectra show some variability (two examples are given in **Fig. 7**). Nevertheless, the peaks do not move, allowing the clear identification of fungi on the fresco surface.

In summary, all the sampled areas of Sucevita show common features:

- frescos are under low or medium biological attack by fungi,
- aureoles have been protected with paraloid during the restoration, however the protection layer has been applied only where residual gilding was found.

Fig. 5 – Picture of the Saint at Christ's right side in "Christ King" fresco in Sucevita (top). The corresponding false color image (bottom), obtained with the scanning LIF system emitting at 355 nm, highlights: in green, the pigments; in white, pigments discoloration; in red, the gilding; in purple, fungi (main areas of biological attack circled by a yellow line).

Fig. 6 – Picture of Christ in "Christ King" fresco in Sucevita (left). The corresponding false color image (right), obtained with the scanning LIF system emitting at 355 nm, highlights: in green, the pigments; in white, pigments discoloration; in red, the gilding; in purple, fungi (main areas of biological attack circled by a yellow line).

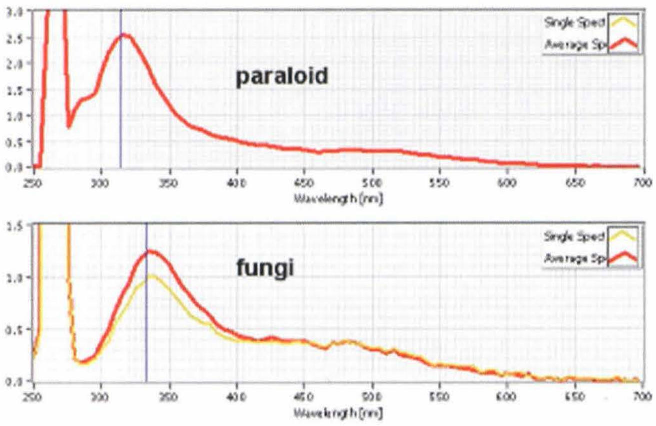

Fig. 7 – Spectra of paraloid (top) and fungi (bottom) of the fresco "Jesus Heals the Demon-Possessed of Gadarenes" (Matthew 8, 28-33) in Sucevita excited at 266 nm. Spectral intensities are given in arbitrary units.

3.2 Popauti Monastery

An example of the data acquired in Popauti is given in **(Fig.** 8). Part of the sampled area was previously cleaned. Two discontinuities are clearly discernible in the false color image. According to the restorers, they could be explained by successive plaster depositions. The sampled area of Popauþi shows that:

- the cleaned part of the fresco is under low or medium biological attack by fungi,
- the non cleaned part of the fresco is under medium or high biological attack by fungi,
- salts efflorescence and pigments discoloration have been detected.

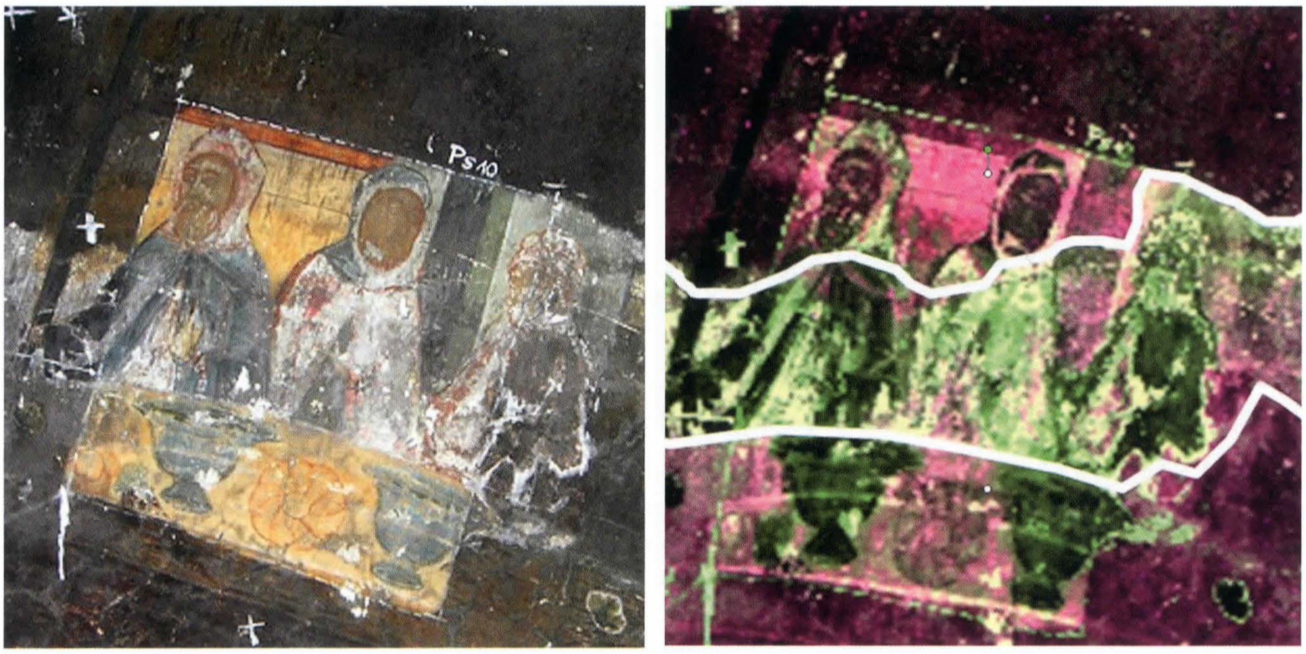

Fig. 8 – Picture of sampled area 1 in Popauti (left). The corresponding false color image (right), obtained with the scanning LIF system emitting at 355 nm, highlights two discontinuities in the fresco marked by white lines.

3.3 Balinesti Church

Four sets of data have been collected in Balinesti, either on complete large painted zones or in small areas selected by the restores to test the efficiency of different treatments. Two sampled areas (1 and 2), corresponding to the latter case, were examined upon excitation at 266nm and 355 nm, respectively. Results (not shown here) allowed to distinguish:

- a first zone, corresponding to a non treated sector,
- a second zone, corresponding to the sector treated with a biocide,
- a third zone, corresponding to the cleaned sector.

The spectra, similar to those shown in **Fig. 7** in the case of excitation at 266 nm, indicate that biological attack by fungi is high in the non treated sector. They are also present in low concentration in the sector treated with the biocide (the treatment has been carried out few months before the measurements, thus allowing fungi to grow again). Conversely, the cleaned sector is almost free of fungi. No fluorescence band originated from the biocide was detected in either the cases.

In **(Fig. 9)**, data relevant to a large image of a saint are shown. The false color image, elaborated after data collection upon excitation at 355 nm, reveals peculiar features: the reddish pigments in the red circles and in the red triangle, indiscernible in the picture, have different

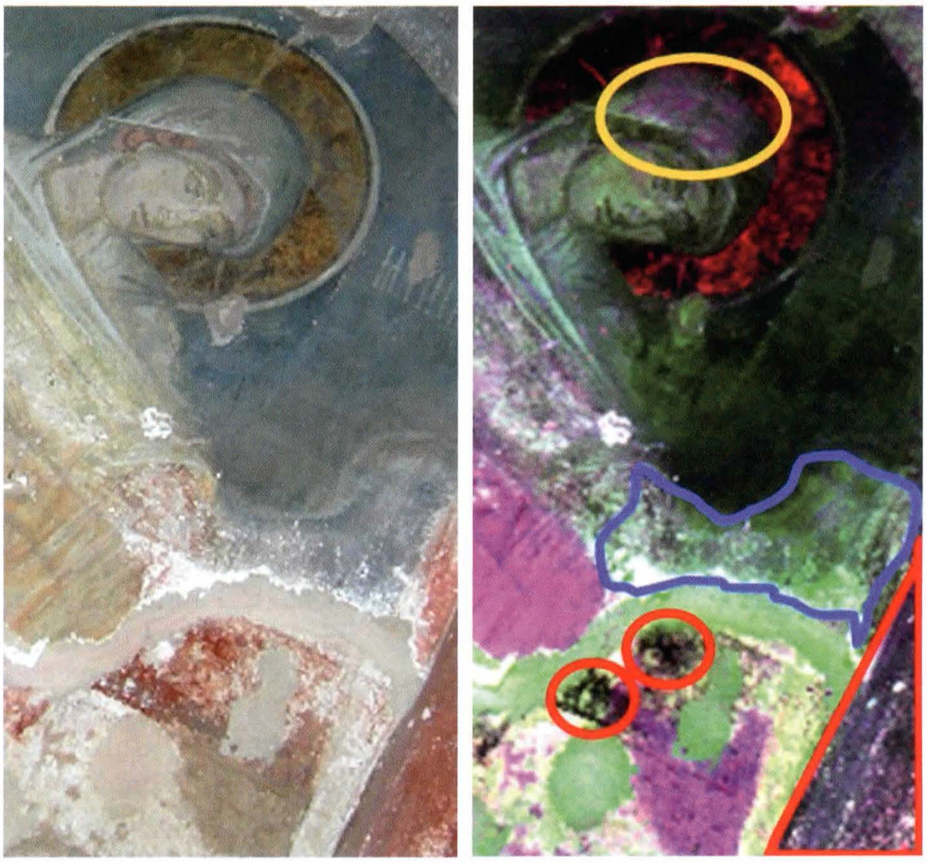

Fig. 9 – Picture of a saint (sampled area 3) in Balinesti (left). The corresponding false color image (right), obtained with the LIF systnem emitting at 355 nm, highlights: pigment differences (the reddish pigments in the red circles and in the red triangle); salts efflorescence and pigments discoloration (surrounded by a blue line); in red, the gilding; in purple, fungi (main area of biological attack surrounded by a yellow line). The large green areas correspond to plaster without pigments.

fluorescent responses. The big purple spots on the bottom-left part of the sampled area are also relevant to pigment differences. Conversely, green zones appear where plaster is without pigments. Salts efflorescence, pigments discoloration, gilding and fungi have been detected as well.

Fig. 10 reports data collected on the sampled area 4, a small detail of the queen clothing (see the picture where the complete figure is shown). In this case black and white images collected at different emission wavelength, upon the same excitation wavelength (266 nm) are presented instead of the RGB reconstruction. The black and white images in the fluorescence bands at 480 and 340 nm, are remarkably different: while the first one corresponds to the white pigment (casein and lime, according to the restorers), the second one reveals the pattern of the biological attack by fungi.

In summary, the sampled areas of Balinesti show:

- frescos under biological attack (fungi), ranging from low to high, depending on the restorer intervention (cleaning, treatment with biocide, no treatment, corresponding to low, medium and high attack, respectively),
- salts efflorescence and pigments discoloration,
- differences due to pigments utilized.

4 Conclusions and perspectives

The results presented in this paper demonstrate that LIF gives information on realization techniques, biological attacks and restoration methods of painted surfaces. In particular, it provides the optical characterization of

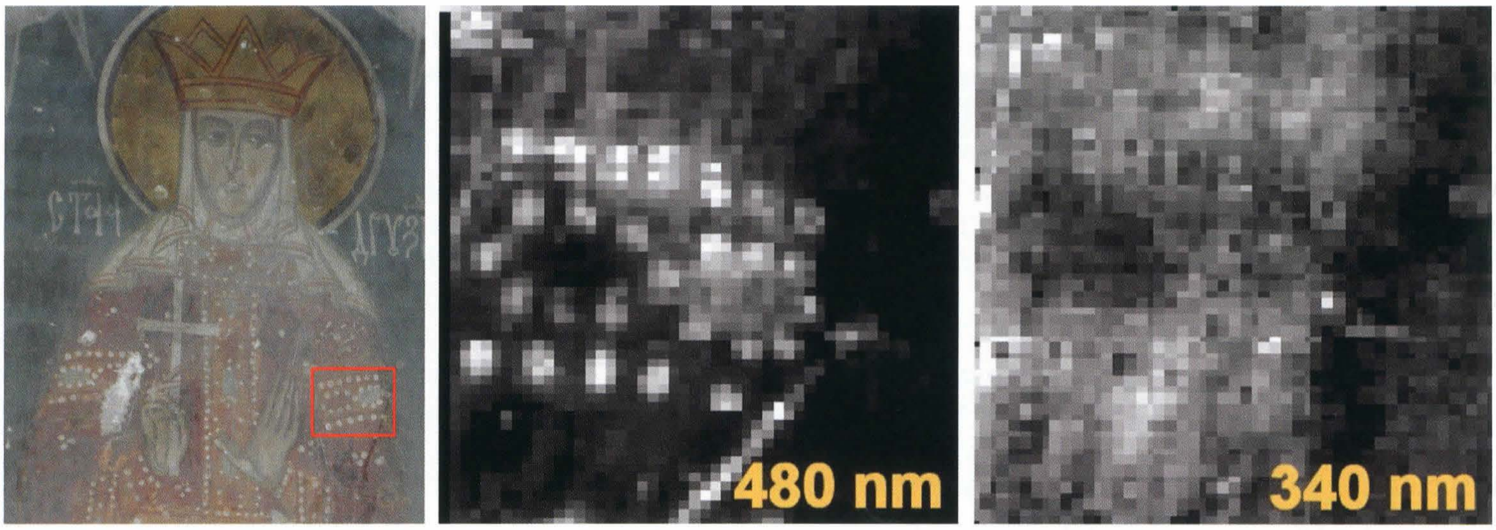

Fig. 10 – Picture of sampled area 4 of Balinesti (left, inside the red box). The corresponding black and white images in the fluorescence bands at 480 nm (center) and 340 nm (right), obtained upon emission at 266 nm, highlight the white pigments (casein and lime) and the biological attack (fungi), respectively.

pigments, fungi and chemicals used in restoration. In other words, it is an effective tool for specific diagnostics of cultural heritage.

LIF offers the advantage of being highly sensitive (e.g. biological attacks are detectable well before being discernible by the naked eye) and completely non invasive (the target is probed remotely by a light beam). Moreover, the LIF system used in Bucovina showed its suitability to a field measurement campaign being compact, lightweight, transportable, rugged, fast and relatively cheap (of the order of 10 k•).

The combined deployment of the LIF system and of the ITR laser range finder allows the restorer to accurately localize biological attacks, frescos detachment and consolidation actions in a three-dimensional model with sub-millimeter resolution. As far as the biological attack is concerned, present data revealed the absence of contamination from photosynthetic microorganisms, and a large presence of fungi which might be identified from their spectral features after growing laboratory cultures for comparison.

Future work on the system includes:

- calibration, in order to provide quantitative measurements, for inorganic (pigments), organic (ligands) and biological materials found on the plaster surface,
- realization of data bases of spectral features for the unambiguous recognition of painting substances (fluorophores, pigments and microorganisms) upon excitation with the commonly available UV laser wavelengths (266 and 355 nm),
- development of algorithms based on principal component analysis (PCA) to effectively extract the most relevant features from the large number of monochromatic images acquired, in order to successfully direct the false color reconstruction.

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HUMIDITY ANALYSIS AND CONTROL

José Gonçalves

Resume

Humidity is probably the worst enemy of constructions and we can relate its multiple appearances with the majority of degradation processes in traditional buildings. Is also difficult to deal with the real origins of humidity in buildings when some far easier solutions (like hiding their final results) usually achieve a cheaper alternative. The best way to tackle humidity problems is always by preventing its final contact with the building or, when that proves impossible, to conceive a method to reduce that contact with efficient draining systems. The ways to solve this problem are synthesise in this report with examples of practical solutions in traditional buildings and monuments by using ancient techniques that proved particularly well in actual rehabilitation works.

Summary

1 – Introduction
2 – Construction humidity
3 – Ground humidity
4 – Rain humidity
  4.1 – Exterior walls
  4.2 – Horizontal construction elements
  4.3 – Window frames
5 – Humidity from damage installations
6 – Condensation humidity

1 – Introduction

Humidity problems in constructions are the worst scenario when the restoration experts came on site for damage evaluation. The causes of degradation are usually disguised with cover material problems which are far easier to deal with in a rehabilitation process. If far simpler to show a new appearance to an ancient surface, or apply an authentic finishing to an old object, than to look for the origin of the damage in that object or artefact. Normally technicians involved in diagnosis and restoration using modern methods and techniques of evaluation tend to create a different approach for the problem and sometimes have not the necessary background to ear what the other have to say about the situation.

Problems relating humidity in constructions are not only the cause for the interaction of these different mentalities but a reason for establishing common principles in modern conservation practice. Is therefore important to study these scenarios for evaluations proposes and modern techniques appliance. The organization of recovered information in work surveys is the basis for the correct evaluation and establishment of protective measures, and that is the aim of this report considering the possible loss of existing patrimony due to bad decisions based on deficient evaluations.

2 – Construction humidity

The manifestation of humidity due to the construction is a problem that is apparently overcome by the passage of time and its consequences on the construction behaviour and response. This is not ultimately true because is always possible that the building have been repaired with a modern material using ancient techniques or have suffered from an important alteration in its constitution or organization. That is the example of new floor rehabilitation in which the wood planks had not conveniently dry before application and start to adjust due to water loss (Fig. 1, 2 – Teatro Nacional de São Carlos, Lisbon), or even some mortar application in old surfaces with water transmission inside the walls and consequent moisture migration to their exterior layers. (**Fig. 3** – Teatro Nacional de São Carlos, Lisbon).

The appearance of humidity in the walls or the degradation of the wood on floors are the major consequences of that problem and the repairing solutions are not always easy because usually involve possible substitution of material or moisture control inside the building with all the evident consequences for its inhabitants or visitors. Is much preferable to prevent the problem itself during repairing with simple solutions like interposition of impermeable paper beneath the wood floor before final application of the material or improve the ventilation in certain zones on the repaired walls.

All solutions however need some discussion beforehand with the intervention team because of all the implications

Fig. 1. Humidity in floor

Fig. 2. Damage floor due to humidity

Fig. 3. Construction humidity

on the final aspect of the surfaces or their economic repercussions for the overall budget and management.

3 – Ground humidity

Ground humidity is a far worst scenario when it comes to deal with humidity in an existing building that have obviously been subject to alterations or degradation in its environment.

The humidity from the ground beneath the building is always the consequence of hydraulic changes in the foundation that causes the migration of water trough the walls and foundation materials until the water reach the higher levels of the walls inside the building or the floor elements at ground level (**Fig. 4, 5** – Igreja de São Miguel, Lisbon).
A usually alteration in the moisture content of the ground is when the conditions around the building change due to the application of impermeable materials like bituminous surfaces or hydraulic tiles in the area around the exterior walls in a urban intervention. That alteration prevents the water from the rain to infiltrate to the ground in the same way as it used to and may conduct the same water for certain zones on the walls with the known consequences.

Fig. 4. Ground Humidity

The solution, in this case, is an easy one. All we have to do is dig a water barrier around the exterior walls of the building and, with the application of water proof solutions like polyethylene membranes or geo textile materials to block the access of water in its way to reach the outer layers of the walls. This solution must be completed with an efficient method of conducting the water to an existing draining system, with convenient drilled tubes placed in the lower level of the water barrier and the use of small rock sand to facilitate the water migration to the draining tubes (**Fig. 6, 7, 8**; Drawings 1, 2 – Capela de São Sebastião, Moita).
Another situation comes with the presence of water around

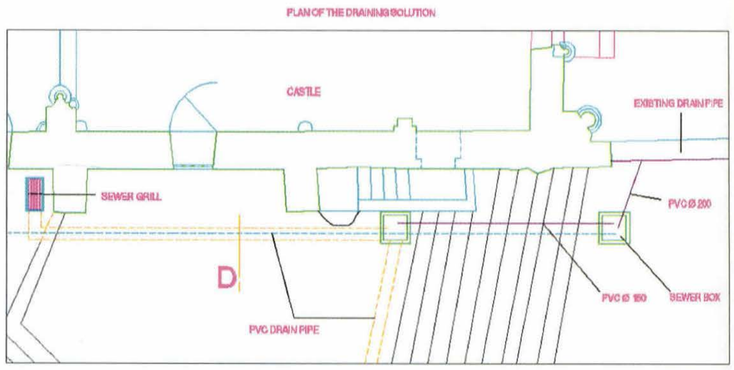
Fig. 5. Damages due to gound humidity

the exterior walls in a sub level of the building with no access on the outside, like the above mentioned situation. In this case one must seriously consider a construction of a second wall on the inside with an efficient draining system in the space between the two walls.

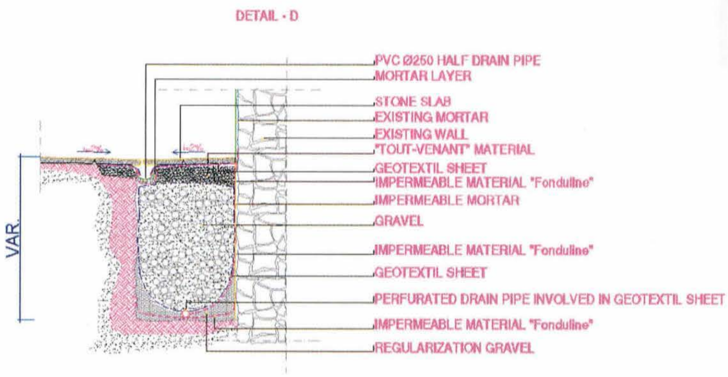
Fig. 6. Geo textil on draining solution

Fig. 7. Draining solution materials

Fig. 8 . Sewer Box of draining solution



Drain Detail -1



Drain Detail -2

A third solution could be achieved with the use of a chemical solution of silicone resins, or other water repellent product, injected with a pump system in predetermined holes on a level below the affected zones of the walls.

Each of these solutions must be used with great care due to the obvious difficulty in an exact determination of the water origin and its future effect on the building. Some of the mentioned techniques also involve the use of expensive machinery and equipment so a carefully planed intervention must be carried and each solution conveniently adapt to the building because of its singularities or specifications.

4 – Rain humidity

Rain humidity if perhaps the first preoccupation in the design phases of the intervention and can be, by that reason, one of the only reasons for water prevention systems to exist. That is not obviously correct and a global study of this problem can be achieved with the consideration of all elements of the exterior enclose of the building.

4.1 – Exterior walls

Exterior walls are the first element in a building where humidity related damages are best perceived in a visual inspection or survey. Normally, considering the permeable materials of walls constitution, the visual aspect of humidity in the interior of an element, signifies that the entire wall is humid and a special protective treatment must be applied.
Also the great thicknesses of monument walls, with heterogeneous materials and sometimes problems of structural origins, facilitate the water migration trough dangerous regions where its presence is a major handicap to building preservation and interior protection.

The water migration inside a wall is not only a cause for major alarm and concern due to the consequences for the existing materials but also because of the long time effect of salts dissolution and future crystallization in the outer layers of the walls that causes the premature degradation of the element (**Fig. 9** – Edificio do Café Barreiro, Barreiro).

All solutions based in mortar applications must be conveniently study and adapt considering the existing elements and materials in the walls. Also, modern composites namely hydraulic products, cement materials and non expansive solutions should carefully chosen or alternatively a lime based mortar with a limited portion of Portland cement can be applied with a limited risk for

Fig. 9. Loss of paint due to imcompatibility of materials

the existing walls. That is an option to each case as there is no universal solution for all historical buildings and monuments.

However must be considered the execution of at least two layers, following the first consolidation (or in some cases reinforced) layer, with mortar compatible materials, preventing the migration of water, or in other cases, allowing water migration to the exterior of the wall.

Special care must be taken also with the use of modern water repellent painting systems that, as well as preventing the water passage to the inner layers of the walls, prevent the migration of the water vapour to the exterior, and, consequently became non adherent to the wall and fall after some time (**Fig. 10** – Edifício do Café Barreiro, Barreiro). In this case, lime based inks are preferably a better option for ancient walls because allow a certain hydraulic equilibrium in both sides of the element, exposed to climatic conditions.

4.2 – Horizontal construction elements

Horizontal construction elements formed with ceramic tiles or terraced floor tiles represent the principal problem in dealing with water access to buildings and monuments.

Fig.10. Salt migration for exterior

The singularities of the respective draining elements like pipes, gutters and all sorts of accessories related with water conduction to inferior levels of the building are a major concern in humidity prevention design and the solutions should be reached from the first sketches of the project until the final phase of construction.
Is therefore of great significance the rehabilitation of all the horizontal elements that support the draining systems, like trusses, ceiling beans or structural frames, because its deformation or collapse leads to water problems in the building and the future loss of the remaining elements (**Fig. 11** – Convento de São Francisco, Tomar).
There are some ways to prevent this problem and normally

involves the interposition of a water barrier material underneath the cover elements with no alteration of the final aspect of the building. These solutions are relatively easy to adjust to existing structures and modern water proof materials are generally of great quality in humidity prevention if all the actions concerning its maintenance are taken along the way (**Fig. 12, 13** – Convento de São

Fig. 11. Damage on structure due to infiltration

Francisco, Tomar).

Is also necessary to think of all the exterior parts of the building elements like chimneys, salient walls, ventilation pipes, joints between buildings or dilatation joints in which case special isolation elements and connections must be considered in water prevention systems.
Modern methods are based in water proof painting systems

Fig. 12. Rain water protective elements

easily applied with normal brushes and other tolls in which a good adhesion is achieved with satisfactory results in rehabilitation programs.
Is interesting to compare the value of all water prevention systems with the loss of the building and its interior valuable pieces due to water damage or humidity related problems. Is a far better solution to prevent things to happen than to repair what went wrong in building design or maintenance.

Fig. 13. Rain water protective element

4.3 - **Window frames**

All the exterior elements in a façade are singular points in which humidity problems can occur if there is that possibility. Window frames in historical buildings represent a problem itself because its materials, like wood and iron, have some characteristics that change due to climatic exposition and that alteration can bring humidity problems to the interior of the building.

The major problems related with the presence of water in these elements are the attacks by insects or other bugs, in the case of wood, and the corrosion problems, in the case of iron. Both put a delicate problem in water prevention analysis because the maintenance of existing materials in exterior widows and doors of historical buildings, are generally imposed as a preliminary condition and so an easy method for its rehabilitation must be achieved.

Protective elements in monument windows and doors have obviously been subject to exterior actions along the life of the building and some importance due to that fact they had had. The substitution of these elements must made with identical materials and using the same techniques as the original ones. The intervention should be programmed to achieve a good integration of materials and building awareness because no other solution could be easily justifiable.
Generally is far cheaper to build identical new elements in a window and door frame rehabilitation program then to treat existing ones in site, even if the degradation is not prohibitively significant. The first question is to know whether treatment products and methodology are well tested in similar conservative processes, considering the risk of future degradation due to the same phenomena.

The second one is to evaluate the degradation level of the element and to compare between its integral substitution value and the restoration value with all the factors involved.

That can be achieved for a particular case not meaning that the same result can be achieved for a different one.

5 – **Humidity from damage installations**

Installations in historical buildings are not generally original due to the evolution of our necessities in the building fruition process. The number of different installations inside an existing monument is a consequence of the historical value of that monument as a cultural object and a signal of its importance for the visiting public.

One can assume the risk of a small water leakage in a fire security pipe system but obviously not the risk of loosing the monument because the fire security system inexistence. The same applies to bathroom water systems or draining pipe systems as mentioned before.

Another completely different problem is some existing systems that have suffered from bad interventions in previous alteration processes or pretence reparations with non adequate materials as mixing modern techniques with ancient concepts (**Fig. 14** – Teatro Nacional de São Carlos, Lisbon).
That is the case of modern materials like plastic tubes in hot water supply systems that need a considerable dilatation space when applied in existing walls which have not been devised to receive those elements. In this case, a special technical duct should be considered and all the systems easily placed there for conservation and maintenance purposes.

Fig. 14. Water suply pipes with leakes

The problems related with new installations or new supply systems should similarly be considered and all the materials carefully chosen to prevent future problems due to the presence of water sometimes in different places of the building.

6 – **Condensation humidity**

Humidity problems related with condensation phenomena are generally of great difficulty to solve and even, in cases where its occurrence is considered as natural, to assume as a problem.

Condensation derives of the fact that air, in contact with cold environments turn into water, damaging the support material that was supposed to stay dry. This is apparently easy to solve applying insulation materials on the walls or by heating the interior of the zones where this occurrence is significant. The problem derives of the fact that with any changes in the moisture degree of the place, for example in kitchens, bathrooms or rooms with great number or people, the dryness capacity of the interior air is easily achieved and all the remaining moisture turn into water, with the known consequences for the material surfaces (**Fig. 15** – Igreja de São Miguel, Lisbon).

Is also possible to ventilate the places where condensation problems are expect to happen, and allowing a certain amount of water to evaporate before its concentration is perceived or generate any damage. That is not always possible because monuments and traditional buildings are not usually easily adapted to modern ventilation systems.

Fig. 15. Efect of condensation water

Is this case, it must be considered small ventilation systems or strategically placed openings functioning according to convection laws and exploring existing air movements to permit a certain evaporation capacity and reducing the risk of condensations.

In the majority of situations, however, construction systems itself can accommodate the water level increase using exterior walls stiffness to allow a certain moisture infiltration and adjusting ventilation conditions to climatic environment with air permeable doors and window frames, using traditional materials like iron or wood (**Fig. 16** – Universidade da Beira Interior, Covilhã). In this case, application of modern materials such as aluminium and PVC should be considered only in a limited scale.

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Fig. 16. Iron frame doors allowing some air penetration

PERSPECTIVES ON THE RESTORATION OF THE BALINESTI CHURCH

Oliviu Boldura

General historical data

Placed in the North of Moldavia, close to the border with Ukraine, the Church from Balinesti is part of Gramesti locality; it is situated at approximately 15 km away from Siret town in Suceava county (**Fig.1**).
The church was built by the chancellor Ioan Tăutu, one of the few Moldavian noblemen who were allowed by the prince Stephen the Great to build churches (**Fig.2**).

Fig.1. St. Nicholas church, Balinesti

The disputes arisen at the date of the church building are determined by the various contradictory elements identified. We shall take into consideration only the date mentioned on the rotive in the church porch and that is „*With the Lord's wish, with the help of the Son and with the committing of the Holy Spirit, pan Ioan Tautu... finished it in the year 7007 [1499] December the 6th*".
All the information provided by the documentary resources, epigraphic or stylistic don't offer reliable data regarding the building or the painting of the church but only hypotheses which, we hope can be proved with new elements, discovered probably, in the present stage of the monument restoration.
In the architectural context from Stephen the Great age, the church from Balinesti is peculiar from the architecture shape point of view, the hall type divided in chancel, nave and narthex, and from the internal and external painting. The peculiarity consists in the polygonal transformation of the western wall of the narthex, the chancel disconnected pentagonal outside and circular inside, as well as the sculptured decoration of gothic origin.

Fig.2. St. Nicholas church, Balinesti. Nave. Votive painting, after restoration

An important moment in the research of this church is constituted by the discovery accomplished in 1964 by Sorin Ulea related to the inscription that mentions the name of the painter. The researcher discovered this inscription on the votive painting at the base of the throne on which Jesus Christ sits, which tells us: "*Gavril the hieromonk wrote/painted*" (**Fig.3**). This painted text has a major importance as it offers us the name of the first known painter who signed on a wall ensemble from Moldavia.

THE PAINTING OF BÃLINESTI CHURCH

ishing of the church. The figurative painting form inside was done by Gavril the Hieromonk and is distinguished as one of the most valuable wall painting from Stephen the Great age. The external painting was done between 1535 – 1538 during Petru Rares' reign, Stephen the Great's son.

The internal painting

Out of the direct study of the surface and of the stratigraphic research we distinguish two superposed layers of painting:

- ***the first decoration*** had a temporary character, from the termination of the construction until the painting of the church. After the loss of the figurative wall painting on the lower areas and on the vaults, we can identify the first painted decoration mainly with geometrical elements, made up of horizontal rows of brick layers (**Fig.4**). This type of decorative painting is met on the whole surface inside the church as well as on the vault of the porch.
- ***the second wall decoration, is a painting accomplished „a fresco"*** applied over the first decoration. This painting layer covers great part of the church, but there are also some empty spaces, especially on the vaults because of the infiltration moisture.

Fig. 3. The inscription of the painter

We must notice the fact that the church from Bãline°ti is part of the group of monuments with internal and external painting from the 16th century and we remember Arbore, Voronet, Probota, Moldovita and Suceava churches.

Regarded in general the wall decoration from Balinesti has a unitary character from the technological point of view, as we notice similar characteristics both inside and outside. Their accomplishment met more stages of painting starting with a first decoration that imitate the brick or stone layers immediately applied after the fin-

Fig. 4. The two painted layers of the church

The external painting covered the entire church and was applied directly on the wall, covering the first decoration with ceramic plates of the higher areas (**Fig. 5, 6**). There are still maintained fragments of it on the altar layer, on the steeple and partially on the Western side where the colour layer is eroded by the mechanical action of the winds.

Fig. 5. Exterior wall of the chancel. Superposition of the murals over the enameled disks

PRELIMINARY RESEARCH

Fig. 6. Chancel apse. Outside

The restoration intervention started in 2002, along with the archaeological research of the church and the drafting of the preservation plan – restoration of the internal and external painting from Bãline°ti. Up to present this intervention was done at the request of Professor Riyki Miake as representative of the Japanese Keio University from Tokyo that supported the financing of the research and the restoration of the wall painting until 2005.

Through lab **physical – chemical analyses** they aimed at knowing original materials (pigments, mortar), their chemical composition and dosage of the mortar as well as the identification of the cases of abnormal alteration of the colour layer, especially of the pigments and their delimitation by the notion of "shade". The pigments identified on the wall painting are those used in that age: azurite blue (used for backgrounds and applied on a black layer of wood coal), ground green (**Fig. 7, 8**), red ochre, yellow ochre, white chalk and red cinnabar. The chromatic alterations are mainly determined by the long presence of different types of moisture (capillarity or infiltration) that develops as shadowed extended surfaces. A particular case of alteration is determined by the reaction of burette that takes place under the conditions of an organic binding, in a basic environment and in the presence of copper ions. After this reaction a

Fig. 7. Pigments identification by lab analysis

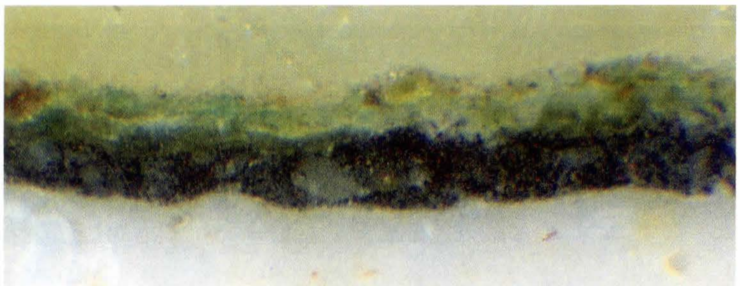

Fig. 8. Pigments identification by lab analysis

Fig. 9. Pigments alteration due to "the burette reaction"

Fig. 10. Elimination of the biological attack. Tests

Fig. 11. Identification of the biological attack

violet alteration takes place in the contact areas of white calcium carbonate that contains protean binding near the azurite pigment based on copper or gold decorations in copper alloying (**Fig. 9**).

An important part of the restoration process is the recognition of the salt types contained by the painting layer. Out of the accomplished analyses we especially notice the presence of the sulphate ion (especially gypsum) and of the nitrate with the origins in the church attic, that is the organic accumulations of the birds (guano).

Out of the technological analysis and of the internal mortar quality it was established that the painting is done on a specific plaster (intonaco) made out of lime mortar with tow of 7 – 10 mm thick and outside can have 30 – 35 mm.

Microbiological analyses

Out of the research of different types of accumulations on the wall painting surface various phenomena of biodegradation were noticed bare eyed and evidenced, inside by the heavy pungent smell and confirmed by the lab exam. The most affected areas are those where moisture of capillarity and infiltration acts. The microbiological forms developed easily in the presence of water, lack of light and optimal ventilation. Thus, inside were identified various types of bacteria such as Aspergilus, Penicillium, Alteraria, Actinomycete and other and outside developed colonies of lichens from various species such as: Lecanora, Xanphoria, Parmelia, Physcia and Rhizocarpon. As a consequence, the whole church was contaminated by an intense microbiologic

Fig. 12. Tests for the elimination of the biological attack

attack, illustrated in the present work (**Fig. 10, 11, 12**).

Moisture measurments undertaken inside the church indicates a high level of humidity reaching values superior to 8,6 in altar, nave and pronaos, up to a height of 2,00 m, diminishing in height (**Fig. 13**). As a consequence of capillarity moisture, on the lower part can be noticed a loss of the support layer cohesion due to the mechanical action of the salt crystallisation process. In the higher part, on the domes, vaults and archways, big areas affected by moisture of infiltration and a loss of the support layer adherence can be noticed.

Fig. 13. Chancel. Inside. Degradadtion and loss of the painting du to capilarity moisture

PRESERVATION STATE AND SAMPLES FOR DEFINING THE INTERVENTION METHODOLOGY ON WALL PAINTINGS

Along with the biological processes identified on the painting accumulated important deposits of dust and smoke from the burning of paraffin candles, that were included in salt crystallisation process, becoming very adherent and hardly soluble.
Traces of wax, the burning of the paintings caused by the candles, the incisions and careless mending with improper materials, argil, plaster, cement and introduction of electricity are the problems encountered in the church.
Under the action of these factors of degradation natural or provoked by human beings carelessly or intentionally, the colour layer encounters multiple degradations from erosions, loss of adherence between layers (scales, swellings, cover slopes) or the cohesion among the particles next to great background surfaces.
In the case of external additional to these degradations we can talk of erosion or even an Aeolian abrasion through the friction of wall surface with minute particles led by the wind that blows from Siret.

METHODOLOGICAL ASPECTS

The complexity of problems in which the painting was when starting the works determined us to deepen the research

Fig. 14. Cleaning test

even on the higher surfaces at which we have direct access after setting the wooden platform.
After the control and absorption tests done on the sample areas, we passed to the execution of different cleaning tests of adherent, and non-adherent deposits (of various nature – smoke, dust, wax, tars, etc), and the fixation of the degraded colour layer (**Fig. 14**). The tests continued on the areas with salt efflorescence as well as on the biological agents. In order to have control over the operations measurements of relative humidity and environmental temperature were done during the tests. These parameters registered in September 2003 varied inside between 19° C and 24° C, and the air relative humidity between 57,7% and 88,6%. The preservation state on each sample, the methodological details and the observations are accompanied by a photo illustration gathered under the form of records, which are part of this work.
The internal painting hardly legible because of the accumulations that covered it (dust, smoke, salts, biological formations, wax, etc) was cleaned in more stages. We approached separately the areas sensitive to various cleaning substances, like the backgrounds on which we found traces of azurite and gilded surfaces. These surfaces, very generous in the altar, were

Fig. 15. Comparative zones during the cleaning

Fig. 16. Comparative zones during the cleaning

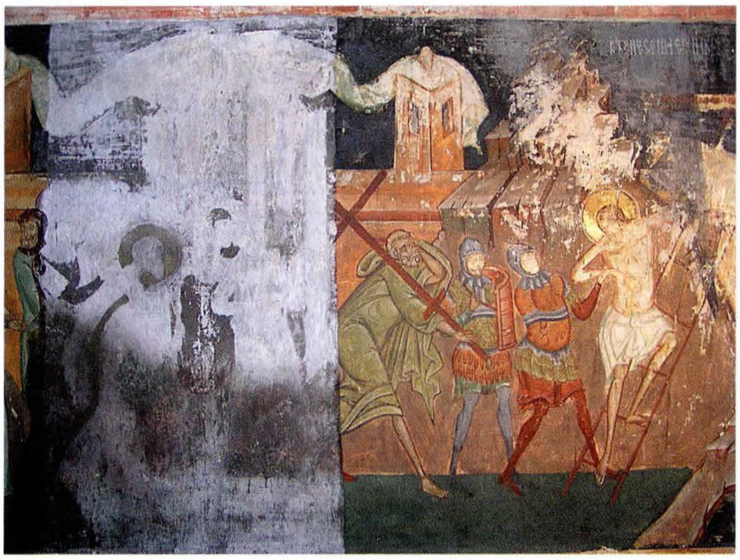

Fig. 17.Comparative zones during the cleaning

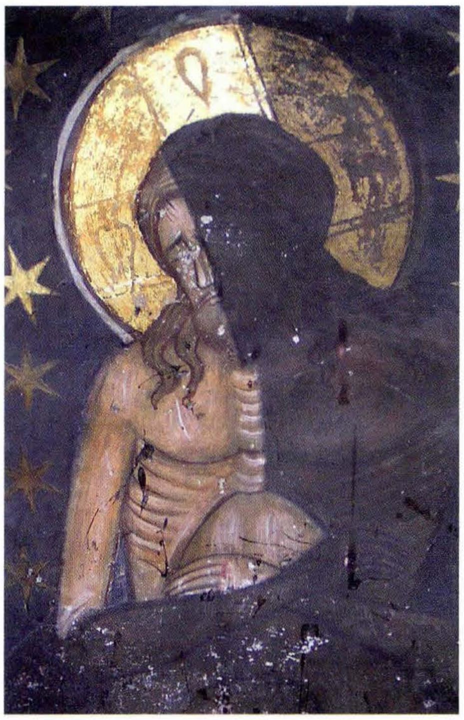

Fig. 18. Comparative zones during the cleaning

Fig. 19. Chancel. Inside. Before the intervention

Fig. 20. Chancel. Inside. The same after the intervention

cleaned with an alcohol substance. For the figurative or decorative elements we used wet ways of cleaning, with ammonium carbonate solutions (from 5% to 10%), or dry ways locally applied. The selective and differentiate approach permitted a unitary cleaning, reported to the preservation stage of every pigment. The esthetical recuperation is remarkable (**Fig.15, 16, 17, 18, 19, 20**).

The thick crusts of salts were cleaned in more stages, combining as in the case of adherent deposits the chemical means (ammonium carbonate and distilled water) with mechanical ones. After the application of compresses we passed at careful removal with the lancet, followed by the removal of veils, using window fibre and erasers of various dourness. For the removal of the very soluble salts like the nitrates we used compresses of distilled water.

An additional problem met at this church was raised by the consolidation of the colour layer. We chose to use mineral substances compatible with wall painting. The restoration of cohesion with barium hydroxide was concluded on the UNESCO site from Probota in the presence of Italian specialists. The method was used on a large scale even on the other sites of the company, that is Sucevita, Voronet, „St John the New" in Suceava, Arbore, Moldovita. In the case of Bãline°ti church, this method was used for surfaces with nitrate concentration lower than 15 mg/l and

Fig. 21. Detachment of the painting layer

for the other surfaces the pigment cohesion was recovered by using ammonium oxalate.

Along with the resolution of this fundamental problem regarding the preservation of the colour layer, the painting from Bãline°ti is marked by great detachments between the two preparation layers and the wall structure (**Fig. 21, 22**). In fact, the painting of the vaults and the dome

Fig. 22.Detachment of the painting layer

of the altar was completely removed remaining suspended through self-support. For the remaking of the adhesion on such extended areas we decided the insurance with support props and local consolidation with anchorage points organised in a sustain network (**Fig. 23, 24**). The network of anchoring points began in the lower areas at a greater distance in the beginning (1

Fig. 23. Consolidation of the painting layer

m) and more and more numerous as the consolidation advanced. The injection under pressure with PLM-AL

Fig. 24. Consolidation of the painting layer

for vaults and PLM-A for vertical surfaces was made at an interval of 48 hours, period necessary for the strengthening of the consolidation introduced in the previous areas.
On the surfaces marked by the microbiological formations we applied biocide treatments with Sintosept QR 15 (an ammonium quaternary salt) in a few stages on the whole surface. This treatment was applied after the cleaning and consolidation of the colour layer operations. Outside, after the biocide, the lichens were removed individually in order to regain the traces of the technological elements that were maintained on the original support layer marked by erosions.

Fig. 25. Chromatic integration

The aesthetic presentation problems, as the final stage of restoration, showed us great incomplete surfaces as a result of the colour layer degradation. The white areas of various forms and sizes were differently approached, according to their problems. Thus, the colour erosions were chromatically integrated in the *velatura* technique by using neutral wash-tints of paint-wash (**Fig. 25, 26**).

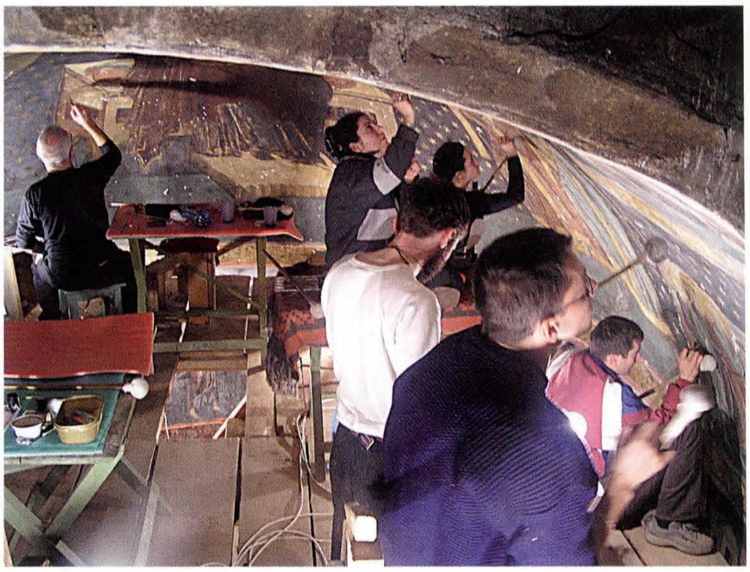

Fig. 26. During the restoration process

The gaps of the colour layer of little sizes were integrated in the *ritocco* technique with grey wash-tints, so that the white areas could be transformed in neutral "background" from the chromatic point of view, putting in value the remains of the original painting, that is the preparatory design, colour fragments, etc.
The integrable gaps of the support layer, previously puttied, are integrated in the "tratteggio" technique obtained through the decomposition and juxtaposition of some colourful vertical lines especially in primary shades.
Outside, the difficulty of intervention consisted in removing the tough mortar of cement that bordered the paintings, as this material was deeply introduced between the layer of intonaco and wall surface provoking unevenness and displacements from the original position. At these we add the resolution of the big incomplete surfaces from the preservation and aesthetic presentation point of view.
Thus, after taking many samples of mortar with different compositions and structures, we used mortar according to the dominant chromatic of the next area working with different types of white. These surfaces were puttied under the level of the original layer and their surface was processed with texture different from the original, trying to put it into value (**Fig. 27, 28, 29, 30, 31**).
The variety and complexity of problems raised by the preservation and the emphasizing of wall painting from Bãlinesti, means application and accumulation of experience in definite and difficult situations encountered at this monument. The objective and unitary approach of restoration means the recognition of the original and unaltered character of the transmitted image over centuries (**Fig. 32**).
Regarded generally, the preservation – restoration intervention from Balinesti is about to put again in the circuit of the values the architectural monument built by the chancellor Tautu and the wonderful painting of Gavril the Hieromonk.

Fig. 27. Chancel apse. Before restoration

Fig. 28. Chancel apse. The same area , after restoration

Fig. 29. Chancel apse. Outside. Zone of the Virgin, before restoration

Fig. 30. Chancel apse. The same zone, after restoration

Fig. 31. St Nicholas church, seen from eastern part, after the restoration of the chancel

Fig. 32. The chancel vault, after restoration

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METHODOLOGICAL ASPECTS CONCERNING THE CONSERVATION AND RESTORATION OF THE PAINTINGS OF THE CHURCH OF SUCEVITA MONASTERY

Oliviu Boldura

1. General presentation. Foundation of the sixteenth century of the powerful Movila Family, the Church of Sucevita Monastery has imposed it self over the centuries to the attention of the large public and the scrutiny of the scientists. The vast mural assembly surprises every time through its extend and gorgeousness (**Fig.1**). Detailed analysis of it by a resorer experienced in mural painting problems (degradations) reveals the true state of preservation of the material carrying the esthetic message. Placed in a small depression at the foot of the Big Obcina, protected by mountains and fortification walls, the church appears today in the same form as it was leaved by its foundators. Proof is the true representation in the Votive picture on the western wall of the nave. But the detailed examination of it shows the traces left in time by the natural degradation agents, like the wind with all the consequences, the most important being the abrasion, thermal variations, the annual hydrologic regimen the sinking and tectonic movements. To all of this it is added the technical flaw determined in part by the up training of the painters Ioan and Sofronie as painters of icons, then the use by these of a mixed technique. An important role in the preservation of the painting it has been held by the human factor. Through unintentional actions or intentional acts the man has contributed in a good part to the alteration of the original image passed on by the predecessors.

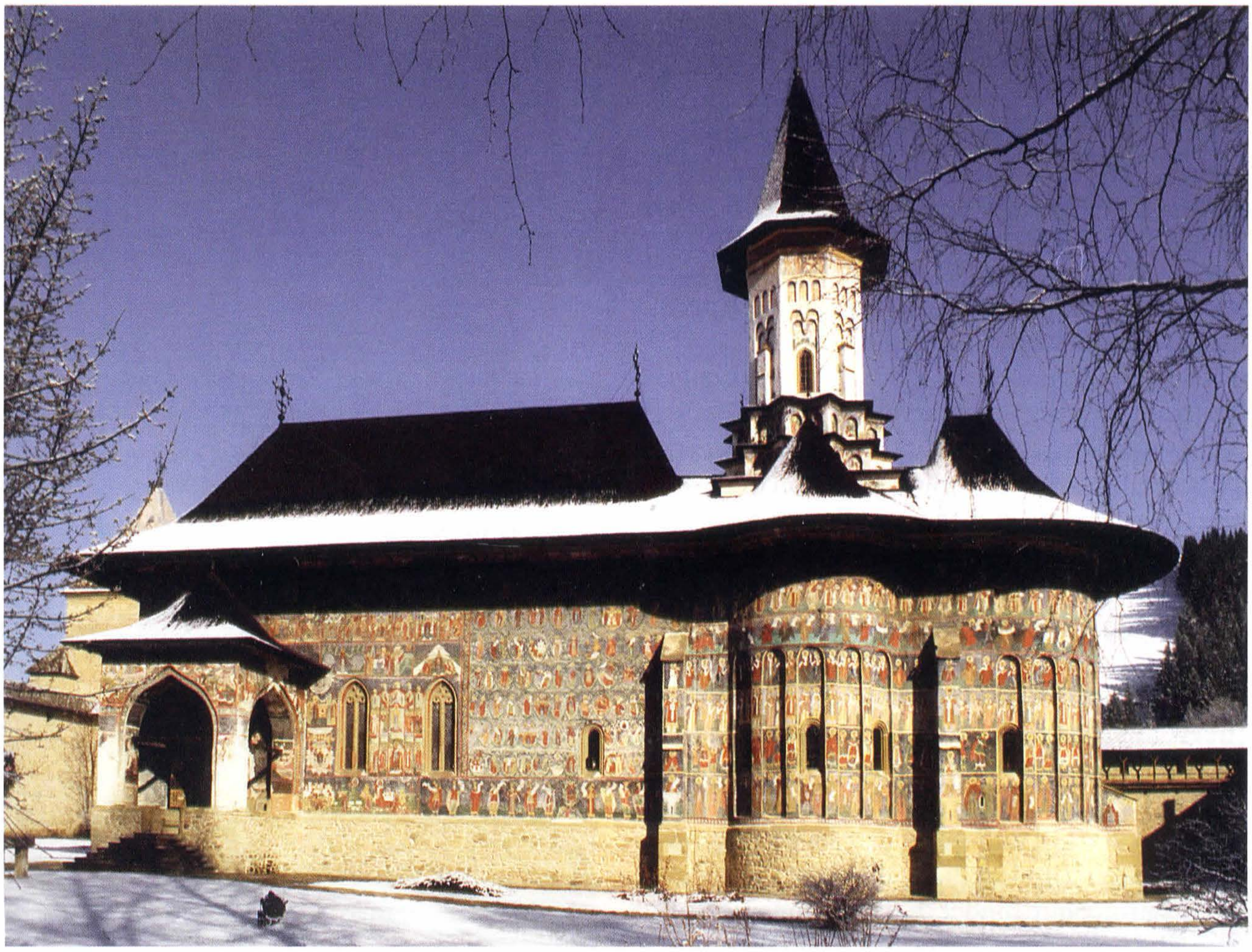

Fig. 1. Southern view of the Resurrection church

2. The preliminary examination performed before the specific interventions for the preservation of the mural painting has presumed, beside the direct observations of the restorers , a stage of laboratory investigations where had been involved the chemist engineer Ioan Istudor and the biologist Ion Ionita. This moment had implied performing chemical tests to identify the materials used by the authors of the painting, and the pigments used on the paint layer and the quality of the paint or the nature of the aggregate in the support layer (**Fig. 2, 3**). Also through laboratory research it has been determined the

Fig.2. Pigments samples

Fig. 3. Analysis result: microscopic stratigraphic image

type of the salts made soluble by the humidity and crystallized again at the surface of the paint layer. The biological tests had the purpose of determination of the interior and exterior biological evolutions that had a part in the transmission in time of the mural painting.
At the same time, there have been made measurements to determine the microclimate parameters, respectively the relative temperature and humidity of the air, measurements needed to identify the repartition of these parameters in the whole interior space of the church and their influence in the preservation of the mural painting.
To establish a correct methodology, along with the chemical tests done by the specialists, an important role had been held by the identification of the execution technique and the possible alterations of the pigments. As it has been mentioned before, the painters from Sucevita had used a mixed technique in the conveying of the polychrome garment of the church. Therefore, the painting has been started and done in a large part on wet, but it has been finalized on dry, through the introduction of a proteomic binder in the composition of the pigments. The parts done “a secco” are, in general the backgrounds representing the sky and the ground, in which realization had been used enamel blue and copper green. It can be noticed the flexibility of the painters in the use of the technique with big differences between the interior and the exterior, in the modification of the succession of the pigment application and also in the replacement of them with others with a better bearing in the exterior conditions, e.g. cinnabar red, sensible to the solar light, has been replaced with ochre red.
Regarding the state of preservation of the pigments, it can be remarked the alteration on extended arias of two of the pigments characteristic to the painting from Sucevita, respectively cinnabar red and enamel blue. The esthetic transformations of the cinnabar red into black metacinabru it is owed to the instability of this pigment in the incident light of the sun with lengths of wave between 400 and 570 mm [2]. This chromatic modification is noticed in the vicinity of the windows, the phenomena decreasing gradual (**Fig.4, 5, 6**).
The alteration process of the enamel has modified the

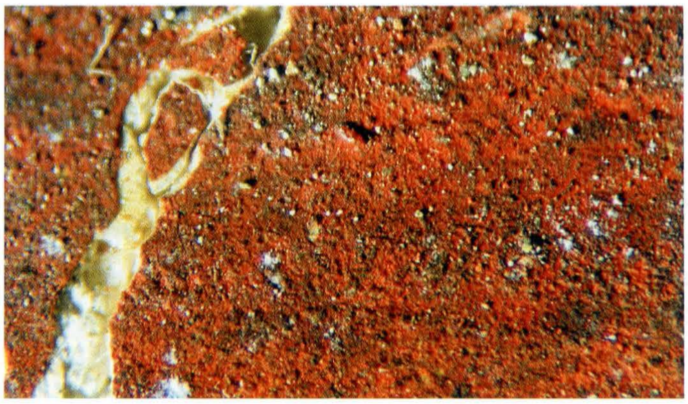

Fig. 4. Good presearved red cinnabar; microscope

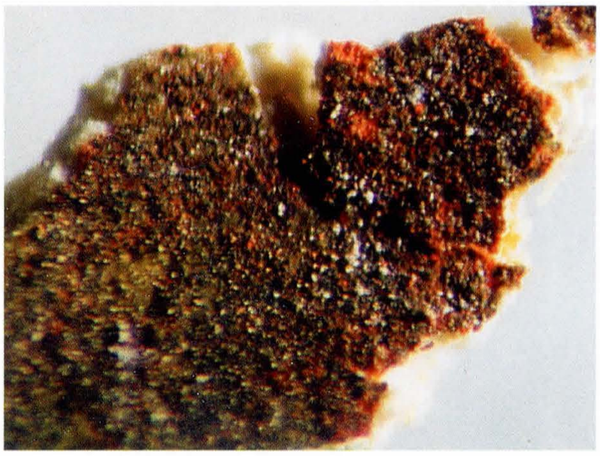

Fig. 5. Alterated red cinnabar; microscope

Fig. 6. Narthex. Alterated cinnabar red, in situ

original appearance of the paint layer from deep blue to a white-cream with chalky look, going through a variety of semitones (**Fig. 7, 8**). The phenomena had taken place at the level of the interior painting as well as the exterior

Fig. 7. Narthex, south window: inalterated enamel blue

Fig. 8. narthex. alterated enamel blue

one. In the interior painting, this process is easy to be identified, especially on the superior areas of the altar, nave, the grave room and narthex, and at the exterior, on the north façade. To understand the alteration process, there have been drawn samples from the areas with well preserved pigment and also from the ones with a white chalky look (**Fig. 9, 10**). Following the examination of the pigment *in situ* and in laboratory, it can be concluded that

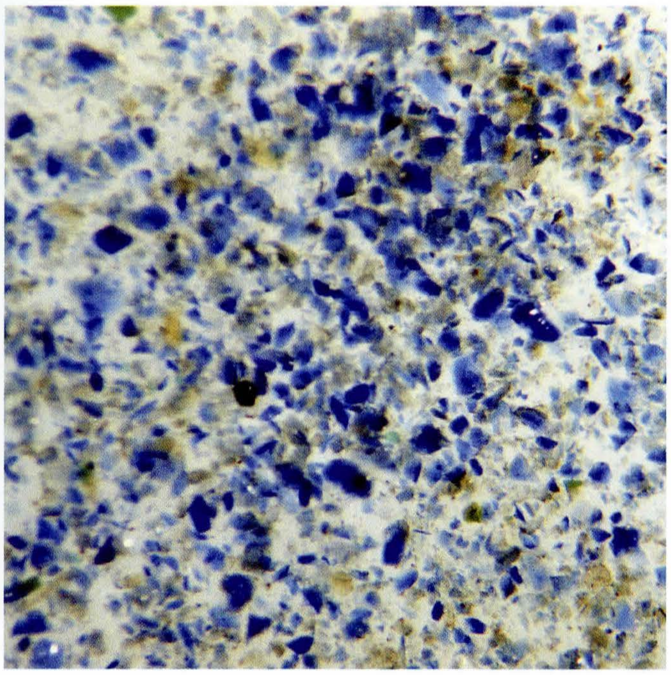

Fig. 9. The inalterated enamel blue; microscope

the degradation of the enamel in the interior and exterior painting from Sucevita is due to interactive causes, e.g.

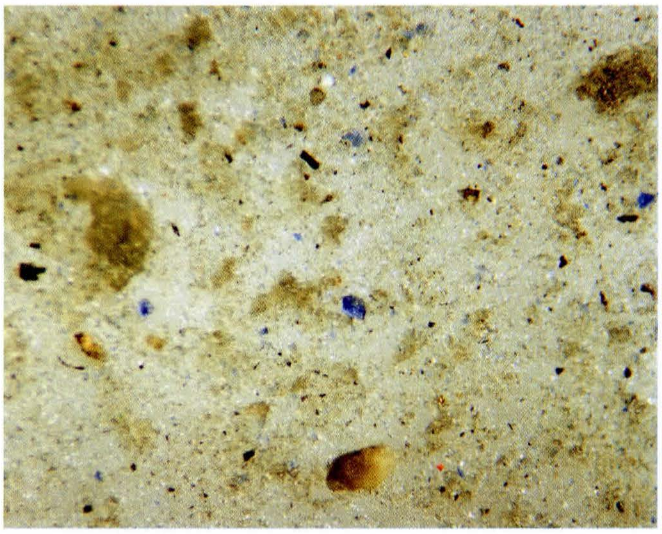

Fig. 10. The altered enamel blue; microscope

the deficiency in the fabrication of the pigment, atmospheric humidity and the presence of the condensation phenomena, the developing of the bacteria and microscopic fungus in the environment of a organic binder/ binding material on the surfaces without ventilation and light.

To observe the preservation of the paint layer in the actual state, it is necessary the implementation of measurements to eliminate the sources that promote the presence of humidity in the interior of the monument, by reducing the number of visitors in groups and spacing out the access in the periods of time with tourist afflux, providing a good airing between visitations in group, reducing the use of candles and improving the circulation of the air in the interior of the church referring to the specific conditions for the interior and the exterior of the monument.

3. The state of preservation and methodological aspects.

The preserving and restaurational interventions done at this church have begun from the exterior, where the preservation state of the painting has imposed emergency operations to preserve the pictorial layer (**Fig. 11,12**). Then, the work continued with the restoration of the exterior mural painting. Considering the particular aspects of the preservation state of the exterior mural painting, and also the nature and the consistency of the interior deposits, the samples and the test for establishing the methodology, have been performed differentiated, depending on the characteristics of every area of intervention.

Proceeding on with the detailed examination of the painting there can be noticed more degradations at the level of the support layer, some of them being taken over from the building structure, and also at the level of the paint layer.

Therefore, it can be identified an ample network of gaps and cracks of different dimensions, existing in the support layer of the mural painting. Some of them are caused by the hydraulic materials- wood fragments, coal and pounded brick accidentally present in the composition of the intonaco layer, materials with a different absorption index then the rest of the support material composed by lime and tow. To all of this are added the cracks formed due to the sinking of the ground in the protbesis area, causing the median sectioning of the altar's apse and the shifting of it with about 5-10 cm, causing the dislocation of the painting from the initial plan (**Fig. 13, 14, 15**). This problem had been solved in the 60's, along with the

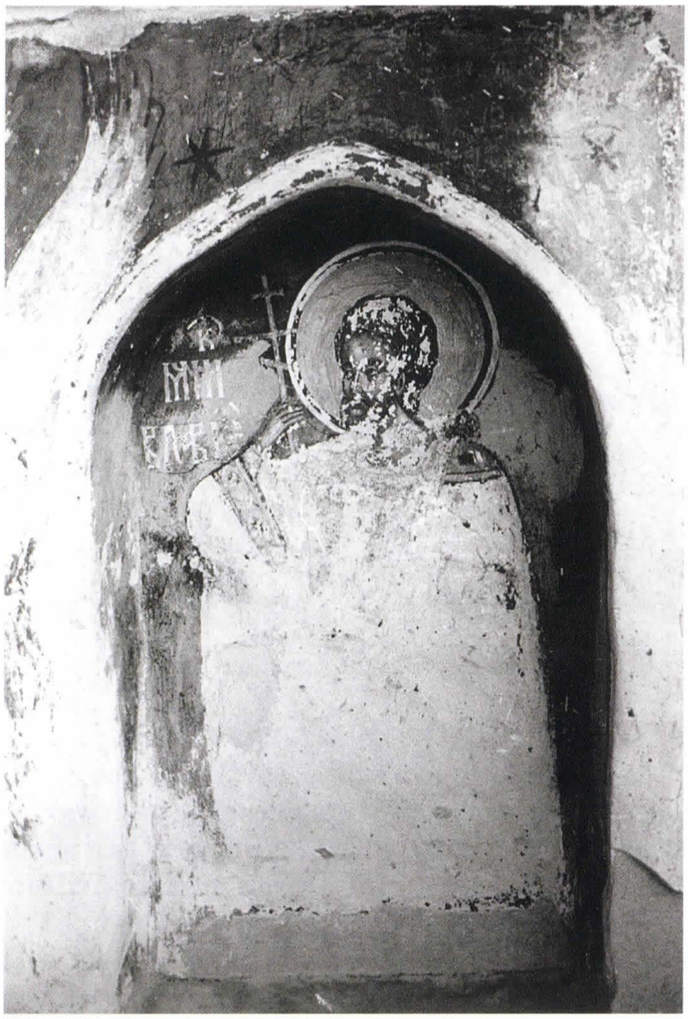

Fig. 11. Outside murals, before restoration

Fig. 13. Triumph arch : cracks and detachments coming from the structure

Fig. 12. Outside murals, before restoration

Fig. 14. Chancel, western arch: cracks and detachments coming from the structure

Fig. 15.Chancel, semicupola. Cracks and detachments

Fig. 16. Nave. Murals damages due to erosion

Fig. 17. Nave. Murals damages due to erosion

consolidation of the church, through casting a peripheral reinforced-concrete belt at the level of the cornice, connected through tie-beam made of the same material. The tests done before and after the intervention are concluding in this direction.

Therefore, we observe that the fissure from door soffit towards nave, did not work after consolidation, that is on tests done after belt assembling did not appear fissures, as there were before. In the beam of the triumphal arch, with extinction to apse altar and with continuation to the outside, near the East buttress, has been noticed a grave state of masonry dislocation. This has been consolidated by emptiness obturation with brick, the same material with the original, puttied with mixture of lime-sand and injected under pressure with a special mortar for vaults, based on hydraulic lime.

These are not the only causes of the profound gaps, besides are those caused by the wood furniture situated on the inferior area of the walls. The stalls protected, one side the picture, because the back surface is lighter, the adherent layings are not consisted as the other areas, limiting, in the same time, the public access (laic or monastic) to painted areas. But on the other side, the stalls have caused a lot of structural fractures to the paintings, blows, frictions, erosions, gaps of different dimensions and depths (**Fig. 16, 17**), from witch some are big and grave enough if we consider they are situated on key position as monk Ioanichie portrait from votive picture (**Fig. 18**). In the same time, the emplacement in the picture

Fig. 18.The portrait of monk Ioanichie, damaged by erosions

neighborhood the stallwok compact wood structure, the lack of any perforation for airing, favourized an intense biological attack, visible after moving off all these. For preventing the reappearance of this noxious phenomena both for layer and for the people, it should return to a system which has to permit the air circulation at picture surface, normal ventilation and the access of diurnal light, as much as is possible in a close space as is church. These microbiological formations which have developed on a space favourized by the furniture have been met even on the superior areas protected by the architecture elements. The microbiological forms met outside were lichens and green alga which developed them selves on areas exposed to the excessive humidity, with reduced air circulation and without being exposed to the direct action of the sunlight.

The adherent layings down accumulated on the interior mural area have a variable consistence, their quantity is growing when we bring up to nave and sanctuary (chancel), having as maxim point of blackening protbesis and diaconicum, where together with dust, smoke, pitches, oils, wax and paraffin accumulations there are burns or calcination of the pictures caused by the candle burnings(**Fig. 19, 20**).

Fig. 19. Deposits on the painting in the diaconicon

Fig. 20. Deposits on the painting in the diaconicon

Specific tests done on original mural painting from the entire mural ensemble showed us that the colour layer is on a precarious state of conservation. At the picture surface prevail decoesive forms of the degradation of the pigments cinnabar red, cooper green, ochre yellow, brown and black of smoke, which have manifested on more evolutions studies (**Fig.21, 22**).These are the gravest and hardest to

Fig. 21. Decohesion of the mural painting, before restoration

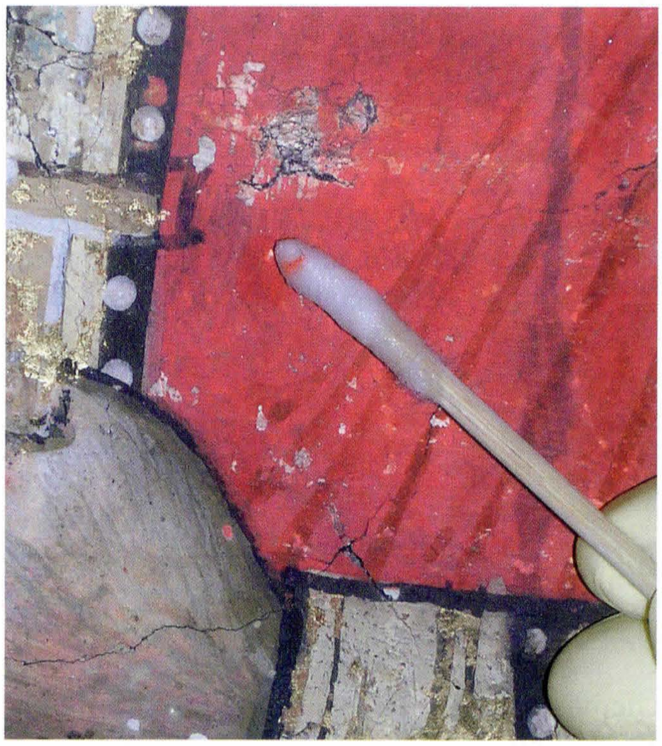

Fig. 22.Contact tests for the determination of the cohesion

be monitorized, because by loosing the binder between the pigments, the picture aspect does not modify visibly; the loss of the picture is slow but irreversible. *Decohesive or powderig forms,* very grave at Sucevita, are made evident through specific tests done by the restaurateur periodically. Re-establishment of destroyed links between pigments had been realized by treatment with barium hydroxide (**Fig.23, 24**).Here, we wish to make a carrying out of some exactingnesses among which the presence of the nitrates. This treatment has been possible in places where were minimal results of the nitrates on mural surface, between 5-15mg\1 (measured on tester scale) (fig. 25). Because these surfaces are affected by infiltrations and capillarity in time, so with a raised content of nitrates, their value being till 500mg\l, barium hydroxide has been replaced with oxalate of ammonium.

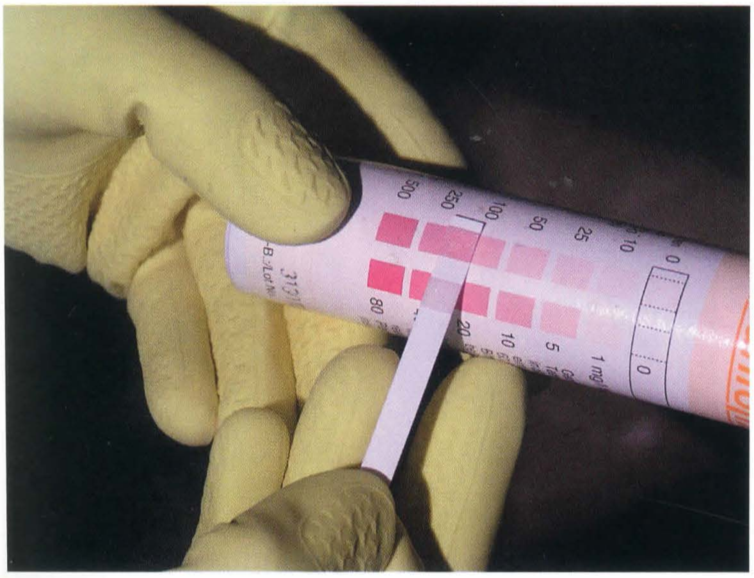

Fig. 23. Identification of the nitrats; tests in situ

Fig. 24. Barium hydroxide treatment

specification regarding the utilization of mineral nature treatments trying a diminution of products having as base acrylic resins used currently, as Paraloid or Primal. The application of treatment with barium hydroxide implies Technology is the same, but the chemical reaction of coesive links remaking varies radically from one method to the other. Chemical inorganic compounds are compatible with the initial layer. They have the

Fig. 25. Barium hydroxide treatment

appropriation of fusing the pigments and cancel dusty effect of the surface, by changing the refraction value of incident light, giving back brilliance, profoundness and initial structure quality at the painting.
Another grave form of mural painting degradation is caused by the loss of adherence at the intonaco or between pigments layers. Because of tension from pigments layers appeared as effect of convergence of different degradation elements, the layer losses its adhesive links and starts detaching from support, creating in this way tiny air bags. This could be determined by an easy touch of the painting from affected area. Gradually, the layer contracts itself and start raising, making little inflations which are increasing till the formation of roof slopes, craters and scales. The last one, continue to loss its peripheric adherence which lies to appearance of fissures, breaks and, by moving of the air, reaches total detachment and therefore to the irreversible loss of the painting. New formatted gaps have white colour, but looking ensemble, erodated area has spoted, dirty, non-uniform look, appeared as result of different laying-down of suspensions from atmosphere that forms patina (**Fig. 26, 27**). We have to mention that forms of loosing

Fig. 26. Loss of adherence of the paint layer

adhesion at support coexist with those de-cohesive (**Fig. 28**). These degradation forms of the painting were very spread on church façade prevailing by comparison with de-cohesive forms. The similar aspects of manifestation and evolution of scales at inside as well as the outside have been treated differently, so the outside painting has been consolidated with transparent dispersion of calcium *caseinate,* in different concentrations, put in more successive stages. The choice of this solution has made after a complex investigation done by chemist engineer Ioan Istudor, under his assistance being traced the exfoliations of the colour layer. For choosing the consolidant has been started from a technological study

Fig. 27. Loss of adherence of the paint layer

of the picture to whom composition was a proteic addition. The used dispersion does not modify the original aspect of the colour layer and allows eventually later

Fig. 28. Loss of cohesion and adherence of the

interventions. Because outside necessary conditions for development of biological attach are not met, for which dispersion becomes maintenance source, have been done samples on the basis of which has been applied successfully the consolidation process.
Inside, and especially in the altar, the problems were more complex because the adherent laying down of dust, smoke, pitches accumulated on exfoliated surfaces isolated the two layers (intonaco and colour), wrapping

detached scales, but making deposits behind them. On these conditions, on which the mural surface was impossible to touch, started the cleaning operation by moving off carefully the numerous spiders' web. Golden surfaces were cleaned locally with alcholized water and isolated with Paraloid B72, for being able to work in optimum conditions others areas.

Moving off these sediments has been done carefully, through a special methodology, which consisted in application of japonesse paper, wetting continuously with ammonium carbonate, till saturation, followed by pressing, through a thick layer of purified and pressed cellulose (**Fig. 29, 30**). This constituted an elastic, soft and very absorbing environment for not causing new problems at

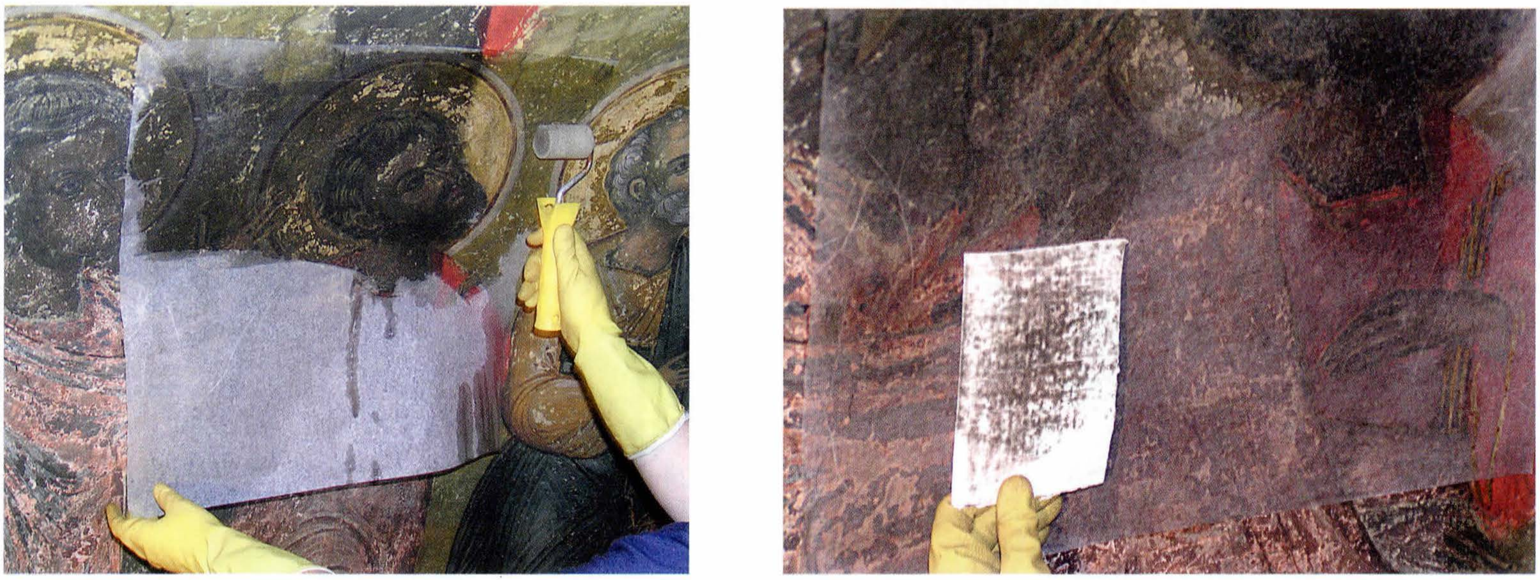

Fig. 30. Chancel semicupola. Cleaning

Fig. 31. Chancel semicupola. Cleaning

the colour layer dip by the solvent. By pressing a blacking of cellulose has been noticed, which means that a part from solubilized sediments by the ammonium carbonate were passing in the compress. The action has been repeated till as much as possible from adherent sediments were moved off. An easy press with a soft wet wishab followed, insisting on more blackened areas, so, finally, colour layer could have a clean and unitary aspect (**Fig. 31,32, 33**).
After finishing this operation the mural area has been let

Fig. 32. Chancel semicupola. Cleaning

for a while, necessary for ammonium evaporation and for forming of tiny links among pigments, capable to hold the colour layer near the support, followed by painting consolidation with calcium cazeined and treatment with barium hydroxide.

4. Esthetic approach to the restoration

Fig. 33. Chancel semicupola. Cleaning

A special stage of the restoration process is represented by esthetic recuperation of the original painting. Here

Fig. 34. Nave. Votive painting of the Metropolite Gheorghe Movila. Before the restoration

is very important the restauratore option for authentic image transmition, by a correct utilization of final presentation techniques and his attitude in relation with evolution and material history of the moment. Every stage should be recorded on paper, well motivated and sustained by arguments, without taking from the originality of the monument by unjustified interventions which can falsify the original aspect of the painting.

In this direction we would like to emphasize the evolution of the concept of esthetic presentation of mural painting from Suceviþa. Outside, combination of conservation function with that of esthetic presentation, lead to the use of coloured mortars in materials, for covering the profound gaps from South façade. Using this method, has been obtained a chromatic attenuation of the gaps which have integrated very well to the mural ensemble, but with all these, being easy to identify if it is wished this thing. On North and East façade numerous spots and white fissures could be seen, on background of intonaco coloured ochre-light red, hard to be integrated in classic techniques, because being in outside conditions its resistance is minimum.

At the inside, our esthetic option followed classical step, that is superficial gaps and erosions of the colour layer have been covered with neutral aquatints from point of view chromatic, reported as value to the original. Techniques used on this situation were *velatura* and *ritocco*. All profound gaps and deeper incisions which reached intonaco layer, have been meticulously puttied at the level of the original painting, relating all the time to its borders and integrated chromatically by image reconstitution in *tratteggio* technique. In this way has been obtained a differential through texture confronted by the original, by which method painting has been recomposed chromatically and iconographical (**Fig. 34, 35, 36**).

In the altar, traces of the original iconostasis, printed to North and South areas, are conserved and integrated at the ensemble through putting under level with warm grey mortar coloured in composition (**Fig. 37, 38**) . This option has motivated by that on the moment of painting the church had already mounted iconostasis, probably even painted. The reason for which the ensemble of mural painting has been realized by those two painters of icons brothers, is due to the fact that after the painting test realized on South church porch, The Movilas being discontented, probably insisted that the same artists robe the whole foundation of the voievode. Bounds of fresh intonaco layer, conserved behind vertical pillars, demonstrate the fact that was impossible for the artists to apply fresco between iconostasis and wall, the later remaining simple, only with the visible masonry. After replacing the old iconostasis, lateral traces have been painted with lime mortar, coloured in ochre.

Our declared aim of our esthetical options is that to show authentic painting, without producing a false through an excessive and unjustified completation. Our desire is to transmit an objective message, ruled by respect for work of art, in spirit of restorations principles (**Fig. 39, 40**).

Fig. 35. Nave. Votive painting of the Metropolite Gheorghe Movila. After the restoration

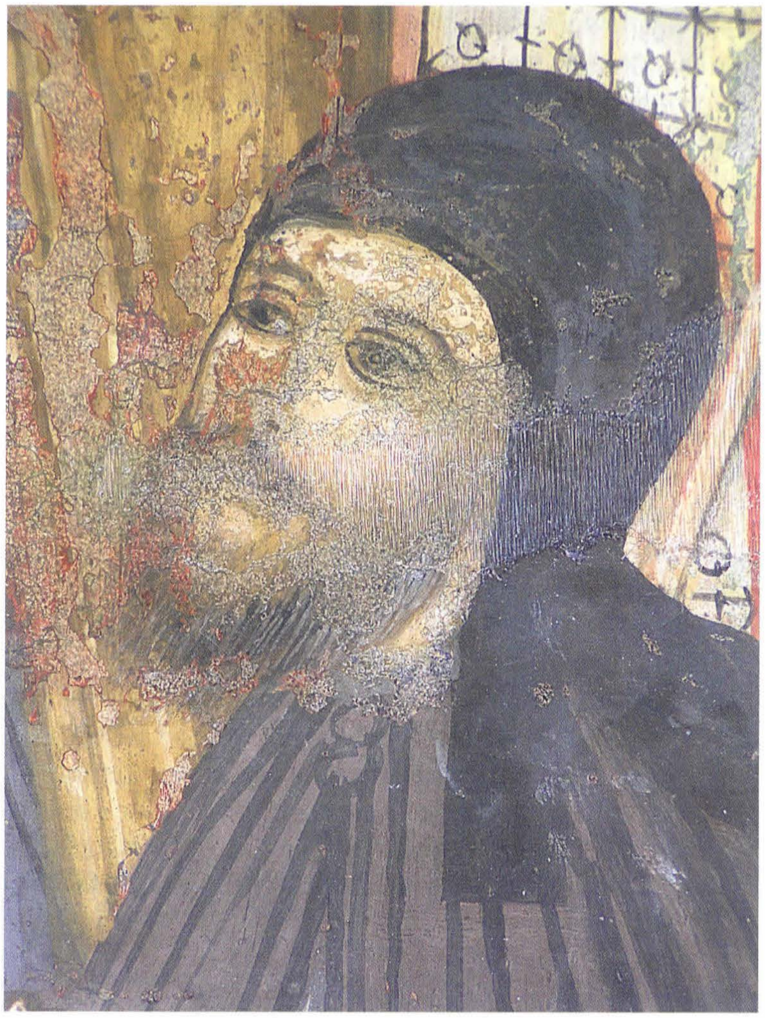

Fig. 36. Portrait of the monk Ioanichie, after the esthetic presentation treatment

Fig. 37. Chancel, behind the iconostasis: before restoration

Fig. 38. Chancel, behind the iconostasis: after restoration

Fig. 39. Paintings in the chancel, after restoration

Fig. 40. Paintings in the nave (western wall), after restoration

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RESEARCH REPORT:

IMPLEMENTATION OF A PILOT PROJECT FOR THE CONSOLIDATION AND CLEANING OF CERTAIN PARTS OF THE INTERIOR PAINTED MURALS OF THE CHURCHES OF SUCEVITA MONASTERY, OF THE MONASTERY OF ST. NICHOLAS OF POPAUTI – BOTOSANI AND OF THE ST NICHOLAS CHURCH IN BALINESTI, AS WELL AS FOR THE IMPLEMENTATION OF CLEANING TESTS ON THE ARCHITECTURAL STONE DECORATION OF ST NICHOLAS CHURCH IN BALINESTI

Oliviu Boldura, Geanina Rosu
Carmen Cecilia Solomonea

ITEM LIST

- **GENERAL REPORT**
- **PHOTOGRAPHIC DOCUMENTATION**
- **RELIEFS SHOWING THE VARIOUS FORMS OF DECAY**
- **ANNEX 1 - BULLETIN OF CHEMICAL ANALYSES**
- **ANNEX 2 - BULLETIN OF BIOLOGICAL ANALYSES**

The remarkable cultural heritage of Bucovine, a region in the northern part of Moldavia, deserves a special attention with regards to the preservation and restoration of the mediaeval values pointing out the spirituality of a population, for the most part of Orthodox faith, in the eastern zone of Europe. Among the religious monuments in the northern part of Moldavia, the churches of Sucevita Monastery and of the St. Nicholas Monastery known as Popauti in Boto°ani, as well as the parish St. Nicholas Church in Balinesti, included in the CULTURE 2000 Programme, are not part of the UNESCO World Heritage List, although their value, historical and documentary, spiritual-religious, aesthetic and plastic, places them within the elite of the Romanian mediaeval monuments. During 2006, on the mural painted decoration, interventions of consolidation and cleaning took place, on pilot areas. Besides these operations, also cleaning tests were done on the stone decorative elements inside the church, more precisely in the narthex of the St. Nicholas Church in Balinesti.

The Romanian churches with exterior murals are worldwide famous due to the painters' initiative of extending the mural painted decoration also to the exterior of the walls which limits the cult space, and marks the opening of the spiritual world towards the outside. This is a kind of continuation of the holy teachings, also presented outside the church. All the churches included in the Culture 2000 research programme are part of this group of monuments, although the exterior paintings are in different phases of decay, for the most destroyed as in Bãline°ti or fully destroyed and partially replaced with a decorative plating, of fake brick and stone, this last case being unfortunately the one of the church of the monastery in Popauti -Botosani.

The church of Sucevita Monastery, celebrating the Resurrection of Christ, was built between 1581 – 1584 by the prince of Moldavia Ieremia Movila together with his brother Gheorghe, metropolitan bishop of the country. They chose as location of the nowadays renowned monument a quite closed place, situated on the upper course of Suceviþa River, in a subdivision of the depression of Rãdãuþi, to the east of Obcina Mare Mountains .

The church of St. Nicholas in Popauti-Botosani, built by Prince Stephen the Great in 1496, long ago in the countryside, is nowadays included in the limits of the municipality of Botosani, in the contact area of Jijia Plain with the Hills of Siret.

St. Nicholas Church in Balinesti, founded by chancellor Ioan Tãutu between 1493[1] and 1499[2] (according to the stone dedicatory inscription) in the nowadays homonymous village, is situated in the northernmost area of Moldavia, very close to the frontier with Ukraine, and is part of the commune of Gramesti, situated at ca. 15 km away from the town of Siret in the county of Suceava.

The value of the above monuments is indicated by the harmoniously thought architectural proportions, the special quality of the interior and exterior murals, where the latter ones have been preserved, and by the fact that in these edifices there also lived important personalities of the political and religious life of the Romanian mediaeval life. The initiation of the conservation works on the interior frescoes is required by the alarming evolution of the biological agents and by the presence of salts in the upper areas caused by infiltrations, and also in the lower parts caused by rising damp. These phenomena are associated with the detachment of the paint layer in the context of very adherent deposits of dust and soot. At the same time, the restoration of the interior frescoes was also a natural sequel of the interventions meant to point out the Moldavian monuments of the 15th and 16th centuries.

1. LOCATION OF THE PILOT AREAS

In the case of each monument included in this research programme, a pilot area was chosen so that there can take place operations specific to the cleaning of the adherent and non-adherent deposits, on the paint layer, but also intervention meant to recreate the adhesive links. The loss in time of the adhesive links between the successive layers of paint, or between the paint layers and the limewash support – named intonaco, determined the exfoliated aspect of the mural paintings. The various types of the factors of decay, which caused the loss of the adhesive links, consisted in detachments with flaking aspect, small blisters and "roof slopes".

The locations of the pilot areas, on the above monuments, were the following:

- The church of Sucevita Monastery – burial chamber, register of the standing *Saints* and of the drapery, to the north of this room of the church, between the stair-case of the treasury room and the door to the nave. The surface of the pilot area is 30,48 square meters, out of which the vertical surfaces are of 29,36 square meters while 1,12 square meters are intradoses of arches or very difficult areas.
- The St. Nicholas church in Balinesti - narthex, eastern wall and lower registers of the eastern half of the room. The pilot area is situated between the northern window of the narthex and the main door of the church, situated on the southern façade. The pilot surface is of 82,83 square meters, out of which the vertical surfaces are of 78,17 square meters while 4,66 square meters are intradoses of arcs, vaults or very difficult areas.
- The St. Nicholas church in Popauti Monastery –Botosani– narthex, northern wall, register of the *Martyr women*. The pilot surface concerned only the vertical surfaces, that is about 2 square meters.

STATE OF CONSERVATION AND SPECIFIC METHODOLOGICAL ASPECTS – CASE STUDY

The surfaces approached in the case of these three monuments were first subject to a preliminary research, meant to establish the state of conservation of the murals, the causes of decay, the degree of exfoliation and the measure of the loss of the cohesive connections of the paint layer. The problems specific to the three monuments intensely required the restorer's attention, as more or less similar cases of decay yet in different contexts required different methodologies. These aspects will be further discussed below.

2.1. GEOGRAPHIC POSITION OF THE SITES AND GENERAL MICROCLIMATE CONDITIONS

The monuments within the CULTURE 2000 Programme - SAVING SACRED RELICS OF EUROPEAN MEDIEVAL CULTURAL HERITAGE, i.e. the churches of Sucevipa Moanstery and St Nicholas in Balinesti, both within the county of Suceava, and St Nicholas church of Popauti monastery– Botosani, were built within the same geographic region, that is in the north-eastern part of the country, limited from the physical and geographical

point of view within a landscape of valleys and meadows. The microclimate survey carried out in 1970 by the National Institute of Meteorology and Hydrology, upon the request of the Direction of the Historical Monuments, showed that there were big variations between the temperature values recorded during summer and those recorded during winter, the range between the maximal and minimal values being of about 50°C.

Under these thermal circumstances, the phenomenon of thaw and frost occurs within a longer interval, between the months of October and April.

Also, the quantity of the precipitations in the northern regions of Romania is bigger because they are more frequently under the influence of the activity of cyclones

which move across the Baltic Sea and of their atmospheric fronts.
The daytime annual variation of the relative humidity in the area adjacent to Siret River is of 73-74 % in May and of 85-87% during the winter months.

- the main direction of the wind indicates for this northern area of Romania an annual frequency of about 25 % from the north-east direction and only 11 % from south-east[3].
- the climate is temperate – continental with a rather cool specificity, due to the strong variation from one phase to another. The annual average values of the minimal temperature varies from 0° on the high peaks up to 8° in the plateau of Suceava and the valley of river Siret.
- the hydrographic network fully belongs to the basins of rivers Siret and Jijia.

Taking into consideration the generality of the microclimate parameters of the above zone, we consider case studies are necessary in order to state this type of data for each of the monuments under discussion. The data available at present will be completed by comparative measurements as for the thermal contrast between inside and outside the church, correlated to the wall temperature. Knowing all these, it will then be possible to monitor the frequency of condensation on the interior surfaces.

Bălinesti. St Nicholas Church. Dedication icon. Narthex, eastern wall

From the architectural point of view, the church of Sucevita Monastery continues the tradition of the monuments built by Stephen the Great and Petru Rares, without bringing new elements neither in plan, nor in the rhythm of the exterior surfaces. The mason seems to have been preoccupied to create new flat surfaces, meant to be decorated with exterior frescoes. Full masonry is therefore prevalent, and it is pierced only here and there by the window openings.

TECHNICAL DATA CONCERNING THE EXECUTION OF THE INTERIOR FRESCOES

Considered as a whole, the frescoes of the church of Sucevita Monastery are unitary, aesthetically speaking, but while approaching and trying to identify technologically the features of this painting, we notice some differences that can bring new elements for the understanding of this mural painting.

The stratigraphic studies and the technical means of execution show some differences also in the apparently unitary interior painting and much many in the exterior frescoes. The materials used for the technical execution of the painting are very varied, illustrating the instable political period characterizing the State of Moldavia at the end of the 16th century.

The painting of the church of Sucevita Monastery was carried out in the a fresco technique, in which the pigments, very finely smashed until turned into a powder, were dispersed into water and applied on the wall on top of a layer of fresh limewash. The studies carried out by chemist engineer Ioan Istudor also indicated the presence of a protein, due to the a secco intervention with an organic binder.

The authors of this very valuable mural ensemble are two icon painters, brothers Ioan and Sofronie.

The painting of the church was carried out during several working phases, as indicated by the different composition of the preparatory layers. There are areas where the coexistence of two layers of mortar can be noticed: arriccio (well polished and sometimes even hammered) and intonaco. These are visible in the lower areas, in the lacunae, as well as in the small niches of the burial chamber, where the structure is therefore visible.

An attentive examination of the support layers points out the same structure and composition of the mortars used. The arriccio layer includes limewash, sand, hemp tows, while the intonaco layer is composed of limewash and tows whose width varies between 5 and 10 mm. In the lower part of the walls one can easily notice the two layers of mortar, because in this area the wall was more affected by various accidents, etc. while in the upper part the painting is better preserved and the support is therefore not visible.

For the preparation of the painted decoration, mineral pigments were used as they have a good resistance in an environment of bases. As a distinct feature of this edifice, in comparison to the other Moldavian monuments, in this case we notice the usage of the enamel blue (smalt), for filling the backgrounds representing the sky, in the a secco technique. Apart from this, there is also the black colour obtained from charcoal, the earth green, red-ochre, yellow-ochre, enameled blue, limewash white, copper green and cinnabar red for the interior. These pigments were mixed with the limewash white to obtain the light hues used for the vestments and for the architectural and landscape representations, and this increased their resistance against the aggression of the decaying factors.

The mural painting was carried out in pontate and giornate, and their trace is easily noticed in raking light. The investigations also pointed out the drawing incised in the fresh limewash, the presence of the circle segments for the halos and stars, as well as the axis of the compass used for regularly tracing the circles. These are the technological elements that certify the a fresco execution of the mural paintings. Yet, on the backgrounds representing the sky and the green earth, the intervention of the painters was carried out in the a secco technique, as shown by the fact that the enamel surrounds the giggled decoration, including the golden stars. It is known that gold is applied on the dry paint layer, as the linseed oil mixtion does not resist the alkalinity of limewash. As the blue surrounds the stars, it means that it was applied after this. The same situation applies to the copper green applied on the background suggesting the green earth, with the remark that this does not surround the stars, but the green layer shows here and there drops from the upper enamel layer.

19TH CENTURY INTERVENTIONS ON THE MURALS

Inside the church, there can be identified four areas showing interventions on the original painting, by an overpainting in oil colours. The style of the above 19th century interventions is the one of a decadent manner. The concerned areas are situated in the following rooms: porch, western wall - *The Holy Virgin* and *The Absolved Thief*, of the larger *Heaven* scene, *The Holy Trinity* on the lunette of the portal above the door towards the narthex and on its stone profile, and narthex, western wall above the door to the burial chamber, where the *Resurrection* scene was painted. This oil overpainting covering also the stone profiled framings of the doors and the nearby frescoes followed a stylistic unity with the new iconostases in the nave and the one decorating the eastern wall of the narthex.

STATE OF CONSERVATION OF THE MURALS

Due to the mixed technique of execution, the quality of the materials used, the special microclimate conditions, the presence of the various types of deposits and microbiological growth, the paint layer shows numerous forms of decay. The assessment of the state of conservation of the murals was carried out by direct means of observation, testing and sampling, correlated with dated provided by the stratigraphic representations and chemical analyses, the latter ones carried out by chemist engineer Ioan Istudor.

- *Superficial deposits of dust and soot*

These deposits are irregular accumulations, frequent rather on the vertical surfaces than on the vaults. The very fine atmospheric suspensions of dust and soot determined unequal deposits on the prominences of the stone wall. The above accumulations are associated with the phenomena of powdering and flaking of the paint layer, some of which are covered with organic deposits (**Fig. 1**).

As a particularity, it is noticed that sulfates appear in this consistent form of crystallization especially on the blue backgrounds (enamel). This phenomenon is more intensive in the upper parts, while in the lower ones its presence is more limited.

White salt efflorescence was identified on the areas with humidity of condensation, rising damp and humidity caused by infiltrations.

- *Loss of the adhesion of the paint layer* to the support. The links between the composing layers of the murals, very strong, lose their original qualities and are little by little broken under the action of various factors of decay, this evolving phenomenon being influenced by microclimate parameters, the usual physical phenomena such as frost and thaw, evaporation, rising dams and water infiltration, the development of biological growth in the context of a poor ventilation of the space. One can notice the rather small dimensions of the burial chamber, which caused additional decay of the paint layer, allowing in this case an excess of atmospheric humidity, caused by absence of ventilation, or normal airing of the space. The superficial lacunae, which appeared as a result of the exfoliation of the paint layer, manifested as flaking aspect, small blisters and "roof slopes", were especially noticed on the surfaces covered with earth pigments, such as portraits, hands and elements of the vestments, the charcoal used on backgrounds and even on some gilded areas.

Fig. 1 Adherent deposits

- *Presence of the efflorescence*

The investigations and chemical analyses carried out show us the existence of nitrates and sulfates. The presence of salts whose composition also includes the sulfate ion can be identified on the surface of the murals as a fine white veil of about 1 mm thickness, adherent to the paint layer.

- *Loss of the cohesion between pigments.*

The loss of the cohesive connections between the particles of pigments causes the serious decay of the paint layer, and the manifestation of this form of decay can be found in the dusty, powdering aspect of the surface. On these areas, the painting is opaque, as the index of light refraction is modified, becoming diffuse. This phenomenon characterizes about 80% of the surface of the burial chamber frescoes, especially on the blue and green backgrounds applied in the al secco technique. We notice the very fine powdering of the cinnabar red, which, due to sun light suffered a chemical transformation, the molecule of red cinnabar becoming one of metacinnaber black[4] **(Fig. 2, 3)**.

- *Microbiological growth.* This can be identified especially in the areas with reduced ventilation on the tympanon, arcs and vaults.
- *Erosion of the paint layer* in the lower areas, especially around doors. Such forms of decay are caused by the very frequent contacts to the walls of the participants in the religious service, visitors of the edifice, so that whatever has still been preserved of the mural painting looks greasy, shiny. To these, there add the erosions caused by the maintenance, by the nuns, who use sticks and brushes to remove the cobwebs and so they also remove the already exfoliated paint layer. This is how new white lacunae appear in the area of the joining of the walls or around the windows.

METHODOLOGICAL ASPECTS OF THE CLEANING OPERATIONS

After the research of the state of conservation of the paint

Fig. 2. Phenomena of loss of cohesion between the pigments. Details in directed light

Fig,3. Loss of adhesion of the paint layer in its thickness or on the intonaco support

layer, by adherence and absorption tests and directed lighting, so to point out the decay of the painting and the deposits accumulated along the time, cleanings tests were carried out in order to remove the deposits from the murals.
To remove the deposits, the following cleaning methods were used:

- CLEANING OF THE PAINT LAYER LACKING COHESION

The paint layer applied a secco, and the a fresco areas showing loss of cohesion were treated in a special manner. Because it was impossible to apply humid compresses, the preliminary operations had to be mainly dry. The following methodological aspects were carried out:
1. Mechanical dusting and easy removal of the cobwebs with a soft brush. This mechanical operation applied in a dry environment used for removing non-adherent deposits of dust and soot was carried out in a very careful manner, especially on the areas of the enamel blue. As shown in the results of the technological survey, it was applied on the backgrounds in the al secco technique, with the help of a protein binder, which in time got decayed and lots its original quality, the enamel pigment losing its cohesion and acquiring a dusty aspect. To this, there should be added the fact the enamel pigment which is a potassium glass colored with cobalt oxide, suffered a chemical decay, which resulted into the transformation of the blue colour into a whitish gray. The tests carried out by us showed that the above surfaces cannot be cleaned with moistened compresses because the altered enamel lacking cohesion turns into a clayish paste, modifying its original aspect and destroying the traces of brushing.
Therefore, the action taken in this regard were isolated, only on the accumulations of the suspensions of dust and soot, without touching the very decayed pigment. It needs to be said that the deposits existed in those places where the enamel layer was thicker and more adherent, and therefore the mechanical interventions were rather easy. As a result of this operation, very few of the non-adherent deposits were removed, the paint layer lacking cohesion has a more unitary aspect by the diminution of the contrast between the accumulations of dust and soot and the eroded areas.

2. The mechanical cleaning with wishab. The action was carried out directly on the paint layer which had previously proved to be resistant to the contact tests, removing very few of the non-adherent deposits. The painting looks cleaner.

3. The mechanical cleaning using a soft eraser of the Conté Golet type. The painting was very carefully cleaned, insisting on the more consistent dot-like accumulations, with a bigger adherence, following permanently the traces left by the eraser. In order to carry out the above operation the eraser was cut into small and rather long pieces so to enable to act strictly on the resisting accumulations and avoid the erasure of the surrounding paint layer. This is how more numerous non-adherent deposits were removed, and the painting started getting a more unitary aspect (**Fig. 4**).

- CLEANING OF THE GOLD LAYER

The cleaning of the gilded elements (ornaments on the vestments and halos) was done with compresses of 10% water-alcohol solution with the exposure time of 5 min-

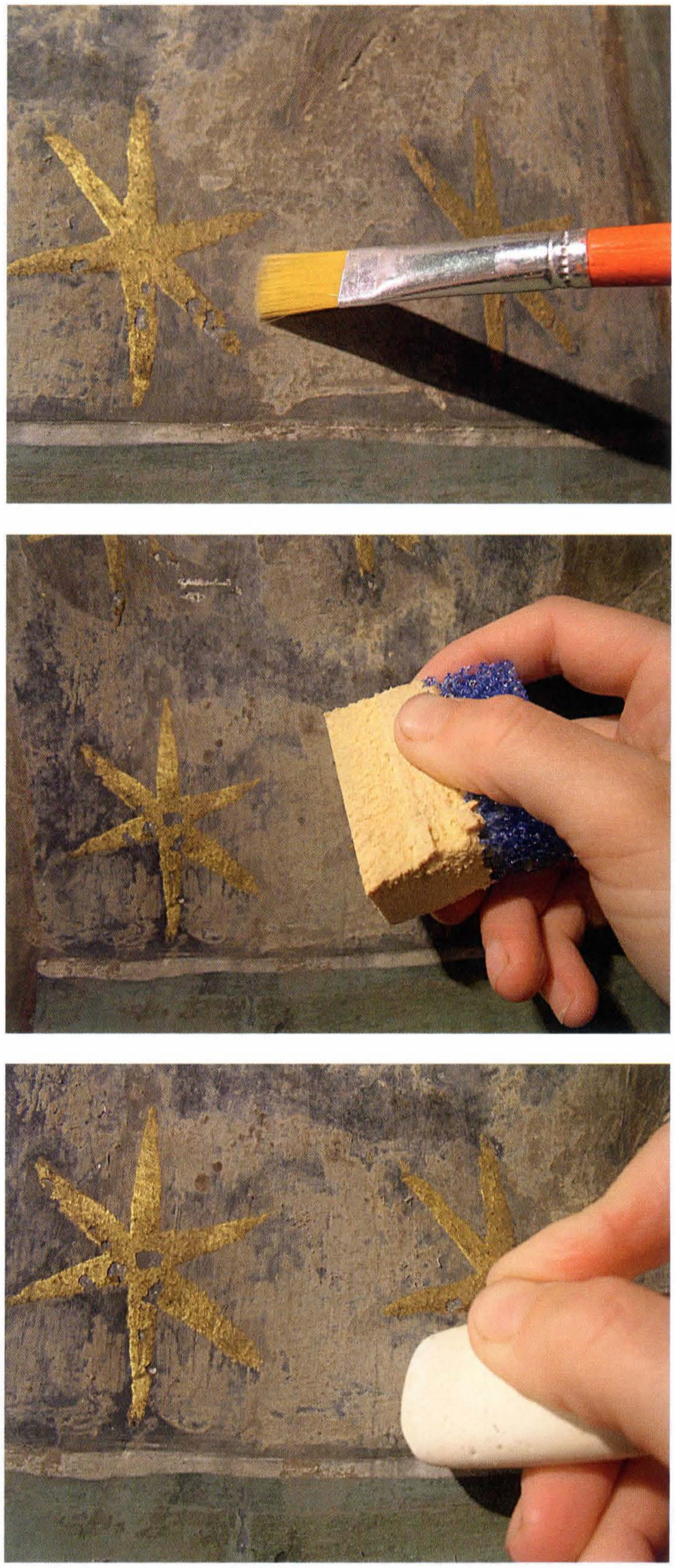


Fig. 4. Cleaning the painting lacking cohesion

utes. On the gilded surface a layer of Japanese paper was first applied in order to protect the original, and on top of it were places cellulose tissues, impregnated with the cleaning substance. After brushing the solvent, the compress was very easily pressed using an elastic rubber roll, so that the solubilized deposits pass into the compress and the various forms of exfoliation, such as flaking aspect, small blisters and "roof slopes", are brought back to the original shape. Thus, one can notice that while the compress is pressed, the cellulose turns black, due to the accumulation of various particles which were not initially part of the paint layer, from which they are actually now removed by the solvent through solubilization.

At the end of the exposure time, the tissue compress was removed and so was also the layer of Japanese paper. In order to remove the remaining deposits solubilized by the compress, the concerned area was cleaned with the help of a soft wishab sponge. Thus, many of the adherent deposits were removed.

The golden stars and the isolated gilded elements within the painting were cleaned in a different way. Taking into account the irregular, radial aspect of the stars applied on the sky background, surrounded by the altered enamel lacking cohesion, the cleaning of these elements was carried out by acting directly on the gold. To do so, small swabs of cotton were used. The cotton was tightly rolled around a bastoncinio and impregnated with 10% water-alcohol solution. This instrument was then slightly rolled over on the working surface, pressing at the same time until the black deposits were removed. The swab used and blackened was frequently changed so to obtain a unitary cleaning without traces of dirt. The operation was repeated until the complete removal of the adherent deposits.

Once the gold within the painting was cleaned, it was then fixed and isolated with 5% solution of Paraloid B72 in acetone, applied by brushing strictly on the fragments of gold. This intervention was necessary because for the cleaning of the surrounding paint layer a 10% ammonium carbonate compress was applied as this could not cause additional decay to the mixtion, unless they were isolated as described above. After the cleaning of the paint layer, the isolation film was removed with acetone, with the help of a cotton swab rolled on bastoncini (**Fig. 5**).

Fig. 5.a,b,c. Cleaning the layer of gold. Methodological aspects.

Fig. 6. a,b.c,d. Cleaning of the paint layer

- CLEANING OF THE PAINT LAYER

As a result of the tests and samples previously carried out (presented in Annex 1), it was noticed that this operation is a very complex one and it involves a big responsibility from the restorer. In fact, the operation is two-fold. That is, on the one hand the flaking paint layer is stuck back to the wall, by slightly pressing on the paint layer, previously moistened in the cleaning solution and on the other hand, the removal of the deposits accumulated on the paint layer.

The first phase of the operation of physico-chemical cleaning, with the help of moistened means, started by the application of a protective layer of Japanese paper followed by the compress of cellulose and its impregnation in a 10% ammonium carbonate solution, with the exposure time of 5 minutes and taking always into account the local state of conservation of the paint layer and of the intonaco layer. During the exposure time, the compress was continuously moistened to maintain it active and the exfoliations of the paint layer moistened by the solvent were also pressed. While part of the deposits solubilized already by the solvent passed into the compress, the blackening of the compress became obvious at each pressing. After the careful and successive removal of the layers of the compress, the painting was cleaned with clean water, with a pH equal to 7, measured to the indicative paper. To do so, a soft wishab was applied and locally new erasers were also used in view of removing the more adherent traces (**Fig. 6 a,b,c,d**).

- CONSOLIDATION OF THE EXFOLIATED PAINT LAYER

The adherent and non-adherent deposits were removed from the various forms of exfoliation of the paint layer by using the same methodology as for the rest of the painting. After the murals were dry, there followed the operation of consolidation of the degraded mural painting. For the above operation, a 1,5% transparent dispersion of calcium casseinate was used while the gold layer was fixed with 5% solution of Paraloid B72, solubilized in acetone. These fixatives were used only in isolation on the surfaces with exfoliations of the mural painting. The exfoliations were pressed with a soft rubber roll, through a transparent sheet of polyethylene. Caution measures were taken on the areas with earth pigments. Serious forms of exfoliations were also identified on the layers with limewash addition.

- CLEANING AND TREATMENT OF SALT EFFLORESCENCE

The operation was carried out by applying a 10% solution of ammonium carbonate through compresses with Japanese paper. After the removal of the compress, mechanical interventions were also carried out with various erasers, depending on the resistance of the salts and the conservation of the paint layer. Then, the surface was cleaned with a soft whishab.

The white veils of salts extracted by the application of the compresses with distilled water but the traces of very fine whitish veil were removed mechanically with a soft eraser, after the painting was fully dried.

- TREATMENTS APPLIED ON THE BIOLOGICAL AGENTS

The infested areas were cleaned with a preliminary treatment which consisted in the impregnation of the area at 10 day-intervals, repeated twice, and applied by powdering using a cationic agent, with tested biocide qualities on the painted surfaces, in a 4 % solution of active substance. This product was selected and tested on several species of fungi and lichens, by dr. biologist Ion Ionita, as it had been successfully used in other situations too. The b108iciding product is called Sintosept Q R 15 (50 % Preventol R 50). After the application of the biocide, the murals were cleaned from organic traces and the fructification elements of the biological agents, by dry mechanical means (average whishab) and humid means (sponges) as well, that is impregnated with water or 3% ammonium carbonate solution.

Upon the completion of the treatment on the concerned area, there was applied, by brushing, a preventive biocide treatment, with the assistance of the same biologist (**Fig. 7**).

Fig. 7. Methodological comparative aspects during the operation of cleaning of the paint layer.

Founded by Prince Stephen the Great in 1496, the church has the same stylistic features as the other five town churches built at his initiative during the period 1490-1496, but it is mainly similar to St Nicholas Church in Dorohoi and St George Church in Harlau.

TECHNIQUE OF EXECUTION OF THE MURAL PAINTING

The painting of this church was carried out in the a fresco technique. The intonaco support was applied directly on the masonry mostly in a single layer, while in some areas there are two successive layers. The composition of the intonaco includes limewash, straw, uncut tows, and small fragments of bricks.

The drawing was applied on the preparatory layer moistened by the brush with ochre pigment – it is visible in the register of the Hierarch Saints, Deacons, Military Saints and sometimes it was marked with black. Incisions were carried out on the intonaco for the vestments, portraits, architectures, backgrounds of the scenes, various objects, decorative elements etc.

One can also see the traces of polishing of the fresh limewash and some elements are gilded: halos, parts of the floral decorative elements, the stripe separating the register of the Passion from the register of the Hierarchs.

STATE OF CONSERVATION OF THE MURAL PAINTING.

The first preparatory layer - arriccio - was locally applied, with the aim of equalizing the areas with differences of level, of the masonry support. The arriccio, due to humidity, in the lower parts (where it is actually visible) is slightly friable and shows superficial fissures. The support layer for the painting - intonaco - also shows fissures which can be superficial and deep, developed in a net-like structure, and caused by the ageing and temperature and humidity variations. The fissures in their turn caused detaching and this last situation can be identified acoustically and are local or cover large areas. Due to the human factor as well as to variations of humidity and temperature, detachments higher than 1m² appeared between the preparatory and support layers. The lacunae of the paint layer are of different sizes, on various areas, caused by various decaying elements. Thus, the badly-intended human behaviour and negligent conduct resulted into abrasions, scratches and degradation by hitting. Both the detached areas and the lacunae were favored by the lack of cohesion caused first of all by the combined activity of humidity (rising damp, infiltration, condensation).

The paint layer also suffered decay due to humidity, variations of temperature and humidity –microclimate conditions, but also due to the previous interventions, which resulted into over-painting of various aspects and dimensions.

Such decay consists into adherent and non-adherent deposits. The latter ones are foulings of dust, soot, atmospheric particles, cobwebs. The quantitative fouling of such deposits is favoured by the obliqueness of the painted surfaces.

The adherent deposits consist into foulings of greasy aspect, including massive biologic growth, a fresco and a secco over-painting, with an organic binder, leaking of paint, wax from the candles, nitrates, salt efflorescence, which are rather difficult to solubilise in comparison with the non-adherent deposits.

In the case of the paint layer, the fissures are the same as those of the intonaco layer, as they evolve from the interior

Fig. 8. Narthex, norhern wall. *Holy Women*; before cleaning

towards the exterior and therefore also involve the paint layer.

The sensitive paint layer shows erosions, abrasions, lacunae, powdering, detached areas and biologic growth. The erosions, abrasions, lacunae are mainly in the lower part, where the paint layer was rather exposed first of all to the human factor. The lower parts of the surface of the painting, meant to illustrate the drapery, are fully covered with mortar made of limewash and sand and which is friable.

The circulation of the masses of air, caused by the draft present as the door and windows are not airtight, together with the oscillations of the values of temperature, determined the erosion of pigments. The areas on which there are repeated overlapping and no binder was added are easier victims of decay as the carbonation power is diminished.

More visible erosion can be noticed at the level of the azurite layer (applied on top of the black layer), the prevalent chromatic tone being black, as shown by the erosion of the blue pigment.

The phenomenon of powdering – lack of cohesion at the level of the paint layer, is especially noticed in the case of the earth pigments: red, ochre, brown and green. These are more sensitive especially to the microclimate variations inside the church, but each pigment has a different state of conservation.

More resistant to the microclimate conditions are the pigments to which a binder was added, more exactly "limewash milk", and the metal pigments – oxides of the iron.

Following the previous restoration interventions, on the surface of the intervention area there could be noticed numerous limewash mortars, applied in the lacunae, but also around them, covering even the nearby paint layer and therefore causing an additional deterioration of the frescoes. Thus, the paint layer which turned very sensitive due to the loss of cohesion – loss of the power of the of the calcium carbonate coating due to humidity – shows erosions, powdering, detached areas, lacunae.

Thus, the portraits show total (**Fig. 9**)) or partial over-painting of the fresco, carried out in a manner rather similar to the original operation, probably dated to the 16th century. In some cases, the overpaintings themselves are overlapped to each other (**Fig. 10**) but there are also more recent interventions carried out a secco with another type of painted mortar

Fig. 9. Overlapped overpainting of the portrait

Fig. 10.Total overpainting of the portrait

The fouling of thick soot, tar are caused by the oven using wood as a fuel and by the candles as well.

The halo was repainted with golden sheet, but this was lost and numerous superficial lacunae were thus caused. The surface of the paint layer showed the remains of some local overpaintings carried out in the a secco and a fresco techniques, and in this latter cases a strong carbonation is visible.

The biological growth was carried out on surfaces painted especially in earth colours. This was also identified in combination with the salt efflorescence to the left of the lower part of the register.

The phenomenon of powdering is especially encountered in the areas painted with ochre and red: portrait, hands, vestment. Red vestments still show the colour only partially. They were almost fully covered by a greasy over-painting carried out in the a secco technique, without a preparatory layer applied before-hand.

METHODOLOGY OF INTERVENTION

Methodological phases:

a. *Partial removal of the non-adherent deposits*

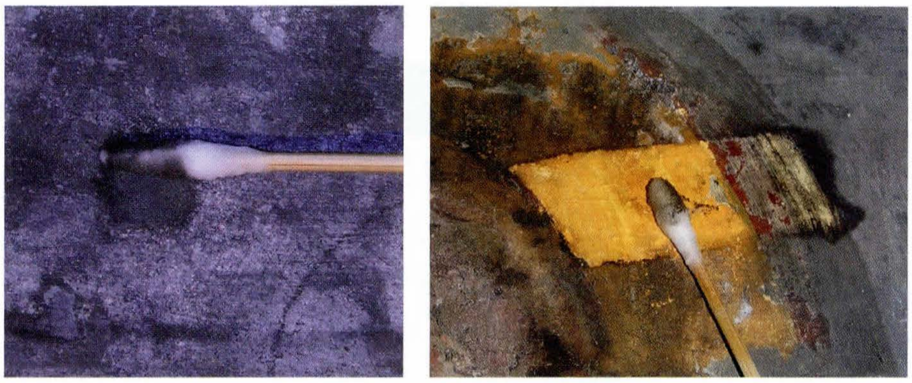
Part of the thick fouling covering the paint layer was removed (that is the deposits of insect cobs and particles of atmospheric dust) with a soft brush made of hair threas and a pear-shapes rubber air blower. The partial removal of the painting allowed the observation of the state of conservation of the paint layer.

The biological growth created a thick fouling mixed with dirt deposits, which in time turned the pigments friable in the structure of the paint layer. Some areas already require a difficult cleaning procedure imposed by the delicate condition of the paint layer, which in some area has no cohesion any more. This situation is among the most serious as far as the state of conservation of the paint layer is concerned.

b. *Applying the biocide treatment* on the surfaces affected by biodegradation – the biocide Sintosept Q.R. 15 was applied in a 4% water solution, as pointed out by the biologist. It was applied by brushing on top of a layer of Japanese paper stuck to the paint layer, with the aim of impregnating the solution on all the surface of the murals;

c. *Cleaning the paint layer*

Application of the compresses with ammonium carbonate on the surface of the paint layer. (**Fig.11**).



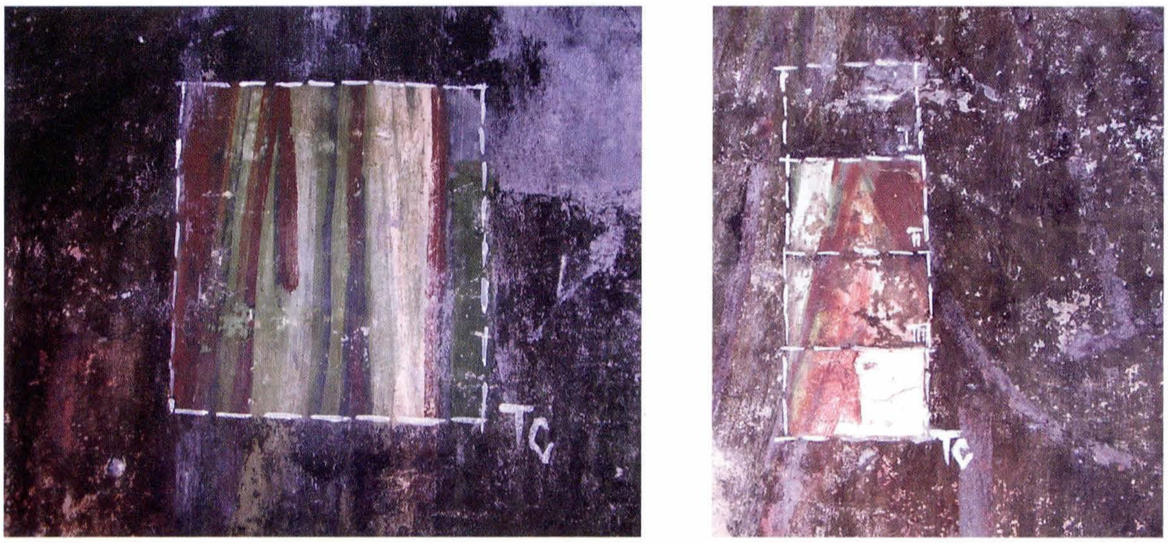


Fig. 11. Phases of the cleaning operation: removal of the compress and elimination of the dirt fouling: a) Contact and adhesion tests; b) Removing of adherent deposits and repaint tests; c) Application of celulose compress

The operation is meant to eliminate gradually the thick adherent fouling covering the paint layer. The operation consisted in the application of slightly basic mixtures, applied in different compositions and concentrations, according to the nature of the pigment on top of which it was about to be applied.
These mixtures were applied by brushing on top of Japanes paper (used as an absorbing tool meant to limit the action of the solution strictly to the surface of the paitn layer) or introduced in inert materials serving as a support in order to increase the exposure time .
The cleaning of the adherent deposits was therefore carried out in different ways, according to the sensitivity of the paint layer, and the non-aggressive limit of the cleaning means, following the surfaces contained in the decoration. The compresses were applied on separate shapes, that is on a single colour.
The cleaning operations were carried out in the upper part of the area of intervention towards the lower part.

METHOD APPLIED:

- Diluted solutions of ammonium carbonate (3%) in compresses, in order to increase the exposure to the murals;
- 5 %- 10% ammonium carbonate solutions applied in compresses of Japanese paper or paper paste (Arbocel BC 200), where the deposits of dirt were very adherent to the murals;
- Saturated solutions of ammonium carbonate on top of Japanese paper, on those areas affected by the phases of rising damp.

This type of cleaning was carried out in order to remove the opaque veils of salt at the basis of the register with the Holy Women, and it was undertaken in association with mechanical means.

Phases of removal of the deposits:
- Removal of dirt with humid means - natural sponge and distilled water , without applying pressure.
- Application of a compress of water and ethyl alcohol, exposure time 5min., by brushing on top of Japanese paper, in the upper area on the blue background
- Removal of the soluble dirt from the surface of the blue pigment with bastoncini + cotton and the above solution.
- Application of a compress with 3 %- 6% ammonium carbonate solutions on top of Japanese paper, exposure time 5- 15 min., on the areas representing vestments (**Fig.12**).
- Application of a compress with 10% ammonium carbonate solutions in Arbocel BC200 cellulose paste, exposure time 15 min. on the areas with adherent overpainting.

After the compress has been removed, the dirt fouling was eliminated by the slight pressure with a humid sponge and a wishab sponge. After the reaction of the applied solutions, the fouling or overpainting materials was removed easily with the help of a humid sponge (natural or synthetic) and then the operation was repeated locally wherever necessary for a minute cleaning.

- Detailed cleaning of the inscriptions with the names of the saints, portraits and lighter hues on the vestments – this operation was carried out with bastoncini + cotton and a solution of water-alcohol.

Some small areas were treated mechanically more intensely and this applies to the areas where the overpainting colours were adherent to the original.
Generally, all the areas of the scene required a multiple-phase cleaning, the operations being required by the condition of the particles in the pigments already affected by lack of cohesion, and the removal of the deposits and overpainting.

Remarks:
- The application of the solutions in compresses reduced the risk a direct cleaning might expose the original to, taking into account the paint layer is already friable.
- The halo of the holy women were initially gilded areas by the golden sheet has been destroyed in time by both the human element (overpainting and anaesthetic prior interventions) and – especially- the microclimate of the church in the past.
- During the interventions, at certain time intervals, the paint layer was being inspected and the operation repeated so to assure the complete removal of the salt accumulations, dirt fouling and other foreign material deposited on the surface of the murals.

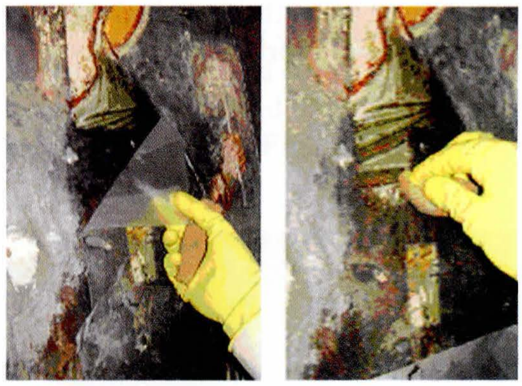


Fig. 12. a) Removal of the compress;
b) Wishab cleaning

d. Removal of the various previous repairing materials (semi-tough mortars and cement mortars)
The removal of this type of tough and very compact intervention, very adherent too, was carried out by mechanical removal on the areas where they had been applied directly on the masonry. In the case of the repairing mortars covering parts of the paint layer as well, it was necessary to associate the mechanical means with chemical ones, in order to reduce the resistance of the repairing mortars. Also when the repairing mortar had been applied in a thick layer, its removal was done little by little, so that initially it was thinned so to be finally

Fig. 13. a,b. Narthex, detail with the painting of the register of the *Holy Women*, on the northern wall, before and after the intervention

fully eliminated. While this operation was approaching the paint layer, compresses started also being applied their exposure time being rather long. After the compresses were removed from the mortar, the mechanical intervention continued little by little until the complete removal of the mortar covering the original paint layer.
Stratigraphic tests were then carried out in order to determine the types of mortars (generally overlapped) and their thickness.

The operation of removing the repairing mortars was carried out taking into account the following situation which is also connected to the activity of mortar removal:
In the case of the intonaco layer which showed fissures and detachments from the masonry, it was necessary to carry out a local consolidation of the area, and the removal of the mortars was of course progressive.

The church of Balinesti is one of the most representative foundations of a nobleman dated to the epoch of Stephen the Great. Councellor Tautu, excellent diplomat, with rare aesthetic qualities, exigent, charitable and attentive to the historical realities, with a peculiar artistic sensitivity, he built at his residence of Balinesti, the church that will become a representative monument, both architecturally speaking and from the point of view of the mural paintings. Its artistic and historical importance determines its inclusion in the elite of the Romanian mediaeval values.

TECHNICAL DATA CONCERNING THE EXECUTION OF THE MURAL PAINTINGS

Considered in its ensemble, the mural painting decoration of Bãlineºti has a techniquely unitary aspect, with similar features inside and outsid ethe church. Their preparation involved several phases: it started with the decoration wich imitated the brick or stone rows. Interior figurative painting was realised by Gavril the Hieromonk[6]. Exterior murals were executed between 1535 and 1538, during Petru Rareº's reign[7].

- TECHNOLOGICAL STUDY OF THE FIRST DECORATION – FAKE BRICK DECORATION

Inside the church, this decoration covered almost completely the surface of the walls with horizontal rows of unequal rectangles red and gray (alternatively disposed), and imitates a brick masonry and alternates on the vertical surfaces with big white fields painted in the a fresco technique.

The preparation of the support includes greasy slake lime with additions of fine siliceous sand, and only a very small amount of brick powder. This mortar was applied on all the surface of the walls, the thickness of the layer being of 0,5 – 1,5 cm, pending on the structure of the wall. Once the intonaco was set, the rows of bricks were marked both horizontally and vertically by incisions in the slaked limewash with the help of a pointed instrument. There followed the application of a white limewash layer on which were painted in red and gray (mixture of charcoal black and "limewash milk"), the rectangles of the rows of bricks. The final phase was to mark the limits between the fake bricks with lines of white limewash. The cross springers (arcs doubleaux) were painted so to suggested a masonry made of ashlars, their surface being covered with a thin layer of fresco and then split in rectangular shapes, delimited by narrow red stripes. The exterior painting was carried out in a different manner. Thus, on the masonry mortar applied as an intonaco layer there were marked white stripes between the bricks and red stripes between the ashlars on the cornice and cornice. There are zones such as the vault, the arches of the porch, and few surfaces on the south wall which still preserve the intonaco layer, identical with the one inside the church. In this case though, the layer of red paint was applied on the whole surface, the incisions were carried out on the joints of the brick masonry. For the grey bricks, a thin layer of intonaco was applied and it was later on polished.
Around windows, doors and ceramic disks, a thin layer of intonaco was applied and painted with fake-stones (delimited by red stripes) (**Fig. 14, 15**).

Fig. 14. Cleaning the rows of fake-brick decoration.

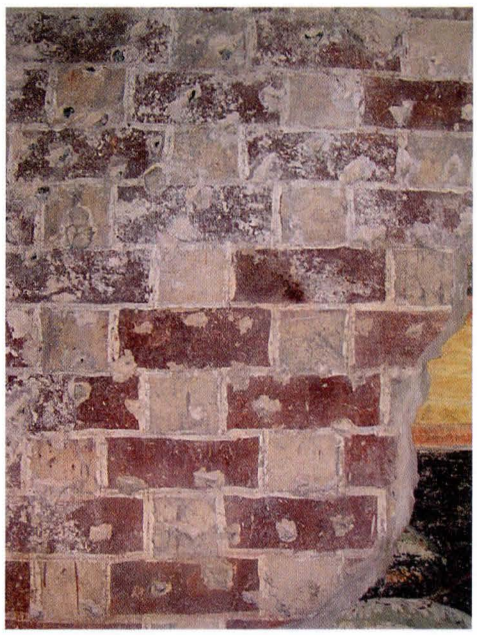


Fig. 15. First decoration.

• TECHNOLOGICAL STUDY OF THE FIGURATIVE PAINTING

The polychrome "vestment" which assures the incredibly high value of the church of Bãline°ti, together with its importance for the history of architecture, is the mural painting preserved on quite big surfaces inside the church and here and there in small "islands" on the exterior walls.

The whole decoration is carried out in the a fresco technique, and the specific identification elements will be pointed out when appropriate during the technological presentation.

The support layer, generally called intonaco, is formed of a homogenous mixture of greasy slaked lime with vegetal fibres (hemp tows). This mortar was applied on the first decoration hammered so that a better adherence can be achieved inside and outside. The painting was carried out according to giornate and pontate whose limits can still be seen in raking light.

After the application of the intonaco layer, the water colour drawing was carried out and then a more intensive drawing, with red, was traced, followed by its polishing so that the calcium carbonate layer created by the limewash intervention is destroyed and also for bringing to the surface the water molecules from the support. There follows the incision of the drawing with a pointed instrument and the application of the successive layers, starting with the backgrounds, up to light colours and white or gilded lines.

The halo of St Nicholas in the *Dedication icon* is in relief carried out with the help of a limewash mortar identical with the one of the intonaco support with the help of a mould which impressed geometrical motives in the fresh mortar. To give the painting a nobler aspect, very much gold was used for the stars, halos, vestments and decorative elements. For the same purpose, the limewash in relief was used in order to imitate the pearled jewellery. The inscriptions are generally carried out with limewash.

The pigments used are those specific to the a fresco painting as they resists to the alkalinity of the limewash, and they are mineral pigments, obtained from the natural ores. More precisely, these are: yellow ochre, earth green and earth red, cinnabar and azurite, applied on an intermediary layer of charcoal black.

STATE OF CONSERVATION OF THE MURAL PAINTINGS

Due to the technique of execution, the quality of the materials used and the special microclimate conditions, as well as due to the various types of deposits, the paint layer suffered numerous deteriorations.

- Superficial deposits of dust and soot

These are irregular accumulations pending on the surface of the wall and on the architectural elements. The accumulation are associated with the phenomenon of powdering and flaking of the paint layer, sometimes covered with organic deposits such as bird excrements or cobwebs, microorganisms or salts.

- Presence of efflorescence

The investigations that were carried out indicated the existence of the sulphates and nitrates especially towards the lower and upper areas. These accumulations are caused by the evolving and persisting phenomenon of humidity, which determines the solubilisation of the salts existing in the support or of those resulting from the organic accumulations. White salt efflorescence were identified on the areas of rising damp and on those affected by infiltrations (in the upper parts of the studied area) and on the surfaces showing condensation.

- Superficial lacunae are decays of the paint layer, consisting in the loss of the paint layer as a result of the adherence to the support. This phenomenon can be noticed on the vestments, portraits, hands and on the layer of gold.

- Loss of cohesion between the particles of the decayed paint layer, indicated by the presence of powdering areas. To this should be also added the lack of adherence of the paint layer to the support, which caused small blisters, detached areas as if roof slopes and flaking areas, present on the earth pigments and on the artificial copper green layer.

We also notice the sensitivity indicated by the very fine powdering of the following pigments> red, green, azurite, yellow ochre and also the small flaking of the gold decorations.

The specific decays of the paint layer present as powdering, flaking, small blisters and roof slopes have different causes. They may turn more serious if the surface is covered with various deposits of dust and soot. In this situation, the consolidation of the paint layer needs to be associated to the operation of cleaning or to the treatment of the salts.

Main causes of the decay of the paint layer are:

- Technical vices, that is the time interval necessary for the application of the pigments in the a fresco technique. Our observations show that the pigments applied on backgrounds which were in their first phase of carbonation have the highest resistance and are the last pigments to disappear. In this regard, mention should be made of the azurite blue, used for the background of the sky. The colouring of vestments and architectural elements during the second phase was done using rather argillaceous pigments, and this determined an average adherence, the pigments becoming in time powdering. More resistant are the pigments which were mixed with limewash to obtain lighter hues, but also in this case there appears the phenomenon of loss of adherence (flaking). Finally, the most sensitive areas are the portraits and hands, which were carried out during the last phase with argillaceous pigments (ochre, red, sienna) sometimes mixed with limewash for modelling the lights. On these zones, where the carbonation phenomenon is less intensive, the paint layer proves to be flaking, with "roof slopes" or small blisters. Generally, one notice the rather limited

use of hues obtained from the mixture of pigments.
- The loss of cohesion of the paint layer is determined by the weakening or complete loss of the binder, in this case, the calcium carbonate, due to physical causes. As a result of this phenomenon, the paint layer becomes powdering and sensitive to the action of mechanical factors.
- The presence of humidity (rising damp or infiltration) is an important element in the evolution of salts, which, by their mechanical action, determine the detachment of the paint layer, in various forms, and the destruction of the cohesion of the support layer.
- Phenomenon of condensation. The study of the painted surface determined the identification of chromatic modifications, on the traces of the drops, due to the humidity of condensation. Therefore, one can conclude that the relative humidity of the air inside the church was of more than 75%, and this is how condensation appeared on the cold surfaces. Consequently, the layer underneath got moistened and this situation favored the processes of biodeterioration and alteration of pigments.
- Microbiological growth. The phenomenon of microbiological contamination is present on wide areas in the pronaos on about 90% of the surface of the walls and is indicated by the evolving thick white veils, with a puffy soft aspect and humid when touching it. The inadequate ventilation associated to the excess of humidity and a rather constant relative temperature favored such violent biological growth.
- The erosion of the paint layer is visible on the areas with rising damp in the lower areas or in those affected by infiltration. The erosion is also accentuated by the mechanical action of humans, who frequently touch the painting or really lean against the walls.

METHODOLOGICAL ASPECTS OF THE OPERATION OF CLEANING

After the specific tests were carried out and the after the preliminary research, various cleaning samples were taken from the adherent and non-adherent deposits (of various origin– dust, soot, tar, wax, etc.) and tests were done for the consolidation of the decayed paint layer. These tests continued also on the areas with salt efflorescence and biological growth as well. In order to have control on the operations, measurements of the relative humidity and ambient temperature were done all along during the implementation of the operations of cleaning and consolidation of the paint layer.
The microclimate parameters varied around 18,9^{0}C for temperature and 54% for the air humidity.

- PRELIMINARY CLEANING OF THE PAINT LAYER

The preliminary phase of the operation of cleaning included the removal of the superficial deposits caused by dust, smoke, less adherent organic growth such as cobwebs. For this operation, the following dry mechanical means were used:

- Mechanical dusting and removal of the cobwebs with the help of a soft brush and only here and there the cobwebs were removed with the help of a surgical clip.
- The cleaning of the biological growth with mechanical means using the wishab. There followed a slight dusting and then the direct intervention on the paint layer which proved resistant within the contact tests, removing most of the thick layer of microorganisms developed on the upper surfaces, marked by infiltration. The painting has a rather clean aspect, but white, because irregular salt efflorescence are still present.
- The mechanical cleaning was done with a soft eraser of the type Conté Golet. This operation was done very at-

Fig. 16. Non-adherent deposits on the surface of the painting, together with paint layer showing lack of cohesion

tentively, insisting on the more consistent accumulations, more adherent to the painting, permanently following the traces left by the eraser. Thus more of the not very adherent deposits were removed (**Fig. 16**).

CLEANING OF THE LAYER OF GOLD

The cleaning of the gilded elements (decoration of the vestments and halos) was done with compresses moistened in 10% solution of water-alcohol applied for 5 minutes. The gilded surface, very generous in the case of this church, still preserves only little of the original decoration, the gold being now lost on very big areas. Moreover, compresses moistened in 10% solution of water-alcohol were applied for 5 minutes, the area was then pressed with an elastic rubber roll and then cleaned with water. On the areas showing exfoliation of the gold layer, there was first applied an intermediary protective layer of Japanese paper of the type Bip Tengujo. After that the traces of dirt were cleaned with a wishab sponge. The traces of gold were consolidated and isolated using a 3% solution of Paraloid B72 in acetone. Later on, the cleaning was done with compresses impregnated in 10% solution of ammonium carbonate, in order to solubillize the very adherent and consisting deposits in the lacunae of the areas once coated with gold.

Fig. 17. Comparative aspects of the operation of cleaning of the paint layer. Details of the painting of the eastern wall, register with the *Holy Trinity*

The gold stars within the painting were cleaned directly with bastoncini on which a small cotton swab was rolled and impregnated in 10% water-alcohol solution. This operation consisted in a slight rolling on the surface of the painting, pressing at the same time and insisting until the black fouling is removed. The swab used and blackened was frequently changed, so to obtain a unitary cleaning, without traces left. The operation was repeated until the complete removal of the adherent fouling. There followed the same isolation with Paraloid B72. After the cleaning of the paint layer, the isolating sheet was removed with acetone and a cotton swab rolled on bastoncini.

- CLEANING OF THE PAINT LAYER

This operation is very complex and supposes a big responsibility from the restorer. In fact, the operation was two-fold: on the one hand the flaking areas were stuck back to the wall by a slight pressing on the paint layer, moistened before-hand with the cleaning solution and on the other hand the removal of the fouling accumulated on the paint layer. The impregnation was done on small surfaces (measures in square dm) with the help of a Japanese paper, through which the 10% ammonium carbonate solution was applied. In a first phase, the pressing was done with moistened cotton swabs and then with elastic means (eraser of the type Whishab low roughness) and from case to case with a soft rubber roll with the help of a plastic transparent sheet. Special measures was taken in the case of the backgrounds, as there might still be traces of azurite. Therefore, the 10% water-alcohol solvent was replaced so to prevent further damage to this very sensitive and valuable pigment.

The operation of cleaning of the adherent dirt, in itself, is carried out by applying in compresses of cellulose applied through Japanese paper, a 10% solution of ammonium carbonated with the exposure time of 5 minutes. After cleaning the traces of the moistened wishab, part of the adherent deposits were still there as they had not been solubilised and the painting therefore looked quite dirty and had an irregular aspect. In this situation, the operation was repeated several times, and after some intervals necessary to the paint layer to get dry, until the complete removal of the traces.

The efficient cleaning of the adherent deposits was done by combining physico-chemcial means with dry mechanical means, such as the wishabul and erasers of varied roughness, the soft ones being more common. Thus the painting has in the end a final clean and regular aspect (**Fig. 17**).

- CONSOLIDATION OF THE EXFOLIATED PAINT LAYER

After cleaning, on isolated areas the consolidation of the painting was carried out, with a 1,5% transparent dispersion of calcium casseinate, and the exfoliated layer of gold was fixed with 5% solution of Paraloid B72 in acetone.

The consolidation of the exfoliated paint layer was done by direct impregnation, obtained by brushing the solution, followed by the slight pressing of the detached areas, with the rubber roll with the help of a isolating polyethylene sheet. This intervention will be followed by the mineral treatment with barium hydroxide, in order to recreate the lost links among pigments.

- CLEANING AND TREATMENT OF THE SALT EFFLORESCENCE

The operation was carried out by applying through compresses of Japanese paper a 10% solution of ammonium carbonate. After the removal of the compress, there followed mechanical interventions with the surgical scalpel so to reduce the thickness of the efflorescence, but also with fiberglass sticks and erasers of various roughness, according to the consistence and resistance of the salts, and taking into account the state of preservation. The operations were repeated until the complete removal

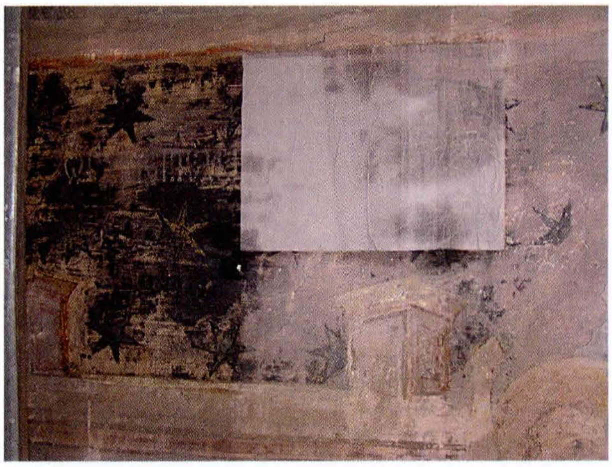


Fig. 18. Treatment of the crystallized salts on the murals

of the salts. The white veils, left by the soluble salts, were extracted by the application of compresses with distilled water and the very fine traces were mechanically removed with the soft eraser, after the painting got completely dry (**Fig. 18**).

- TREATAMENTS AGAINST THE BIOLOGICAL GROWTH.

The surface contaminated with biological growth was of about 90% of the whole. The infested area was treated before-hand with a 5% solution of Preventol as active substance, applied by spraying, in two phases. After the biocide, the organic traces were removed from the frescoes and so were the bodies of fructification of the biological agents, using dry mechanical means (whishab average) and also water moistened means. The preventive treatment was applied by brushing on the whole surface of the painting, after the completion of the operations of conservation of the paint layer (**Fig. 19a, b, c, d**).

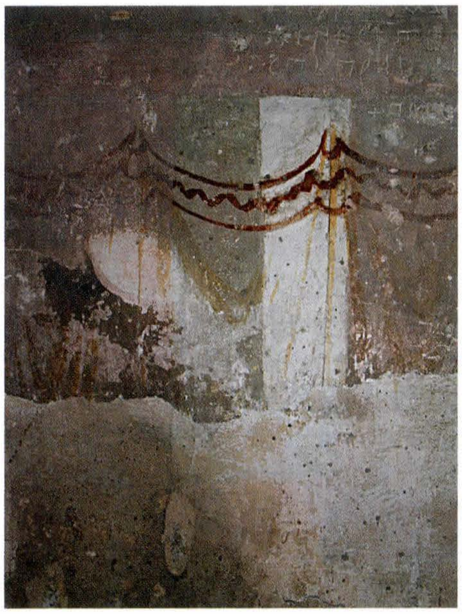


Fig. 19a,b,c,d. Carrying out biocide tests and treatments. Details from the lower area of the frescoes

- TREATMENT OF STONE ELEMENTS

The cleaning of the adherent fouling on the stone profile of the door to the nave was done according to the methodology used in the case of the mural painting that is by the application of 10% ammonium carbonate solution later on cleaned with water and a soft wishab sponge. The operation was repeated until the complete removal of the particles adherent to the stone.

The operation of recreating the structural cohesion was achieved by the impregnation of the surfaces showing lack of cohesion with a solution of Syton X 30, in low concentrations (3-5%) and repeating it at various time intervals, according to the degree of absorption, so to favour the in-depth penetration of the binding material. This operation was also applied on the masonry elements, and equally on the bricks which became friable due to the infiltrating water.

NOTES

[1] Sorin Ulea, *Gavril Ieromonahul, autorul frescelor de la Balinesti. Introducere la studiul picturii moldovene°ti din epoca lui Stefan cel Mare (Gabriel the Hieromonk, autor of the frescoes of Balinesti. Introduction to the study of Moldavian paintings of the time of Stephen the Great*), in vol. "Cultura moldoveneasca în timpul lui Stefan cel Mare (The Moldavian Culture during Stephen the Great's reign), Bucharest, 1964, pp 419-461.

[2] The carved stone inscription is situated on the south façade. It reads: "*With the will of the Father, the help of the Son, and the completion of the Holy Spirit, pan Ioan Tãutu, during the days of the well-honouring and lover of Christ Prince Stephen, started building a house on behalf of the one who is among the saints, archbishop and wonder-maker Nicholas and completed it in the year 7007 [1499] the month of December, the 6th*". To the right of the profiled frame, the stone inscription is completed by a signature: "*Dragota Tautulovici [Dragota of Tautul /son of Tautul*]".

[3] "*Studiul parametrilor climatici locali pentru stabilirea condiþiilor de restaurare si conservare a picturilor murale ale unor monumente istorice din Moldova*" (*Study of the Local Climate Parameters for Establishing the Mural Painting Restoration-Preservation Conditions of some Historical Monuments in Moldavia*). March 1970, Institute of Meteorology – Bucharest.

[4] Istudor I, Geanina Rosu, *Un fenomen de alterare a pigmentului rosu cinabru în pictura bisericii manastirii Sucevita (A Pigment-Alteration Phenomenon in the Case of the Cinnaber-Red of the Church of Sucevita Monastery*), National Session of Conservation-Restoration, the Museum of the Romanian Peasant, 15 -16 November 2001, published in the Bulletin of the Restoration-Conservation Centre of Iasi, no.3, 2004.

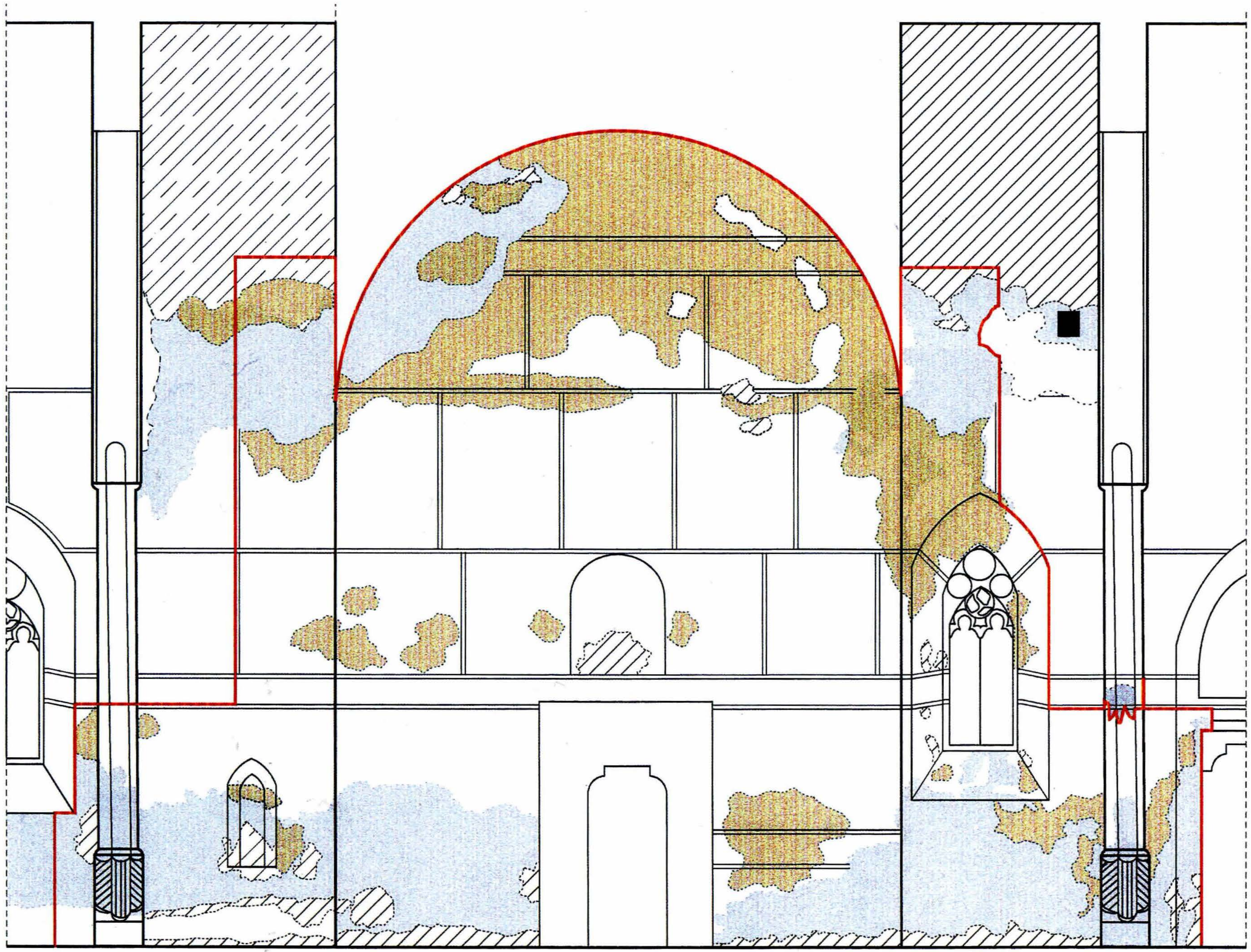
[5] Text elaborated by Carmen Cecilia Solomonea, restorer, responsible with the restoration of the murals in St Nicholas Church of Popãuþi Monastery – Botosani.

[6] Sorin Ulea, *op. cit.*

[7] Corina Popa, *Balinesti*, Bucharest, Meridiane Publishing House, 1981. p. 12.

Fig. 20a, b. Narthex, eastern wall. Before and after cleaning

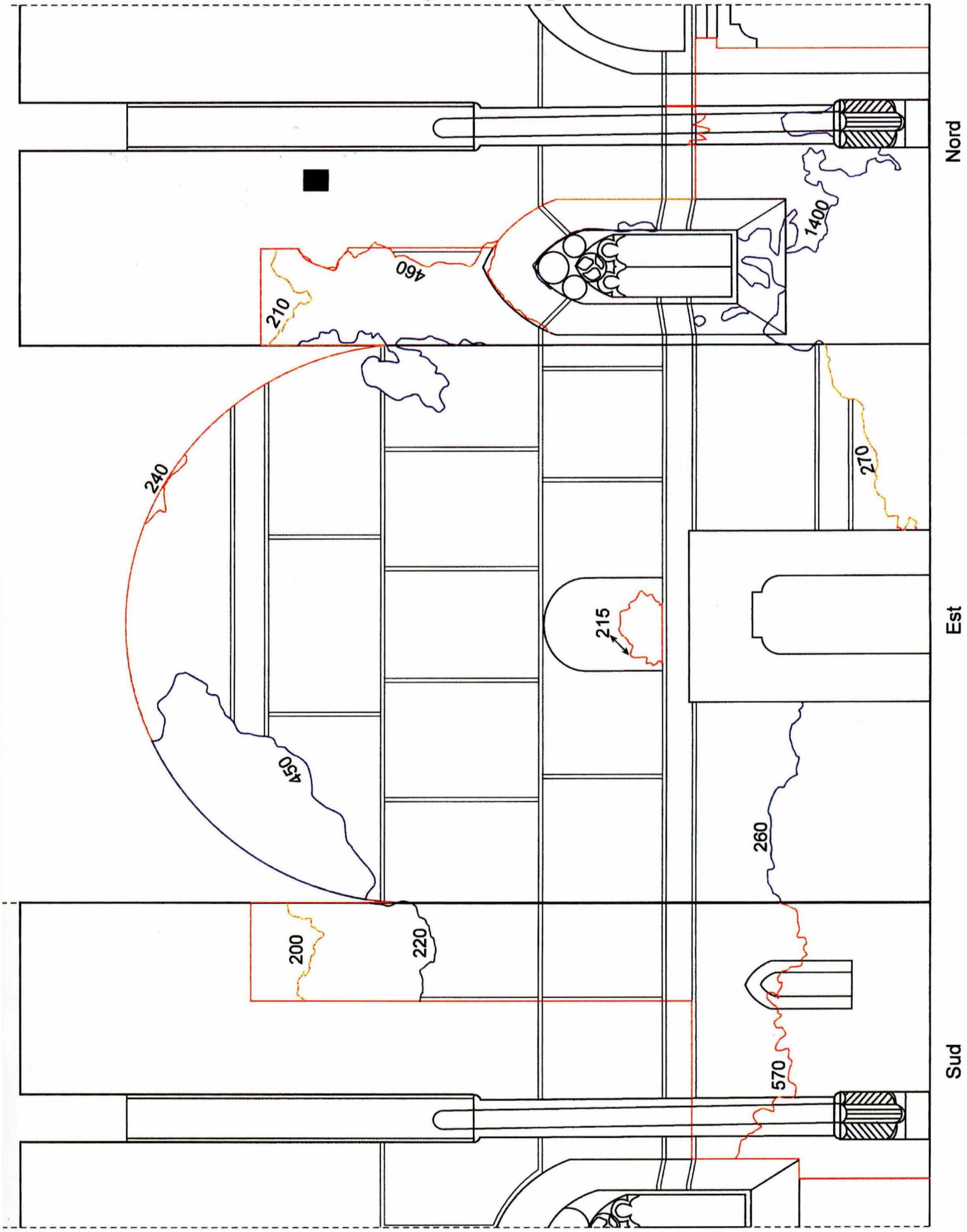
BALINESTI. ST NICHOLAS CHURCH
NARTHEX



Legendă

- Desprinderile picturii murale
- Zonă - operaţiuni efectuate
- Prima decoraţie
- Lacune profunde cu vizualizare de suport

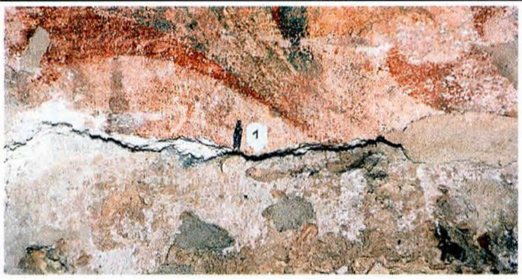
BALINESTI. ST NICHOLAS CHURCH
NARTHEX.
Fitting of the edges of the painted surfaces

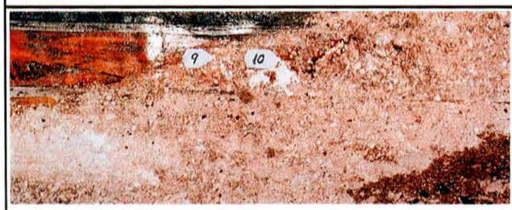
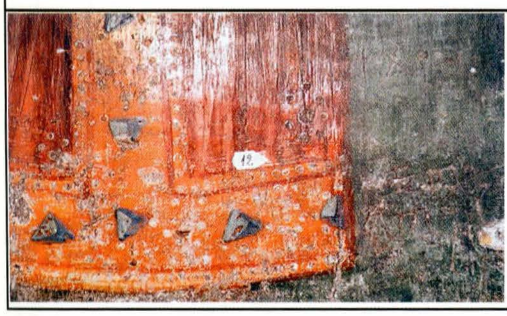


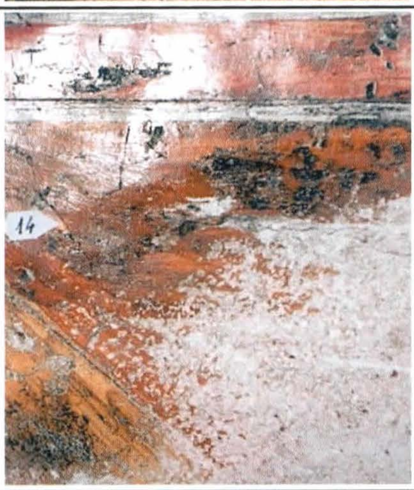
2.1. ST NICHOLAS CHURCH OF BĂLINEŞTI

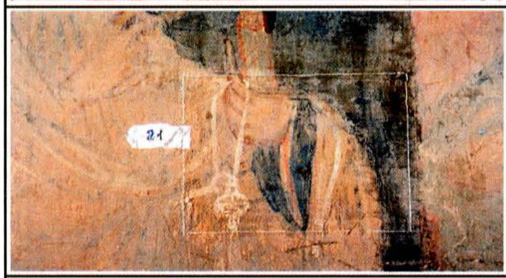
Bulletin no. 02 of 30.01. 2006

Analyzed edifice: Church of St Nicholas village of Bălineşti, com. Grămeşti, Suceava county
Aim of the analysis: Samples of the frescoes inside and outside the church
Sample taken by: Chemist engineer Ioan Istudor, expert restorer Oliviu Boldura and professional restorer Geanina Roşu
Chemical analyses carried out by: Chemist engineer Ioan Istudor

No. and image of the sample	Sampling location	Sampling area	Type of sample	Result of the analysis
	Nave, northern wall	drapery register	Masonry mortar specific to the a fresco painting; *intonaco*	Intonaco made of limewash mortar with traces of tows, powdering, 15 mm thick. Contains nitrates (NO2-) and sulfates, especially gypsum (CaSO4 • 2H2O). Due to the advanced rising damp on the drapery register, the mortar got dislocated and mostly fell off.
	Nave, northern wall	North-western pilaster	Intonaco mortar	Intonaco made of limewash mortar with a minimal addition of hemp towns, 2-3 mm thick. The mortar contains nitrates (NO3-).
	Nave, northern wall	Drapery register	Masonry mortar; *arriccio*	Mortar meant to level the surface of the walls ("arriccio"). It is made of limewash mortar with white, fin, siliceous sand, and a small amount of brick powder, 64% of the mortar is insoluble in hydrocloric alcohol, which means a relation between the binder and the material of about 1:2. The mortar is tough and resistant to humidity as a result of the high content of active silica. The mortar also contains nitrates
	Nave, western wall, to the north	St Procopie	Sample of blue background; *sky*	The blue was obtained with the pigment azurite [basic copper carbonate, $2CO_3 \cdot Cu(OH)_2$] applied on a background of *black charcoal* .

	Naos, western wall, to the north	Holy Emperors Constantine and Helen	Sample of green from the background of the *earth*	The green is obtained from the *earth green* [hydrosilicate complex of Fe, Al, Mg, K,) applied on a background of *black charcoal*. The paint layer included gypsum ($CaSO_4 \bullet 2H_2O$) and nitrates (NO_3^-).
	Nave, western wall, to the north	*Holy Emperors Constantine and Helen*	Sample of green from the background of the *earth* for the stratigraphic analysis	The sample contains a layer of earth green and a layer of charcoal black, applied on an intonaco made of limewash and tows.
	Nave, western wall, to the north	*Holy Emperors Constantine and Helen*	Sample of blue from the background of the *sky* for the stratigraphic analysis	The sample contains a layer of azurite blue and a layer of charcoal black, applied on an intonaco made of limewash and tows.
	Nave, western wall, to the north	*Holy Emperors Constantine and Helen*	Sample of red, from the vestments of *St Constantine*	The red colour contains the *cinnabar* pigment (mercury sulfur, HgS) and *red ochre* (clay pigmented with anhydrous iron oxide, Fe_2O_3). The layer of colour contains gypsum ($CaSO4 \bullet 2H2O$).
	Nave, western wall, to the north	*Holy Emperors Constantine and Helen*	Sample of red, from the stripe	The red colour made with the *cinnabar* pigment (mercury sulfur, HgS) and a little of *red ochre* (clay pigmented with anhydrous iron oxide, Fe_2O_3).
	Nave, western wall, to the north	*Holy Emperors Constantine and Helen*	Sample of red, from the stripe, for the stratigraphic analysis	The red colour made with the *cinnabar* pigment (mercury sulfur, HgS) and a little of *red ochre* (clay pigmented with anhydrous iron oxide, Fe_2O_3), 25µm thick, applied on an intonaco made of limewahs and tows.
	Nave, western wall, to the north	*Holy Emperors Constantine and Helen*	Sample of red, from the vestments of *St Helen*	The red colour made with the *cinnabar* pigment (mercury sulfur, HgS) and *red ochre* (clay pigmented with anhydrous iron oxide, Fe_2O_3)
	Nave, western wall, to the north	*Holy Emperors Constantine and Helen*	Sample of red, from the vestments of *St Constantine*	The red colour made with the *cinnabar* pigment (mercury sulfur, HgS) and *red ochre* (clay pigmented with anhydrous iron oxide, Fe_2O_3). The layer of colour contains gypsum

	Naos, western wall, to the north	Decorative geometric motive underneath *St Procopie*	Sample of yellow	Colour made with the *ochre* pigment (clay pigmented with hydrate iron oxide, $Fe_2O_3 \cdot xH_2O$).
	Nave, western wall, to the north	Decorative geometric motive underneath *St Procopie*	Sample of orange	Colour made with the *ochre* pigment (clay pigmented with hydrate iron oxide, $Fe_2O_3 \cdot xH_2O$), *red ochre* (clay pigmented with anhydrous iron oxide, Fe_2O_3) and a little bit of *cinnabar red* (hgS).
	Nave, western wall, to the north	*Holy Emperors Constantine and Helen*	Sample of the metallic layer from the Cross	Metallic layer made with *golden sheet*, partly eroded stuck with an ochre mixtion
	Nave, western wall, to the north	*St Eustatie*	Sample of green from the vestment	Colour obtained with the pigment *ochre earth green* (hydro-silicate complex of Fe, Al, Mg, K).
	Nave, western wall, to the north	*Holy Emperors Constantine and Helen*	Pearls on the vestment of *St Helen*	Pearls with the diameter of 3 mm made of *limewash* (at present carbonated) and a protein binder
	Nave, western wall, to the north	*Votive painting , Archanghel*	Mortar for the preparation of the halo in relief	Halo in relief made of *limewash mortar with tows.*

	Narthex, northern wall	Lower area affected by biological growth.	Thick layer of salt efflorescence.	The efflorescence contains nitrates (NO_3^-) and little calcium carbonate included mechanically in the intonaco.
	Narthex, western wall	Register of the *Holy Women*	Sample of blue from the background of the *sky*.	The blue was obtained with the pigment azurite [basic copper carbonate, $2CO_3 \bullet Cu(OH)_2$]
	Narthex,, eastern wall, to the norht.	*Apostle Peter*	Efflorescence on the vestment.	The efflorescence contain a big amount of *gypsum* ($CaSO_4 \bullet 2H_2O$), *nitraţ* i (NO_3^-) and dust.
	Narthex, southern wall.	Area situated to the west of the door of the church	Masonry mortar d; *arriccio*	Masonry mortar made of limewash with fine, siliceous sand and brick powder. The relation between the binder and the material is 1 : 2.
	Narthex, southern wall.	The study area is situated to the west of the door of the church	Red-brown hue	The colour was obtained from *red ochre* (clay pigmented with anhydrous iron oxide, Fe_2O_3), *wooden charcoal black* and a small amount of *limewash* as a binder.
	Narthex,, southern wall.	The study area is situated to the west of the door of the church	Sample of the red colour taken from the decorative painted rows of fake brick.	The colour was obtained from *red ochre* (clay pigmented with anhydrous iron oxide, Fe_2O_3), and a small amount of *limewash* as a binder.
	Narthex, southern wall.	The study area is situated to the west of the door of the church	Sample of gray colour taken from the decorative painted rows of fake brick.	The colour was obtained with *wooden charcoal black* and a small amount of *limewash* as a binder.
	Narthex, southern wall.	The study area is situated to the west of the door of the church	Sample of white colour taken from the decorative painted rows of fake brick.	This colour was obtained using *limewash.*

	Narthex, northern wall	*St Catherine*	Sample of the over-painting taken from the portrait	The colours used in the over-painting contain the red ochre pigment and a small amount of yellow ochre pigment applied on top of a light gray layer.
	Narthex, southern wall.	The study area is situated to the west of the door of the church	Structure consolidation material leaked on the wall.	The analyzed material was obtained from *cement*.
	Narthex, south-western wall.	Lacuna in the support layer.	Material for filling the lacuna	The lacuna was filled in with mortar made of limewash and sand.
	Narthex, eastern wall, to the south	Drapery register	Intonaco mortar	Intonaco made of limewash mortar and a small amount of tows, 5 mm thick. The mortar contains nitrates (NO_3^-).
	Narthex, southern wall to the west	Register of the *Holy Women*, the decoration with blind arcades	Black colour	The black colour was obtained from wooden charcoal black.
	Narthex, southern wall.	Register of the *Holy Women*, the decoration with blind arcades	Gray colour	The colour was obtained from wooden charcoal black and limewash.
	Nave, southern wall to the east	Register of the *Military Saints*	Sample of brown taken from the vestment	The colour was obtained from dark red brown (ochre red with a high content manganese dioxide).

Bulletin of analysis

no. 01 of 06.02.2006

Analyzed edifice: St Nicholas Church village of Bălineşti, com. Grămeşti, county

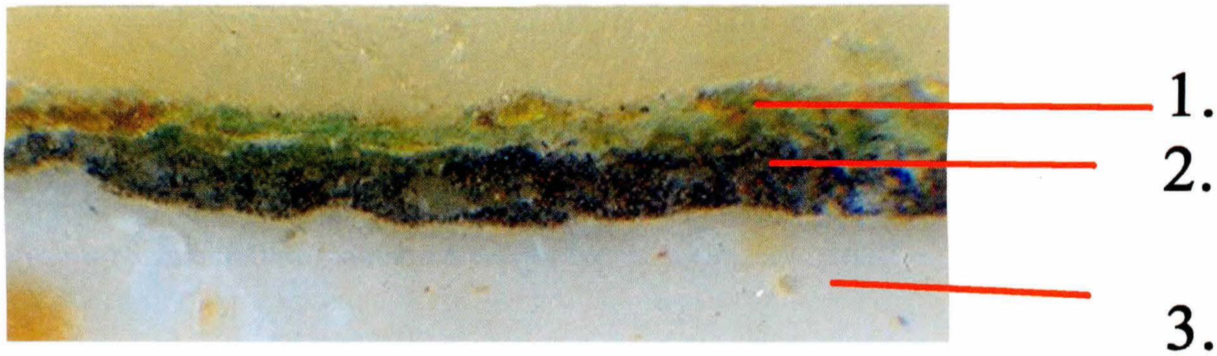
Place of sampling Nave, western wall, scene "*Holy Emperors Constantine and Helen*"

Aim of the analysis: **Sample no. 6** green colour of the background representing the earth, for stratigraphic analysis

Sample taken by: Chemist engineer Ioan Istudor, expert restorer Oliviu Boldura and professional restorer Geanina Roşu

Chemical analyses carried out by: Chemist engineer Ioan Istudor

Result of the stratigraphic analysis:
Section no. 492; grossissement 135 x.



No.	Stratigraphy	Result of the analysis
1	Green colour, 35 μm	Earth green
2	Black colour, 65 μm	Wooden charcoal black
3	intonaco	Limewash with tows

Bulletin of analysis
no. 02 of 06.02.2006

Analyzed edifice: St Nicholas Church village of Bălineşti, com. Grămeşti, county Suceava

Place of sampling Nave, western wall, scene "*Holy Emperors Constantine and Helen*"

Aim of the analysis: **Sample no. 7** blue colour of the background representing the sky, for stratigraphic analysis

Sample taken by: Chemist engineer Ioan Istudor, expert restorer Oliviu Boldura and professional restorer Geanina Roşu

Chemical analyses carried out by: Chemist engineer Ioan Istudor

Result of the stratigraphic analysis:
Section no. 494; grossissement 135 x.

No.	Stratigraphy	Result of the analysis
1	Blue colour, 90 µm	azurite
2	Black colour, 40 µm	Wooden charcoal black
3	intonaco	Limewash with tows

Bulletin of analysis

no.03 of 06.02.2006

Analyzed edifice: St Nicholas Church village of Bălineşti, com. Grămeşti, county

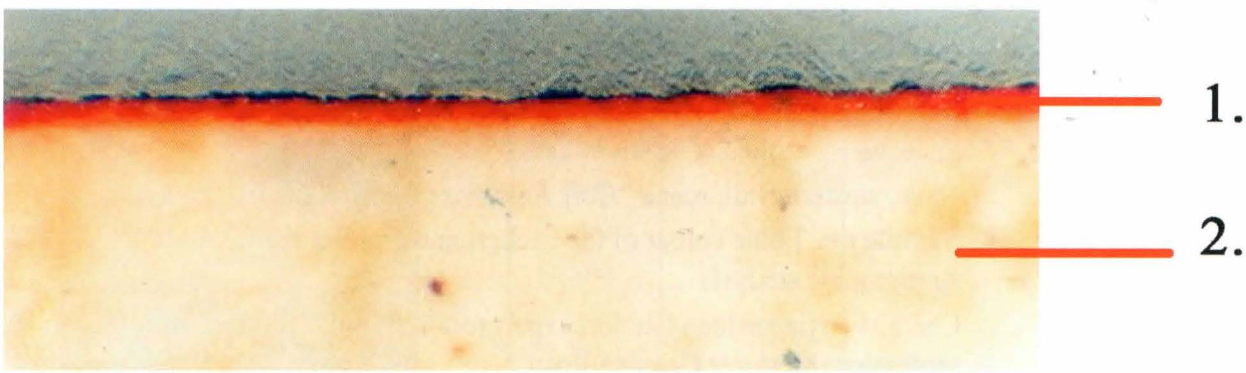
Place of sampling Nave, western wall, scene "*Holy Emperors Constantine and Helen*"

Aim of the analysis: **Sample no. 10** red colour sampled from the separating stripe, for stratigraphic analysis

Sample taken by: Chemist engineer Ioan Istudor, expert restorer Oliviu Boldura and professional restorer Geanina Roşu

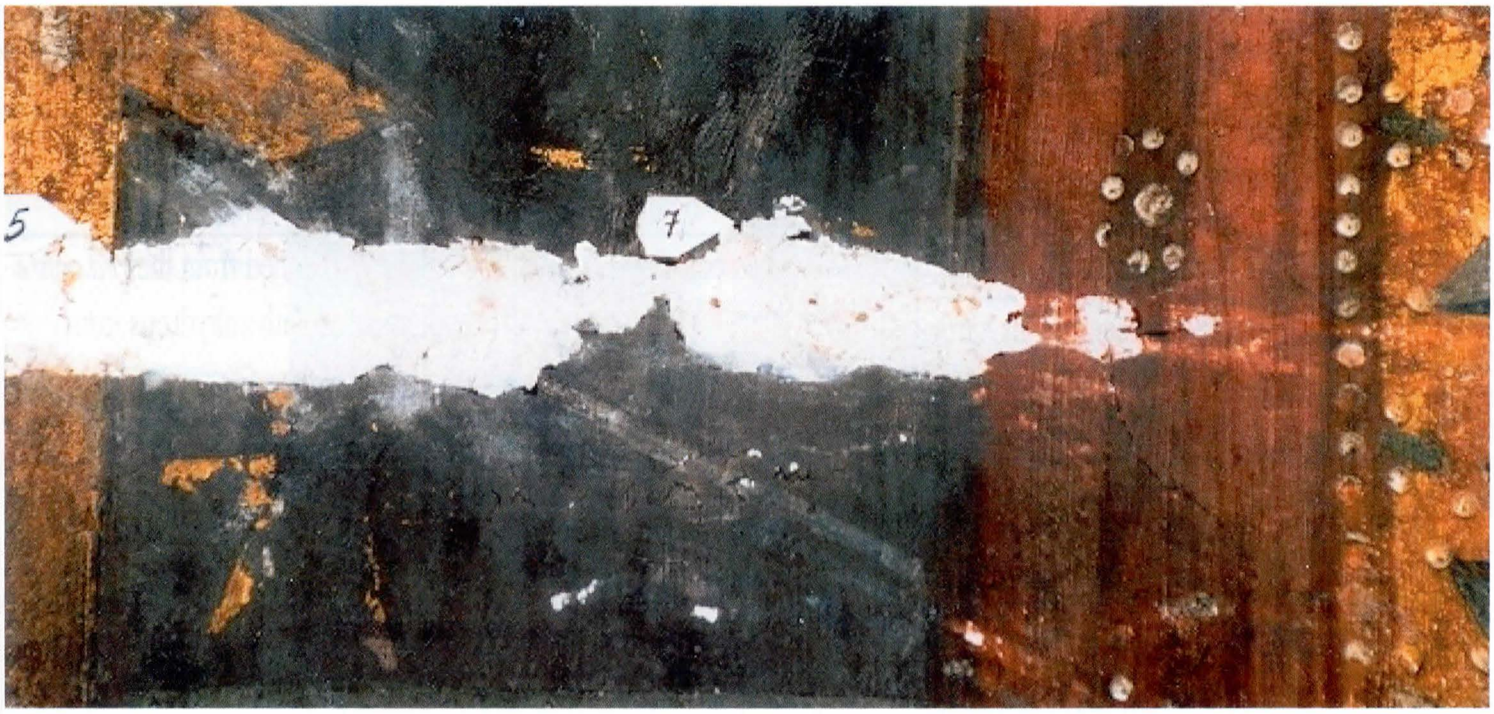
Chemical analyses carried out by: Chemist engineer Ioan Istudor

Result of the stratigraphic analysis:
Section no 495; grossissement 90 x.



No.	Stratigraphy	Result of the analysis
1	Red colour, 25 µm	cinnabar
2	intonaco	Limewash with tows

Location of the stratigraphic samples

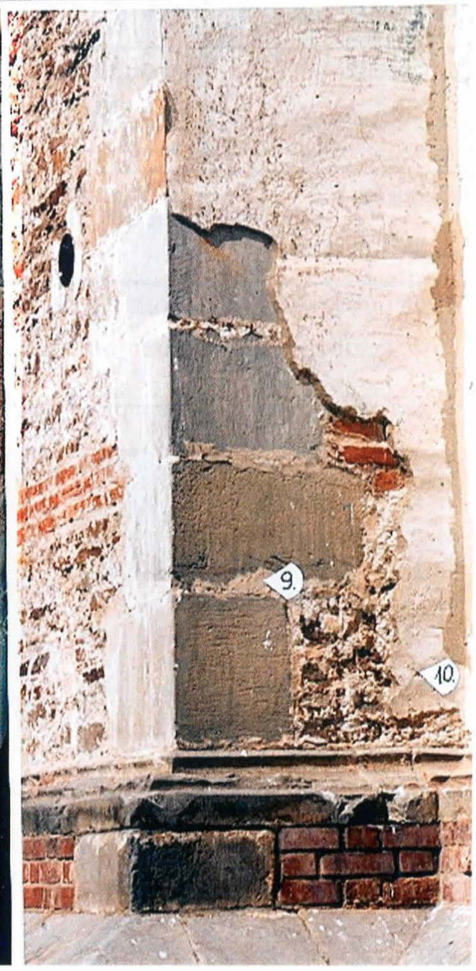


No. of the sample	Sampling location	Sampling area	Type of sample	Result of the analysis
1.	SE pillar	Arch with medallions (E) (rows of fake bricks)	1st intonaco mortar	intonaco made of limewash mortar
2.	SE pillar	Arch with medallions (E)	2nd intonaco mortar	intonaco made of limewash mortar with tows; the surface is covered by a layer of *red ochre*
3.	SE pillar	Arch with medallions (E)	Blue colour	The colour is obtained from the *azurite* pigment [basic copper carbonate, $2CuCO_3 \bullet Cu(OH)_2$]
4.	SE pillar	Arch with medallions (E)	Green colour	The colour is obtained from the *earth green* pigment (hydro-silicate complex of Fe, Al, Mg, K)
5.	SE pillar	Arch with medallions (E)	Colour yellow- ochre	The colour is obtained from the *ochre* pigment (clay pigmented with hydrated iron oxide, $Fe_2O_3 \bullet xH_2O$)
6.	SE pillar	Arch with medallions (E) (area representing the earth)	Red colour	The colour is obtained from the *red ochre* (clay pigmented with anhydrous iron oxide, Fe_2O_3)
7.	SE pillar	Arch wiht medallions (E) (rows of fake bricks)	Red colour	The colour is obtained from the *red ochre* (clay pigmented with anhydrous iron oxide, Fe_2O_3)
8.	SE pillar	Medallions *Holy Women*	Colour red - brown	The colour is obtained from the following pigments: *red ochre, wooden charcoal black and limewash* as a binder
9.	East apse, to the south	first decoration	mortar underneath the paint layer (1st intonaco)	limewash mortar slightly coloured with ochre, compact and very tough
10.	East apse, to the south	Second decoration	2nd intonaco mortar	intonaco made of limewash mortar with traces of tows and various small materials

CONCLUSIONS

The chemical analyses carried out on the murals of the St Nicholas Church of Balinesti, lead to the following conclusions:
The first mortar applied on the interior walls, meant to level the surface of the walls (arriccio), was made of limewash mortar with fine siliceous sand and a small amount of brick powder and it is very tough. On top of this, a painted decoration was carried out. It imitates rows of bricks and was done using the colours red, red-brown, grey and white. The same fake brick decoration is also found on the exterior walls of the church. After a while, this decoration was hammered in order to apply the specific mortar (intonaco) necessary to the application of the fresco painting. This new mortar consists in limewash mortar with tows and it is 10 - 15 mm thick.
The presence of joining areas at the level of the mortar, according to the painting registers (pontate), but also the identification of the incised drawings, of the traces of polishing of the mortar, and of the pigments resistant to limewash alkalinity demonstrate that the painting was applied in the al fresco technique on the fresh mortar. The pigments used for the frescoes were: ochre, red ochre, cinnabar red, azurite blue, earth green, wooden charcoal black, limewash white, brown ochre and gold ink.
Important areas of painting in the naos and pronaos show efflorescence of gypsum and nitrates.

OUTSIDE PAININGS-SAMPLE PLACES



2.3. THE CHURCH OF SUCEVIȚA MONASTERY

Number and date of the bulletin: Bulletin of chemical analyses No. 06 of 13.03. 2006

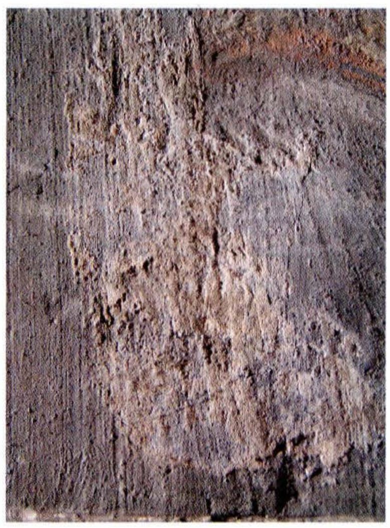
Analyzed edifice: The church of Sucevita Monastery, Suceava county
Aim of the analysis: Samples of the frescoes inside and outside the church

Sample taken by: Chemist engineer Ioan Istudor and professional restorer Geanina Roşu
Chemical analyses carried out by: Chemist engineer Ioan Istudor

SAMPLES TAKEN IN THE pronaos

No. of the sample	Sampling location	Sampling area	Type of sample	Result of the analysis
1	Southern wall	Background of the sky	blue pigment	Enamel blue (cobalt silicate, potassium and aluminum) applied on the layer of black wooden charcoal
2	Northern wall	Scene "St George in the Prison", background	blue pigment	Enamel blue (cobalt silicate, potassium and aluminum) applied on the layer of black wooden charcoal
3	Southern wall	Decorative motive	green pigment	"green earth" pigment (hydro-silicate of Fe, Mg, Al, K) applied on the layer of black wooden charcoal
4	Southern wall	Scene with a ship (on the pillar), background	green pigment	"green earth" pigment (hydro-silicate of Fe, Mg, Al, K) applied on the layer of black wooden charcoal
5	Southern wall	Scene with a ship (on the pillar), stripes	red pigment	"red ochre" pigment (clay pigmented with anhydrous iron oxide)
6	Southern wall	"St Nicholas" scene, decorative	red pigment	cinnabar red pigment (mercury sulfur, HgS)
7	Southern wall	Vegetal motives on the western pilaster l de vest	red pigment	cinnabar red pigment (mercury sulfur, HgS)
8	Southern wall	Drapery	Black pigment	black charcoal pigment



No. of the sample	Sampling location	Sampling area	Type of sample	Result of the analysis
1	South apse	Background of the "earth"	green pigment	"green earth" pigment (hydro-silicate of Fe, Mg, Al, K)
2	South apse	geometric decorative motive	green pigment	"green earth" pigment (hydro-silicate of Fe, Mg, Al, K)
3	Western wall	Near the door, background	green pigment	"green earth" pigment (hydro-silicate of Fe, Mg, Al, K)
4	Western wall	Vestments of the angel	green pigment	"green earth" pigment (hydro-silicate of Fe, Mg, AL K)
5	Western wall	Near the door, stripes	red pigment	cinnabar red pigment (mercury sulfur, HgS)
6	Western wall	geometric motive	red pigment	"red ochre" pigment (clay pigmented with anhydrous iron oxide)
7	Western wall	Votive painting with Gheorghe Movilă, vestment	red pigment	cinnabar red pigment (mercury sulfur, HgS)
8	Western wall	vestment, saint on the vault above the door	Yellow pigment	yellow "ochre" pigment (clay pigmented with hydrated iron oxide)
9	South apse	By the window	Intonaco mortar	intonaco made of limewash mortar and tows, 5 mm thick

SAMPLES TAKEN IN THE TOWER OF THE NAOS

No. of the sample	Sampling location	Sampling area	Type of sample	Result of the analysis
1	Register 1	vestment prophet Solomon	red pigment	cinnabar red pigment (HgS) cinnabar red pigment superficially altered into black (meta-cinnabar)
2	Register 1	prophet Solomon, star on the background symbolizing the sky	Layer of metallic yellow on a black background	Golden sheet applied on a red oily mixion, made of lead minium (Pb_3O_4) and red ochre (clay pigmented with anhydrous iron oxide)
3	Register 1	prophet Solomon, halo	Layer of metallic yellow	Golden sheet applied on a red oily mixion, made of lead minium (Pb_3O_4) and red ochre (clay pigmented with anhydrous iron oxide)
4	Register 2	Painting of an angel, background	green pigment	green pigment malachite [$CuCO_3.Cu(OH)_2$] applied on a black wooden charcoal background

5	Register 3	prophet Jeremiah, vestment	green pigment	Artificial copper green pigment (basic copper acetate)
6	Register 3	prophet Jeremiah, vestment	green pigment	"green earth" pigment (hydro-silicate of Fe, Mg, Al, K) applied on an ochre colour
7	Register 3	prophet Avacum, background symbolizing the sky	blue pigment	Enamel blue (cobalt silicate, potassium and aluminum) applied on the layer of black wooden charcoal
8	Register 3	prophet Zachariah, stripe	red pigment	cinnabar red pigment (HgS) superficially altered into black (meta-cinnabar)
9	Register 3	prophet Zachariah, vestment	Brown pigment	pigment made of red ochre and wooden charcoal black
10	Register 3	prophet Zachariah, light hues of the vestment	White pigment	Pigment made of limewash white ($CaCO_2$)
11	Register 2	Scene with angel, background symbolizing the "earth"	red pigment	Colour made with red ochre pigment (clay pigmented with anhydrous iron oxide)
12	Register 2	Apostle Peter, vestment	red pigment	Colour made with red ochre pigment (clay pigmented with anhydrous iron oxide)
13	Register 1	prophet Solomon	efflorescence on blue background	The efflorescence contains sulfates (gips, $CaSO_4 \cdot 2H_2O$) and nitrates (NO_3") on a background made of enamel blue.
14	Register 2	Scene with angel, stripe	red pigment	cinnabar red pigment (HgS) alterat superficial în negru (metacinabru)
15	Register 2	Seraphs	efflorescence on blue background	efflorescence on enamel blue background containing nitrates (NO_3") 1000 mg/100 g efl. Sulfates (SO_4^{2}') 3000 mg/100 g efl. Chlorures (CI") 100 mg/100 g efl.
16	Register 1	Cherubs by Evangelist Mark	efflorescence	efflorescence containing nitrates (NO_3) 660 mg/100 g. efl. Sulfates (SO_4^{2}") 2660 mg/100 g. efl Chlorures (CI) are absent
17	Register 1	cherubs, background	green pigment	artificial copper green on a background painted with black charcoal

SAMPLES TAKEN IN THE CHANCEL

No. of the sample	Sampling location	Sampling area	Type of sample	Result of the analysis
1	Southern wall	Painting "St. Evghenie", background of the "earth"	green pigment	"green earth" pigment (hydro-silicate of Fe_5 Mg, Al, K) applied on a layer of black charcoal

No. of the sample	Sampling location	Sampling area	Type of sample	Result of the analysis
1	Western wall	scene "Joachim the Righteous", background of the "earth"	green pigment	"green earth" pigment (hydro-silicate of Fe, Mg, Al, K) applied on a layer of black charcoal
2	Western wall	scene "Joachim the Righteous", decorative motive	green pigment	"green earth" pigment (hydro-silicate of Fe, Mg, Al, K) applied on a layer of wooden charcoal black
3	Western wall	scene "Joachim the Righteous",, vestment	red pigment	Cinnabar red pigment (mercury sulfur, HgS)
4	Western wall	scene "Joachim the Righteous", stripes	red pigment	cinnabar red pigment (mercury sulfur, HgS)
5	Western wall	scene "Joachim the Righteous", vestment	Brown colour	Colour made of ochre (clay pigmented with hydrated iron oxide), red ochre (clay pigmented with anhydrous iron oxide) and wooden charcoal black

SAMPLES TAKEN IN THE EXONARTEX

No. of the sample	Sampling location	Sampling area	Type of sample	Result of the analysis
1	Western wall	drapery	intonaco	intonaco made of limwash mortar with tows.
2	Eastern wall	drapery	green pigment	"green earth" pigment (hydro-silicate of Fe, Mg, Al, K) applied on a layer of wooden charcoal black
3	Eastern wall, to the south	scene "Last Judgment", background	green pigment	"green earth" pigment (hydro-silicate of Fe, Mg, Al, K) applied on a layer of wooden charcoal black
4	Eastern wall, to the south	scene "Last Judgment", the fire of hell	red pigment	red ochre (clay pigmented with anhydrous iron oxide) applied on a layer of wooden charcoal black

SAMPLES TAKEN IN THE SOUTHERN PORCH

No. of the sample	Sampling location	Sampling area	Type of sample	Result of the analysis
1	South-western pillar	Apocalypse, northern wall, background of the « sky »	blue pigment	Enamel blue pigment (cobalt, potassium and aluminum silicate) applied on a layer of wooden charcoal black

2	South-western pillar	Apocalypse, northern wall, apocalyptic animal	red pigment	red ochre (clay pigmented with anhydrous iron oxide)
3	South-western pillar	Scene of the Apocalypse, northern wall, angel wings	Brown colour	Colour obtained from the red ochre pigment and the wooden charcoal black
4	South-western pillar	Scene of the Apocalypse, northern wall, background of the « earth »	green pigment	"green earth" pigment (hydro-silicate of Fe, Mg, Al, K) applied on a layer of wooden charcoal black
5	South-western pillar	Apocalypse, northern wall, stripe	red pigment	cinnabar red pigment (mercury sulfur, HgS)
6	South-western pillar	Apocalypse, northern wall, moon	Yellow pigment	ochre (clay pigmented with hydrated iron oxide)
7	South-western pillar	Apocalypse, northern wall, wings of an apocalyptic animal	green pigment	"green earth" pigment (hydro-silicate of Fe, Mg, Al, K) applied on a layer of red ochre

LOCATION OF SAMPLING
IN THE SOUTHERN PORCH

The microbiological analyses were excerpted from the Testing Report of the Biology Laboratory of S.C. ICPE-CA S.A Bucharest, prepared in 2002. They were prepared in order to establish an adequate biocide protection and are part of the ongoing restoration activities. The isolation and identification of the existing microflora on the samples collected from the plinth, the exterior masonry and the interior frescoes of the church of St Nicholas in Balinesti were carried out by a team of restorers together with the researchers of the above laboratory. The sampling on the field was done by CERECS ART, whose representatives also took photos of the in situ aspect of the concerned areas.
The samples were processed at ICPE-CA, where the following operations were carried out: thermostat treatment, cultivation on various culture environments, isolation and identification of the microflora, determining the microscopic aspects, taking photos of the colonies of microscopic fungi in Petri pots, with the help of CERECS ART.

The samples were taken on the exterior walls of the church, in the area of the plinths of northern and southern façades, at the levels of the stone, mortar and brick, but also from the interior walls of this historical monument which is the Church of Balinesti, Suceava county.
The samples were taken as it follows: 4 samples on the western façade, plinth, 3 samples on the northern façade, plinth and masonry and 8 samples inside the church, marked as 1B, 2B, 3B, 4B, 5B, 6B, 7B, 8B in the following rooms and areas of the church:

- Narthex eastern wall, register with scenes of the *Life of St Nicholas* – sample 7B
- Narthex, western wall, register of the *Ecumenical Councils*, under the staircase (to the north)- sample 8B
- Nave, western wall, register of the *Passion*, above the *Votive painting* - sample 1B
- Nave, western wall, register of the drapery, zone of rising damp - sample 2B
- Nave, southern wall, scene of *Peter's Denial* - sample 3B
- Nave, western wall to the north, register of the *Passion* – sample 4B
- Nave, western wall to the north, register of the drapery – sample 5B
- Chancel, register of the drapery, to the north - sample 6B

The works took place in three main phases:

- collection, macroscopic observation and direct isolation of the samples in situ;
- laboratory processing of the samples;
- biocide tests in situ, and monitoring the efficiency in time of the treatment

MACROSCOPIC OBSERVATIONS CONCERNING THE DEGREE OF COVERING WITH MICROFLORA AND LABORATORY OPERATIONS

The direct isolations were done in small bottles for penicillin with a cork and a needle, so to capture a fertile environment, obtained from agar-turned potato. Lichens were collected in small boxes with covers, each with its own number.
The selected samples were processed as it follows:
The small bottles with the potato environment, used for the direct isolation of the microflora (microscopic bacteria and fungi) were placed as such in the thermostat, at the temperature of 30°C ± 2°C and RH of about 90%- 100%, to stimulate their growth and development. To asset the condition of the lichens, the aspect of the collected samples was correlated with the aspect in situ, as shown in photographs of the sampling areas.
To carry out the laboratory operations, the following beforehand steps were necessary:
-sterilization of the glass items: test tubes, Petri pots, etc.
-preparation of the three culture environments, potato, malt and Czapek in Erlenmeyer pots, pouring in test tubes and Petri pots, humid sterilization of the test tubes and Erlenmeyer pots in the autoclave; after a 5-7 day-incubation period in the thermostat, in conditions favorable to the growth and development of microscopic fungi, isolations were done on the potato environment in the small bottles by successive re-picking samples and placing them in test tubes containing a potato environment, in view of their purification.
Also, starting with the 5th day of incubation, the cultures were daily or every other day observed, macroscopic observations being done with the eye and the magnifying glass, with regards to the aspect and colour of the culture as well as with regards to the growing speed in the three culture environments, the back of the colony and its colour, the possible presence of an exopigment in the culture environment.
Cultures were also analyzed by microscopic observations at the stereomicroscope (with the magnifying power of x 50), and in order to identify some of the isolated species microscopic preparations were done. In order to take photographs of the colonies of pure microscopic fungi, these were cultivated in Petri pots, on a potato environment or in a Czapek environment, pending on the species.

Biocide tests done with Sintosept QR15, 4% active substance

MICROFLORA PRESENT ON THE SAMPLES TAKES FROM THE INTERIOR FRESCOES

Code of the sample	*Sampling location*	*" in situ " aspect and colour*	*aspect and colour of the colonies on the environment*	*Isolated and/or identified species of culture*
1B	Nave, western wall, to the south, register of the Passion, above the votive painting	White veil, humid, and soft when touching	- negative	- negative
2B	Nave, western wall, to the south, register of the drapery, area of rising damp	White area, slightly pink	- milky white colony	- un tip de bacterie
			- grey – light green colony with a yellow-orange back	- *Aspergillus sp.2.*
			- grey – dark blue colony with white margins	-*Aspergillus sp.3.*
			- white colony with a skin-like puffy grey back	- *Aspergillus sp.4* *Altemaria sp.*
3B	Nave, southern wall, scene of Peter's Denial	White veil, soft when touching	-White-ochre colony	- a type of bacteria
			- White colony	- a species of *Actinomycete*
			Yellow – ochre colony with a cyclamen back	- *Aspergillus sp. 1* (possibly *Aspergillus ochraceus)*
			-olive colony with a yellow pack	- *Penicillum sp.1*
			- blue-green colony with white margins and slighntly coloured back	- *Penicillum sp.2.*
			- blue-green colony with pink-cyclamen exo pigment	- *Penicillum chrysogenum*
			-colony oliv	- *Cladosporium herbamm*

4B	Nave, western wall, to the north, register of the *Passion*	White soft veil	- milky white colony	- *Actinomycete*
			- dark grey colony with a puffy aspect and black back	- *Hyphomycete,* possibly *Altemaria*
			- light green colony	- *Aspergillus flavus*
5B	Nave, western wall, to the north, register of the drapery	Area pink-brown, soft when touching	- whitish colony	- a species of bacteria
6B	Chancel, register of the drapery, to the north	Area pink-brown, soft when touching	- whitish colony	-a species of bacteria
			- green-yellowish colony	- *Aspergillus flavus*
			- blue-green colony with white margins and coloured back	- *Penicillium sp.2*
			- olive colony with a yellow back	- *Penicillium sp.l*
			- blue-green colony with a pink-cyclamen back	-*Penicillium chrysogenurn*
			- yellow-green colony, Filament of orange reddish hyphae	-*Penicillium sp.3* - a non-identified parasite species
7B	Narthex, eastern wall, 2nd register from down, with scenes of the Life of St Nicholas	White area, drier when touching	Initially big colony with dusty grey beige aspect , with a skin-like brown-black back	*Altemaria alternata*
8B	Narthex, western wall, under the stair to the north, register of the Ecumenical Councils	White area, dry veil	- big colony, white and puffy on the margins, and beige gray in the midlle, with a skin-like brown-black back	- *Altemaria*
			- olive colony	- *Cladosporium kerbarurn*

Species of VERRUCARIA

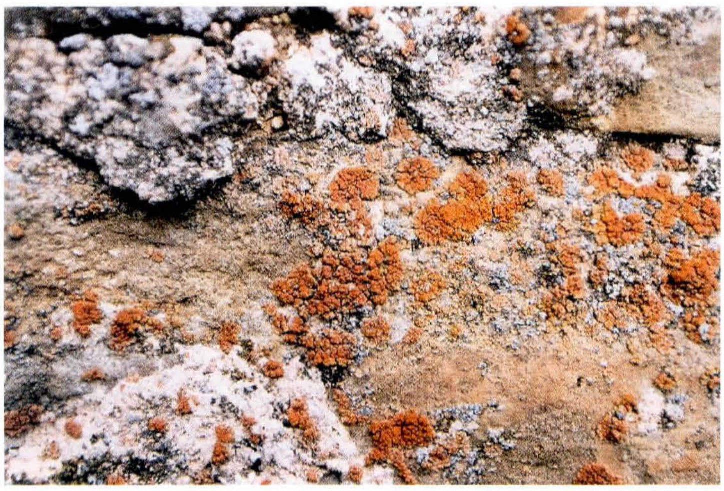
Species of LECANORA ATRA

No. of the sample	*Sampling location*	*Macroscopic aspect*	*Identified species*
1.	Plinth, west façade	Dark black lichens, of small dimensions	*Verrucaria sp.*
2	Plinth, west façade	Grey-bluish aspect on the exterior and green to the interior, of small dimensions	*Lecanora sp.*
3.	Plinth, west façade	Ochre aspect with green margins and orange centre, of big dimensions	*Xanthoria panetina*
4	Plinth, west façade	Lichens of grey-brown aspect with black bodies of fructification	*Lecanora atra.*
5.	Plinth, north façade	Flower petal-like lichens, 2 types: white-grey, grey-green	*Parmelia sp.* *Physcia sp.*
6.	Wall, north façade	Lichens with black-brown aspect, powder	*Rhizocarpon sp.*
7.	Wall, north façade	Small lichens, with white-grey-bluish aspect with dark cold grey bodies of fructification	*Lecanora sp.*

VARIOUS SPECIES OF LICHENS GROWN ON THE PLINTH OF THE CHURCH

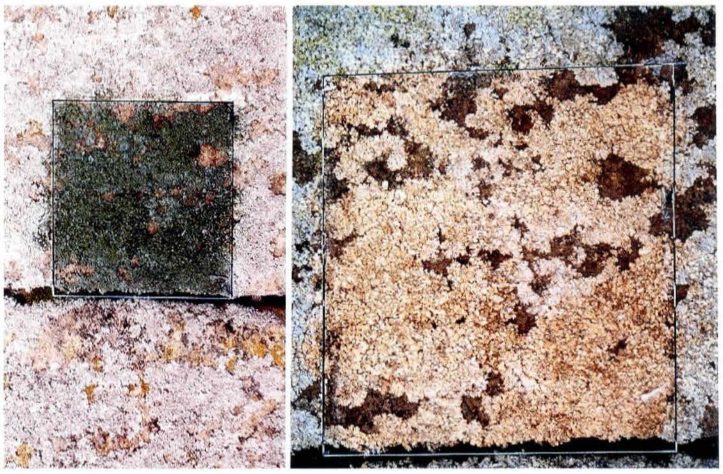
Species of PHYSCIA

Species of PARMELIA



Species of XANTHORIA PARIETINA

BIOCIDE TESTS ON THE EXTERIOR STONE SOCLE



BIOCIDE TESTS CARRIED OUT ON THE EXTERIOR SURFACES, ON THE STONE PLINTH OBTAINED RESULTS

The species isolated from the samples taken of the interior frescoes, the sampling location, the aspect and colour of the colonies in the culture environment, as well as other remarks are synthesized in grid no. 1. The species isolated from the samples taken of the exterior surfaces, from the plinth and masonry, the sampling location, the aspect, colour and other macroscopic remarks are synthesized in grid no. 2. There were isolated 7 species of lichens out of which only 5 were identified. In the case of the foliose lichens (Parmelia and Xanthoria parietina, for instance, their rhizoids (roots) form a compact but superficial cover, without penetrating inside the stone. Crusty lichens (Lecanora atra, Verrucaria s. a.) are almost an integral part of the stone. They use the existing fractures in the material or even cause new fissures by the production of organic acids. In this latter case, the biocide treatment is more difficult (Orial, G, 1988). The microbiological analysis of the samples in grid no. 1 indicates the following:

- 14 species of microscopic fungi were isolated out of which 11 were identified, as it follows: five species of Aspergillus and among them mention should be made of Aspergillus ochraceus and Aspergillus flavus; four species of Penicillium, and among them Penicillum chrysogenum; Alternaria alternata and Cladosporium herbarum. Four types of bacteria and two species of Actinomycete were also identified.
- The most investigated areas were: naos, western wall, to the south, register of the drapery; naos, southern wall, and the chancel, register of the drapery, to the north.
- The areas coloured in brown pink in the naos and chancel are also due to the species of fungi with the back coloured in yellow or cyclamen or with the cyclamen pink exopigment: Aspergillus sp. 1 and 2; Penicillium sp. 1 and 2; and P. chrysogenum.

CONCLUSIONS AND RECOMMENDATIONS

The microbiological analyses showed a strong microbial load especially inside the church: naos, western wall to the south, register of the drapery, naos, southern wall and chancel, register of the drapery. Similarly, the plinth and exterior masonry are strongly covered by various species of lichens. The adequate biocide protection needs to be established. It needs to be non-toxic and non-polluting, so that it does not affect the murals. Therefore, we recommend the continuation of the biocide treatment with Sintosept QR15, which proved very useful during the in situ investigations, both for the interior and for the exterior frescoes.

Coordinator

Expert restorer,

Oliviu BOLDURA, Prof. univ PhD

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