INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE
ISSN: 2067-533X Volume 3, Issue 1, January-March 2012: 11-22 www.ijcs.uaic.ro

WOOD SPECIES IDENTIFICATION, A CHALLENGE OF SCIENTIFIC CONSERVATION

Maria Cristina TIMAR, Lidia GURĂU*, Mihaela POROJAN

Transilvania University of Brasov, Faculty of Wood Engineering, Department of Wood Processing and Design of Wooden Products, 29 Eroilor Street, RO 500036 Brasov

Abstract

Wood species identification is an important step in the scientific approach of conservation of the wooden cultural heritage. The paper refers to the microscopic identification of the wooden species for two artisanal objects, investigated for conservation purposes. A previous macroscopic analysis of these objects, after thorough cleaning of the surfaces offered some basic information on the possible wood species involved, but due to the degradation of the support this was not conclusive for some elements of these objects, so that relevant samples were taken out, prepared and investigated. The identified wooden species were: poplar (Populus spp), sycamore (Acer pseudoplatanus), fir and beech (Fagus sylvatica). This identification was based on the microscopic keys of wood identification, reference microscopic slides of the respective wood species and microscopic measurements followed by data processing employing the ImageJ software.

Keywords: *conservation; microscopy; wood species; identification; ImageJ data processing.*

Introduction

Wood has been a constant presence in the history of humanity, so that almost any important step of the culture and civilization evolution, as well as the spiritual values or the technical achievements have a proof materialized in wood as an artistic and/or functional object [1, 2]. Furniture, very diverse decorative and utilitarian objects, elements of interior design, wooden sculptures and icons as well as other items of polychrome wood, are all components of the wooden cultural heritage, an important component of the Romanian and world cultural heritage [3 - 9].

Scientific investigation is well acknowledged as a component of conservation and in this respect the identification of wooden species is an important step in wood conservation [8 - 11]. A wide range of wooden species was used throughout history for different applications and the selection of the wooden material for a certain application was based on several criteria, such as: tradition, experience, material properties, aesthetical requirements, fashion, cost and also, equally important, wooden material availability. For the art furniture, different wooden species were characteristic to the different styles and periods being the most often employed, though the local tradition and wooden material availability brought noticeable regional differences [8, 11-

* Corresponding author: lidiagurau@unitbv.ro, +40-268-419581

13]. For the artisanal and utilitarian objects locally available wooden species including fruity trees or even bushes were often employed [14] alongside commonly used species.

Consequently, identification of wooden species for conservation purposes or historic studies can be quite a challenge when considering the great variety of the wooden material used and also the ageing and degradation phenomena affecting the wooden material appearance and sometimes even its structural integrity. Seldom, the identification of common wooden species can be made by a macroscopic investigation of the characteristic macroscopic anatomical features, on a cleaned not degraded area, but most often such an attempt is not sufficient nor concluding [9-11]. Consequently, relevant samples have to be taken out and adequately prepared for a microscopic investigation to observe the characteristic microscopic anatomical features. Microscopic identification keys and reference samples are then employed in order to decide on the wood species involved. Moreover, microscopic measurements of some characteristic anatomical features and adequate data processing, to get numerical information on the dimensions and frequency of certain anatomical elements, offer the possibility to compare this data with relevant literature information (i.e. the Holzatlas of Wagenführ [15]) for a more reliable identification. ImageJ is a software specialized for microscopic data processing, which was proved as extremely useful for the microscopic study of wood [16, 17].

The paper refers to the microscopic identification of the wooden species for two artisanal objects employed in the traditional processing of natural fibers, respectively a reel wheel and a winder. These objects originating from two different regions: Buzau and Gherla, were obviously handmade with artisanal tools, dating from around 1930 – 1940 and being used until approximately 40 - 50 years ago. Since then, they were abandoned and neglected, so that extensive degradation, especially by biological attack, occurred. The objects were investigated in this paper for their species of origin for further conservation purposes.

Experimental

The objects under investigation were thoroughly examined and cleaned to remove the dust and the adherent dirt. Both mechanical means and adequate cleaning solutions were employed. After cleaning and drying, some less degraded areas displaying transversal and longitudinal grain were sanded for a first macroscopic examination of the anatomical features for wood species identification. When this was not convincing, samples for microscopic identification of the wood species were taken out from relevant, but less visible areas, using a chisel. These were examined under magnifying glass and then further processed for microscopic investigations.

A general view on the objects under investigation, showing also the areas were from the samples were taken out, as well as the macroscopic aspect of those samples, is presented in figure 1 and figure 2.

In Table 1, the codes of the samples with their approximate dimensions and a short description of their conservation state and anatomic characteristic features visible by the naked eye or under magnifying glass 10x are presented. These observations led to an approximate preliminary assumption of the wood species but could not give an actual relevant identification.

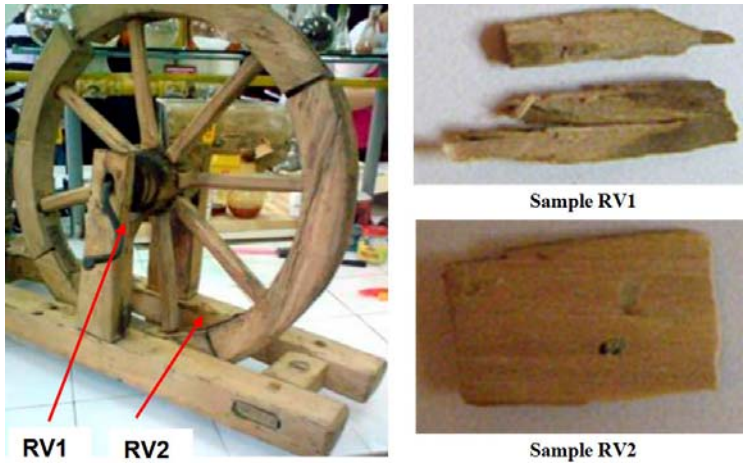

Fig. 1. Macroscopic view of the first object: reel wheel from Buzau region and of the samples collected for wood species microscopic identification. The red arrows are pointing towards the elements and areas where from the samples RV1 and RV2 were taken out.

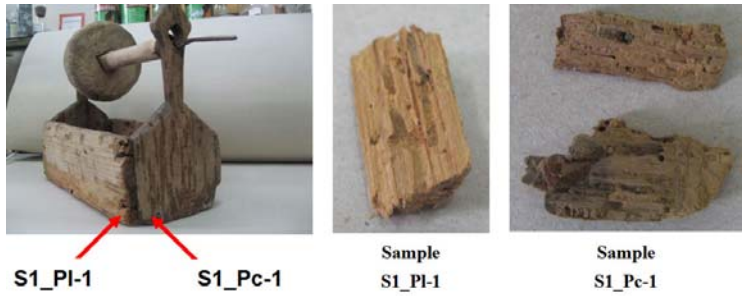

Fig. 2. Macroscopic view of the second object: winder from Gherla region and of the samples collected for wood species microscopic identification. The red arrows are pointing towards the elements and areas where from the samples S1_Pl-1 and S1_Pc-1 were taken out.

Table 1. Objects and samples taken out for wood species identification – dimensions and macroscopic visible features

Object	Samples		Conservation state Macroscopic visible features	Preliminary macroscopic assumption of wood species
	Code	Dimensions (L × l × g), mm		
Object 1 **Reel wheel**	RV1	17 x 4 x 3 30 x 3 x 2	Light colour wood, pores not visible Evidence of insects attack	Not conclusive Possibly poplar? Not conclusive
	RV2	20 x 10 x 4	Light coloured wood, white-yellowish, pores not visible; medullary rays barely visible under magnifying glass on freshly cut cross-section.	Possible species: sycamore, poplar?
	Remark: Other wood species present and identified directly on the object by their macroscopic features: beech, oak, robinia			
Object 2 **Winder**	S1_Pl-1	20 x 15 x 5	Frail wood, massive insects attack Early wood and late wood clearly distinct on the transversal and radial sections	Not conclusive, extensive degradation Softwood
	S1_Pc-1	25 x 15 x 8 25 x 5 x 3	Frail wood, massive insects attack Yellowish colour, medullary rays as lenticels on the tangential direction – barely visible	Not conclusive, extensive degradation Possibly beech?

The wooden samples were plasticized by immersion in water at room temperature for minimum 48 h, being further transferred into a mixture of glycerol / ethanol (1/4). The plasticized samples were then manually trimmed with a very sharp blade to expose the transversal, radial and tangential sections respectively. Thin, transparent microsections of about 30 μm were then cut with a microtome. They were stained with safranine, washed with water and then temporarily mounted in glycerol / water (1/1) for the microscopic investigation. The mounted samples were observed in transmitted light at different magnifications (40x - 400x) under an optical microscope BIOSTAR OPTECH B5 fitted with an image capture system.

The captured images were further processed with ImageJ, an image processing software for determining the edges of features that are envisaged (i.e. different types of cells), capable of returning a mask image where only the objects (areas) of interest are kept. This software also allows dimensional measurements of the selected anatomical features, calculation of their area, proportion and other useful determinations (http://en.wikipedia.org/wiki/ImageJ). This method was tested and found applicable on wood microslides, the sequence of operations for image processing being detailed by Gurau et al. in previous publications [16, 17].

Results and Discussion

The results of the microscopic investigation of the four samples taken out from the two considered objects are presented below. Wood species identification was based on the wood microscopic identification keys and reference microscopic slides of the supposed wood species. Furthermore, measurements were performed on the digital microscopic images and the data was processed employing the ImageJ software in order to get numerical results which were compared to reference literature data [15] for a more reliable identification. The reference microscopic slides / images are part of the collection and electronic catalogue *Wood species for historic furniture*, a result of the research project ID-856/2008 (***http://www.artimar.ro/ct/index.htm***).

Sample RV1 – micrographs and interpretation

The microscopic images for sample RV1 are presented in figures 3, 4 and 5.

The investigated sample RV1 has diffuse pores spread unitary or in radial groups, frequently 2-3 (Fig. 3a and c), as characteristic for poplar species (see reference micrograph shown in Fig. 3b,d). The cross section processed with *ImageJ* (Fig. 3e and f) allowed the identification of 62 pores/mm^2. Wagenführ [15] reports 70-80-90 pores/mm^2 for aspen and 25-40-50 pores/mm^2 for Black poplar. The surface proportion of pores from the total area of cross-section, determined for the investigated sample RV1 with ImageJ based on the "mask" from figure 3e, was of 22.9% for their lumens and this was close to the lower limit for poplar spp. (aspen 24.3%, Black poplar 24% measured including the cell walls) according to literature data [15].

As far as the pores lumen diameter is concerned, the mean measured value was around 68.7 μm. The literature reports are not far from these findings with about 50 μm for aspen and 65μm for Black poplar presented by Wagenführ [15]. In figure 3f were measured largest pores lumen diameters of over 100μm (even 127 μm) on radial direction and minimum values of app. 50μm or slightly lower. Compared to poplar species, these values best approach the Black poplar with 100μm for the maximum pores diameters and 40μm for the minimum pores diameters. The range of variation for aspen lowers these limits to 70 μm, respectively 35 μm [15].

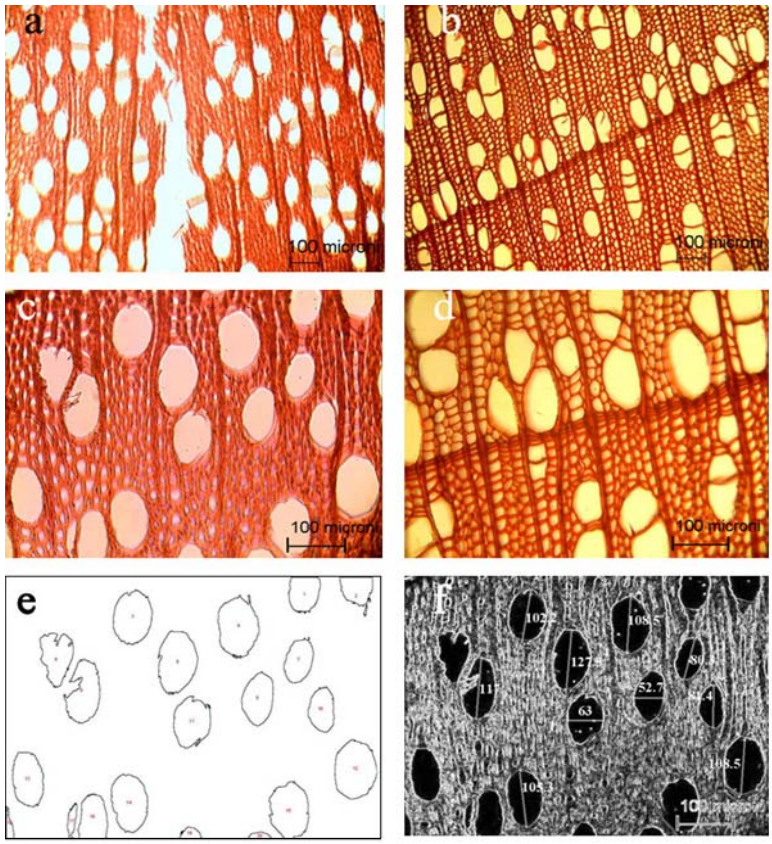

Fig. 3. Cross section micrographs: a - investigated sample RV1, magnification 100x;
b - reference sample (poplar- *Populus* spp.) -100x; c - investigated sample RV1 magnification 200x;
d - reference sample (poplar - *Populus* spp.)-200x; e - "mask" image of the investigated sample RV1;
f - investigated sample RV1 with cell contour enhanced and measurements.
The size of the investigated micrographs: 656.45x491.65 (μm)

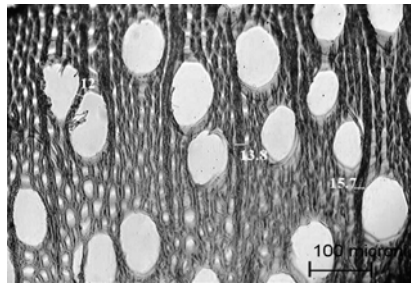

Fig. 4. Measurement of rays for the investigated sample RV1 -100x:
8 rays visible, measured widths: 12, 13.8, 15.7 μm

The medulary rays of the unknown species are uniseriate, about 12/mm as measured in figure 4, where one can count 8 rays spread on the micrograph length of 656.45 μm. The frequency of rays described in the literature reports close results, 9-11-13 rays/mm for aspen and 8-10-13 rays/mm for Black poplar. The ray widths are measured in figure 4 and their values (12 μm, 13.8 μm, 15.7μm) seem to fall within the values of aspen, 10-13-21 μm, and Black poplar, 5-13-21 μm. The radial section from figure 5a shows intervascular polygonal pits, honeycomb type, visible also on the reference image of poplar species from figure 5b.

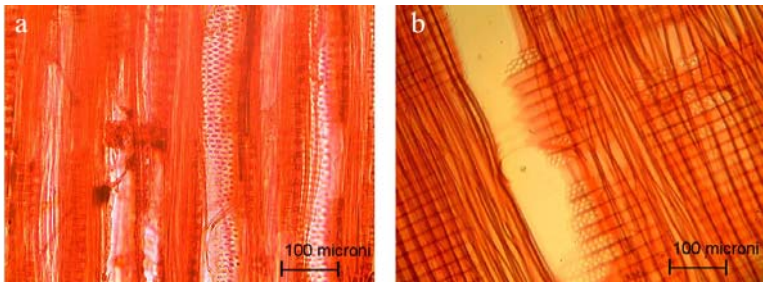

Fig. 5. Radial sections: a - investigated sample- RV1-10 magnification 200x;
b - reference sample (poplar- *Populus* spp.), 200x

Although the investigated species seems generally to be closer to the characteristics of Black poplar rather than aspen, the small sampling just allows for the assumption that there is certainly a poplar species (*Populus* spp.). It has to be remarked that for this sample the original macroscopic evaluation could only presume that it could be poplar.

Sample RV2 – micrographs and interpretation

The microscopic images for sample RV2 are presented in figures 6, 7 and 8.

The investigated sample RV2 (Fig. 6a and c) displays distinct annual rings with even contour and without a contrasting appearance between latewood- earlywood.

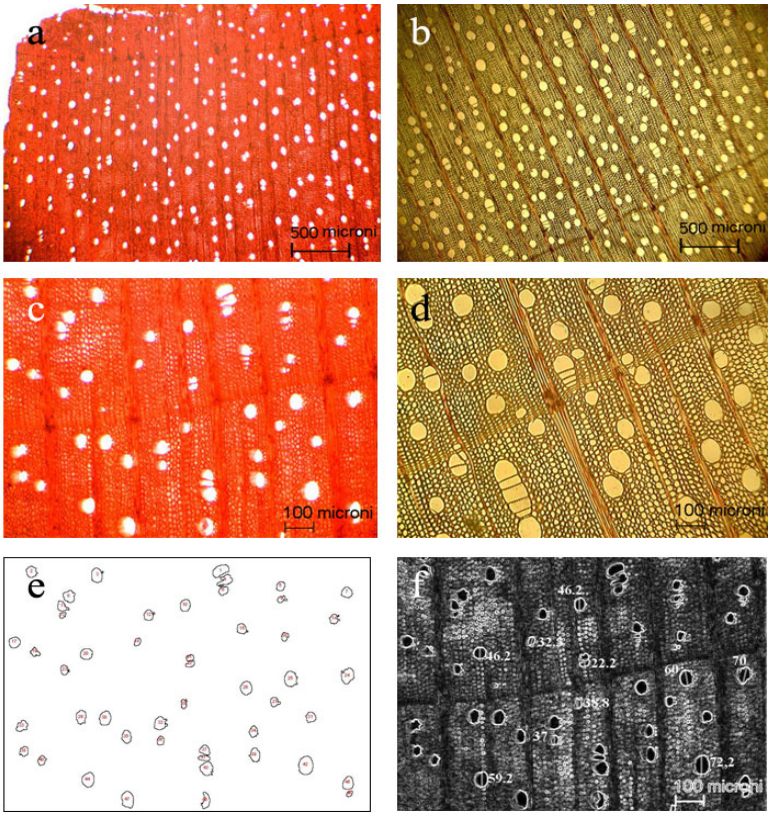

Fig. 6. Cross sections: a - investigated sample RV2, magnification 40x; b - reference sample (Sycamore- *Acer pseudoplatanus*) magnification 40x; c - investigated sample RV2, magnification 100x; d - reference sample (Sycamore - *Acer pseudoplatanus*) magn.100x; e - "mask" image of the investigated sample RV2-10 ; f - investigated sample RV2-10 with cell contour enhanced and measurements. Size of the micrographs for the investigated sample: 1312.96x983.33(μm)

Pores are diffuse dispersed, oval to round in shape, unitary or in small radial groups up to 3, very similar to Sycamore, taken as reference, with pore groups of 2-5 (Fig. 6b and d). The image processing in figure 6e has identified app.37 pores/mm^2 present in a proportion of 4.4%. Sycamore was reported with 34-38-44 pores/mm^2 with a proportion of 4-6.9-8.4% [15].

The calculated mean lumen pores diameter was of 39 μm, while the maximum values as measured in figure 6f were slightly greater than 70 μm on the radial direction. The minimum distinguishable lumen diameters were of app. 22 μm. When looking at the range of variation for the pores diameters of Sycamore, (25)30-50-70 μm [15], the above mentioned values for the investigated sample seem to get very close.

Rays in figures 6a and c, and figures 7a and b are uniseriate and pluriseriate as also seen in their corresponding images of Sycamore reference sample, from figures 6b and d. In figure 7a were identified 5 rays on a distance of 633 μm (the length of the microscopic image), which means about **7**-8 rays/mm. These values fall within the range reported for Sycamore, 6-9-14 rays/mm. The ray width measured in figure 7a indicates values below 60 μm for the pluriseriated rays and of app. 10 μm for the uniseriate. At Sycamore, those values range between 25-50-60 μm for the pluriseriate rays and 12-20-27 μm for uniseriate.

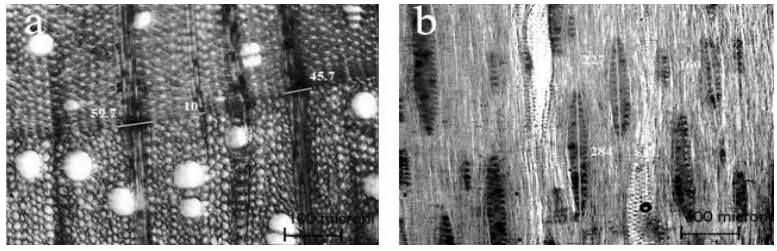

Fig. 7. Ray measurements of the investigated sample RV2-10: a - cross section; b - tangential section, 200x.

The height of rays was measured in figure 7b and was below 300 μm (from 160 to 284 μm). However, it is difficult to make judgments and comparisons based on only one slide and to this, has to be added the bias that can occur at cutting relative to a perfect ray height from an undersized sample. For Sycamore, Wagenführ [15] reports ray heights between 270-460-630 (1000) μm for high rays and 100-235-350 μm for low ones.

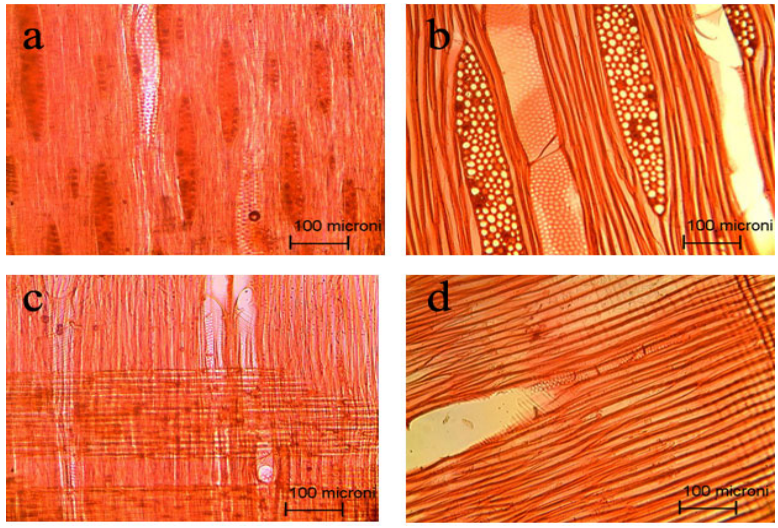

Fig. 8. Microscopic sections (200x): a - investigated sample RV2 - tangential section; b - reference sample (Sycamore- *Acer pseudoplatanus*), tangential section; c - investigated sample RV2 radial section; d - reference sample (Sycamore- *Acer pseudoplatanus*)-radial section.

Honeycombe pitting in vessels is visible on tangential and radial sections of the investigated sample (Fig. 8a and Fig.) as well as on those of the reference sample (Fig. 8b and d). Radial sections have shown spiral thickenings for both, the investigated sample and Sycamore from figure 8c, respectively 8d.

As the most characteristics of the investigated sample were close to Sycamore *(Acer pseudoplatanus)* is reason to assume that this is the species looked for. The initial assumption for this sample, based on macroscopic features and examination under magnifying glass, was not concluding pointing towards sycamore or poplar as possible species. Once again, by microscopy a necessary clarification could be made.

Sample S1_Pl-1 – micrographs and interpretation

The microscopic images for sample S1_Pl-1 are presented in figures 9 and 10.

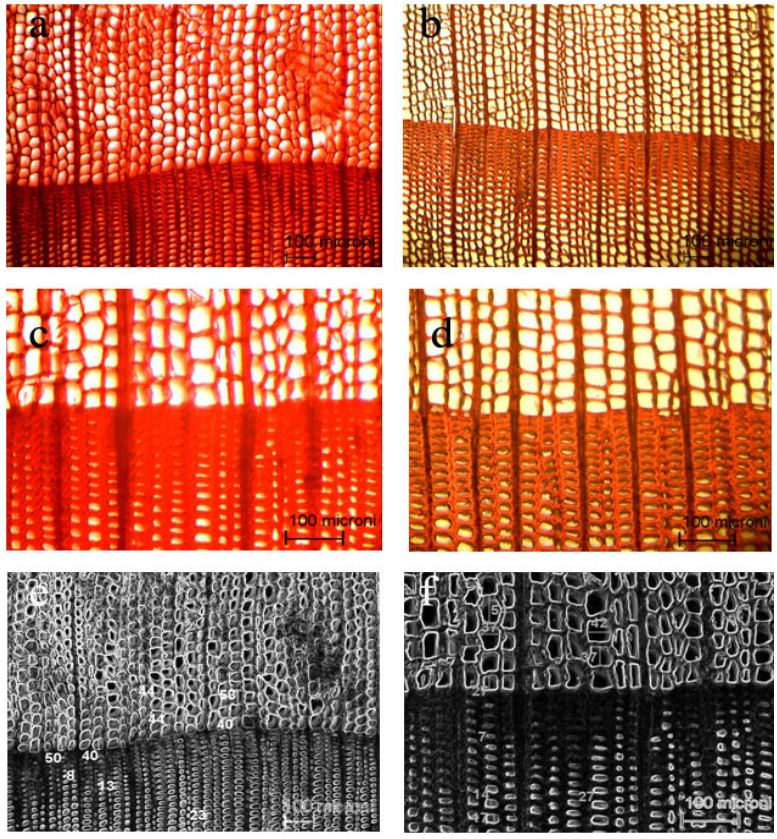

Fig. 9. Cross sections. a - investigated sample S1_PI-1 (100x); b - reference sample (fir-*Abies alba*, 100x); c - investigated sample S1_PI-1 magnification (200x); d - reference sample (fir-*Abies alba*, 200x); e - investigated sample S1_Pl-1, cell contour enhanced for measurement (200x); f - investigated sample S1_Pl-1, cell contour enhanced for measurement, (200x).

The investigated sample appears to be a resinous species, has well delimited annual rings with a slightly wavy contour (Fig. 9a) characteristic to fir species (Fig. 9b). The tracheid dimensions on radial direction measured in areas of earlywood and latewood in figures 9e and

Fig. are complying with usual limits mentioned by literature for fir species, respectively 21-34.6-52.4 μm in the earlywood and 6.8-16.2-24.6 μm in the latewood [15]. Moreover, no resinous canals could be observed.

The axial tracheids visible on radial micrographs of the sample to be identified don't show any helical thickenings and their bordered pits are aligned in single rows (Fig. 10a and Fig.); similar observations can be distinguished on radial micrographs of the fir reference sample (Fig. 10b and d).

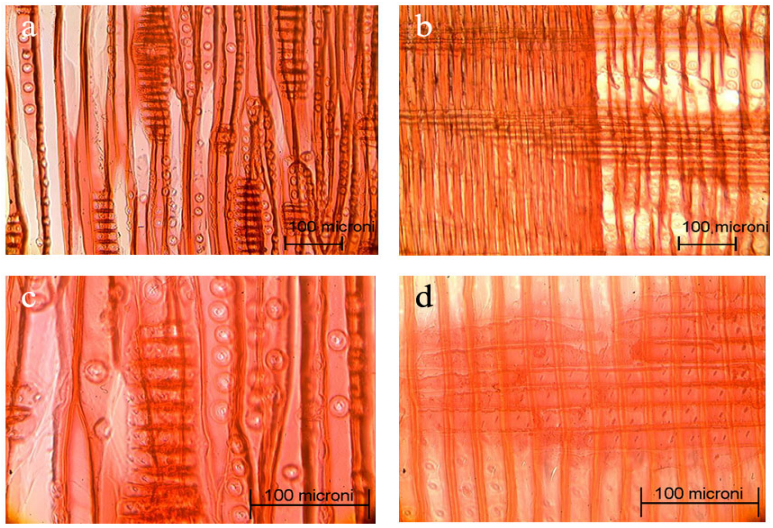

Fig. 10. Micrographs of radial sections: a - investigated sample S1_PI-1 magnification (200x); b - reference sample (fir - *Abies alba*, 200x); c - investigated sample S1_PI-1 (400x); d- reference sample (fir - *Abies alba*, 400x).

A more precise identification criteria for softwoods is the cross field pitting visible on radial sections, which refers to the type of pits characteristic to the communication between rays and axial tracheids. In this sense, in figure 10c of the investigated sample, but also in figure 10d of the reference species (Fir – *Abies alba*) can be seen the taxodioid pits at a magnification of 400x. This criterion clearly includes the sample S1_PI-1 in the category of fir species. The difficulty in distinguishing among the different species of *Abies* by anatomical wood features is well known and there are no reliable diagnostic features at the species level [18]. In this case the preliminary macroscopic observation could only assume that is a softwood, without indicating which wood species, fact which clearly underlines the importance and usefulness of microscopy in a reliable identification.

Sample S1_Pc-1 – micrographs and interpretation

The microscopic images for sample S1_Pc-1 are presented in figure 11.

The investigated sample is a hardwood species due to the presence of pores, whose distribution is diffuse, solitary or associated in small groups (Fig. 11a). The image processing with ImageJ of the investigated sample as "mask" where only the pores contour was retained (Fig. 11c) allowed an automatic count of those features resulting in approximately 145 pores/mm^2. This is within the range reported in the literature for beech species, 80-125-160/mm^2 [15].

The calculated mean of pores lumen diameter from the "mask" image (Fig. 11c) was 44.6 μm and the maxim lumen diameter was around 70 μm, values closed to the mean, respectively maximum reported for beech 8-45-85 μm [15] with specification that the reports from literature have included the thickness of the cell walls and not only the lumen.

The surface proportion of vessels lumen of 22.6% estimated for the investigated sample is close to the lower limit reported in the literature for the proportion of pores (including the cell walls), 24.6-39.5-52.5% [15].

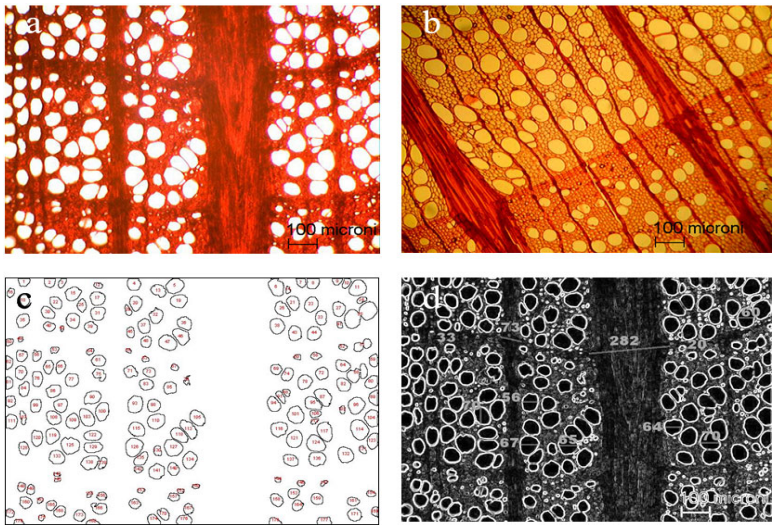

Fig. 11. Cross sections (100x): a - investigated sample S1_Pc-1; b - reference sample (beech - *Fagus sylvatica*); c - mask image of the investigated sample S1_Pc-1; d - investigated sample S1_Pc-1 with cell contour enhanced and measurements. Size of the investigated micrograph: 1289.09x965.45 (μm)

In figure 11a can be observed uniseriated and pluriseriated rays, the latter being strongly widened at the annual growth limit. This is characteristic for beech species and is visible also on the reference micrograph in figure 11b. The largest ray width measured in figure 11d was 282 μm, value close to the usual maxim limit of 200 μm from literature [15]. The number of rays: 2 pluriseriate rays/mm and 6 uniseriate rays/mm for the investigated sample, had a good correspondence with beech species, 2-3-5 pluriseriate rays/mm and 3-6-9 uniseriate rays/mm [15].

Diffuse apotracheal parenchyma is visible in figure 11a especially at the upper limit of the annual ring in the latewood. Similar type, distribution and location of parenchyma cells are characteristic to beech species and can be seen in figure 11b.

The characteristics observed in the investigated sample S1_Pc-1 make it likely a beech species, most probably *Fagus sylvatica*, which confirms the initial assumption based on the macroscopic observation.

Conclusions

Wood species identification is a key issue in the scientific conservation of old wooden objects. This is not only because of the need for a replacement or completion with the same type

of wooden material as the original, but also due to the importance of a scientific documentation regarding the old objects for taking any conservation action.

When a macroscopic identification is not obvious, due either to similarities between some species or occurrence of degradation phenomena, a microscopic approach becomes compulsory.

This was the case for the four wooden samples extracted from two old artisanal objects needing conservation and where the macroscopic analysis had to be backed up by microscopic identification. The microscopic images taken with an optical microscope, were further analyzed for characteristic features by means of an image processing software. The results were compared with relevant data from literature and species database. The species identified in this way were: poplar (*Populus* spp.), sycamore (*Acer pseudoplatanus*), fir spp. and beech (*Fagus sylvatica*). In case of beech and poplar, the result confirmed the initial macroscopic assumption, or clarified them in case of sycamore, but in case of fir, the initial presumption was vague, only pointing for a resinous species.

This outcome makes a proper conservation action possible and proves the need for a scientific analysis regarding the identification of species, approach confirmed by recent literature research.

References

[1] D. Lica, **Civilizaţia lemnului** (Wood civilisation), Editura Universităţii Transilvania, 2006, 85 p.

[2] D. Lica, C. Coşereanu, **Civilizaţia lemnului la români** (Wood civilisation at Romanians) , Editura Universităţii Transilvania, 2010, 103 p.

[3] I. Sandu, **Deteriorarea şi degradarea bunurilor de patrimoniu cultural**, vol. II – **Bunuri din materiale organice** (Deterioration and Degradation of Cultural Heritage Items, vol. II – Artefacts from organic materials), Editura Universităţii A.I. Cuza, Iaşi, 2008, 538 p.

[4] I.C.A. Sandu, I. Sandu, P. Popoiu, A. van Saanen, **Aspecte metodologice privind conservarea stiintifica a patrimoniului cultural** (Methodological Aspects of Scientific Conservation of Cultural Heritage)**,** Editura Corson, Iasi, 2001.

[5] B. Constantinescu, *Romanian Architectural Wooden Cultural Heritage – The Present Status - a survey*, http://www.scribd.com/doc/25203592/Romanian-Architectural-Wooden-Cultural-Heritage

[6] ***, *Caribbean Wooden Treasures*, **Proceedings of the Thematic Expert Meeting on Wooden Urban Heritage in the Caribbean Region**, 4–7 February 2003, Georgetown, Guyana, World Heritage Papers 15, published in 2005 by the UNESCO World Heritage Centre, Paris-France.

[7] N. Macchioni, **Diagnosis and Conservation of Wooden Cultural Heritage**, http://ottimari.agr.unifi.it/~uzielli/Tervuren_proceedings/IVALSA.pdf, http://www.ivalsa.cnr.it/en/research/diagnosis-and-conservation-of-wooden-cultural-heritage.html

[8] R.A. Bernal, A. Valente, I Pissara, Eighteenth Century technological efficiency: the reuse of Brazilian sugar chest wood in Portuguese cabinet manufacture, **International Journal of Conservation Science**, **2** (4), 2011, pp. 217-228.

[9] N. Macchioni, S. Lazzeri, L. Sozzi, Vitiello, R., *Wooden sculptures from XVII and XVIII Centuries in the region of Asti (Italy): Scientific identification of the species*, **International Journal of Conservation Science**, **2** (4), 2011, pp. 251-260.

[10] N. Macchioni, *How to identity the wooden species?* in: **Scientific Examination for the Investigation of Paintings. A Handbook of Conservator – Restores** (Eds. Pinna D., Galeotti, M., Mazzeo, R.) Centro Di Firenze, 2009, pp. 21-22.

[11] M.C. Timar, L. Gurău, M. Cionca, M. Porojan, *Wood species for Biedermeier furniture – a microscopic characterisation for scientific conservation,* **International Journal of Conservation Science**, **1** (1), 2010, pp.3-12.

[12] M. Cionca, **Stiluri şi ornamente la mobilier – Renaşterea italiană** (Styles and ornaments for furniture – Italian Renaissance), Editura Universităţii Transilvania, 2004, 120 p.

[13] M. Cionca, **Proiectarea mobilei stil – Cassoni din Renaşterea florentină** (Design of art furniture – Cassoni from Florence Renaissance), Editura Universităţii Transilvania, 2004, 205 p.

[14] M. Grabener, *Rarely used hardwood species – recent characterisation and old literature*, Hardwood Science and Technology, **Proceedings of the 4th Conference on Hardwood Research and Utilisation in Europe**, Sopron, May 2010, pp. 156-163, http:// hardwood.nyme.hu.

[15] R. Wagenfuhr, **Holzatlas**, 5 Auflage, Fachbuchverlag Leipzig im Carl Hanser Verlag, 2000.

[16] L. Gurău, M.C. Timar, M. Cionca, A. Olărescu, R. Dumitraşcu, *An objective method to analyse some microscopic characteristics of two secondary beech wood resources*, **Pro Ligno**, **6** (1), 2010. pp. 35-45.

[17] L. Gurău, M.C. Timar, M. Porojan, *Microscopic identification of wood species prior to furniture restoration*, **Proceedings of International Conference on Wood Science and Engineering in the third Millenium**, 8th Edition, ICWSE 2011, Brasov, November 2011, pp. 451-458.

[18] M. Romagnoli, M. Sarlatto, F. Terranova, E. Bizzarri, S. Cesetti. *Wood identification in the Capella Palatina ceiling (12th century) in Palermo (Sicily, Italy)* **IAWA Journal**, **28** (2), 2007, pp. 109-123.

Received: January, 07, 2012
Accepted: February, 19, 2012