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(LESSONS LEARNED FROM THE PALAEOLITHIC WOODEN POINT FROM THE LJUBLJANICA RIVER)

KONSERVIRANJE ARHEOLOŠKIH PREDMETOV IZ MOKREGA LESA

(IZKUŠNJA KONSERVIRANJA PALEOLITSKE LESENE KONICE IZ REKE LJUBLJANICE)

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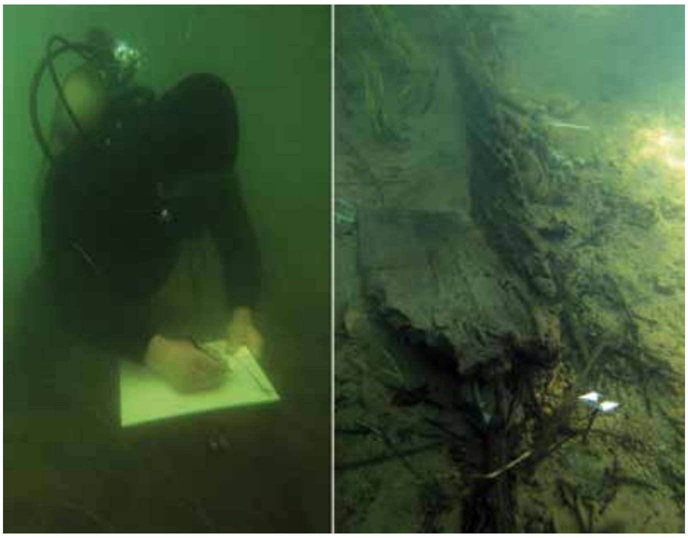
In September 2008, underwater archaeologists discovered a flat bottom barge of Roman Age in the Ljubljanica River near Sinja Gorica, Vrhnika (lat. *Nauportus*; Fig. 1).[1] During the first investigations between September 2008 and May 2009 we observed strong erosion of the sediments around the new discovery, which were caused by the river current (Fig. 2). Later, several computer-based analytical studies of the barge were carried out, which led us to consider a re-conceptualization of the contemporary Maritime Museum. Should we really apply to the original wooden artefacts a possibly destructive conservation process?

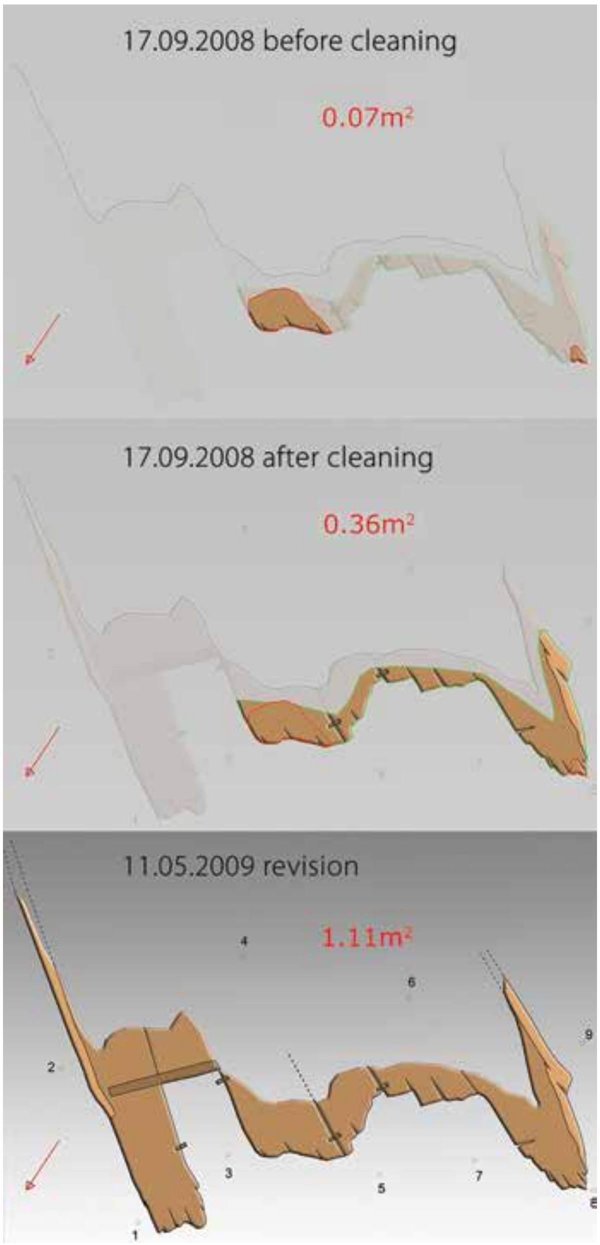
1 Erič et al. 2014.



Septembra 2008 so podvodni arheologi v strugi reke Ljubljanice pri Sinji Gorici, nedaleč stran od Vrhnike (lat. *Nauportus*), odkrili ostanke zgodnje rimske lesene tovorne ladje s ploskim dnom (Slika 1).[1] Po prvih preventivnih preiskavah rečnega dna (september 2008 in maj 2009) so arheologi v osmih mesecih opazili močno erozijo sedimentov, ki jo je povzročil rečni tok na lokaciji odkritja (Slika 2). Kasneje je bilo izvedenih več računalniško podprtih analitičnih študij. Te so spodbudile k razmišljanju o zasnovi sodobnega podvodnega muzeja. Za to bi lahko uporabili originalne lesene ostaline, ki so bile po postopku konserviranja izločene iz njihovega naravnega vodnega okolja najdišča. Z novim pristopom bi lahko tradicionalne metode konserviranja mokrega lesa z melaminom, polietilenglikolom in drugimi sredstvi nadomestili z računalniško nadzorovanim sistemom, ki bi lesene predmete ohranjal v nespremenjenih vodnih pogojih najdišča.[2]

Drugi pomemben artefakt, ki je bil najden na tem mestu, je bil lesen koničast predmet (Slika 3). Oblika predmeta je spominjala na paleolitske listaste kamene in koščene konice, dele lovskega orožja. Nadaljnje raziskave (datiranje z metodo AMS ^{14}C; >43.970 let - Beta 252943

1. Preventive survey of the bottom of the Ljubljanica River at Sinja Gorica showing the first sighting of the Roman Barge / Preventivni podvodni pregled struge reke Ljubljanice pri Sinji Gorici s prvim pogledom na ostanke rimske ladje. (Photo: R. Kovačič)



2. Erosion by river currents of the sediments around the Roman barge in only eight months between September 2008 and May 2009. / Erozija sedimentov okoli rimske ladje, ki jo je po začetnih preiskavah med septembrom 2008 in majem 2009 povzročila osemmesečna izpostavljenost delovanju rečnega toka. (By: M. Erič)

We believe that traditional conservation methods using melamine, poliethileneglicol and other substances should be replaced by modern computer monitored conservation in an unaltered water environment.[2]

However, a second important artefact found at this site was a wooden pointed object (Fig.3). The shape of the object was reminiscent of Palaeolithic leafy stone and bone points. Further research (dated by the AMS ^{14}C

2 Erič et al. 2018. / Erič et al. 2019.

oz. 38.490±330 BP - OxA-19866) so potrdile, da predmet predstavlja konico iz tise,[3] ki je bila pred približno 40 tisočletji uporabljena kot del sestavljenega lovskega orožja.

Lesena konica je bila izdelana in uporabljena na prehodu iz srednjega v pozni Würm, v času, ko neandertalci počasi izumirajo, prvi anatomsko moderni ljudje pa so bili že na poti v Evropo. Reka Ljubljanica pri Sinji gorici se tako pridružuje osmim evropskim najdiščem z ostanki obdelanega lesa iz starejše kamene dobe. Klasično izmerjena dolžina konice je ob njenem odkritju znašala 16 cm, največja širina 5,1 cm in največja debelina 2,5 cm.

Po javni predstavitvi odkritja so se v delu strokovne javnosti pojavili dvomi v interpretacijo raziskovalne ekipe. Nekateri arheologi so ocenili, da gre v primeru »konice« za naravno preoblikovan kos lesa, ki je svojo sedanjo obliko dobil s hidrogeološkimi procesi. Zato je bila dokumentacija konice poslana v nadaljnjo dendrološko analizo in oceno v Švico. Dr. Niels Bleicher (Labor für Dendrochronologie - Zürich) je ovrgel vsakršno možnost, da bi se les lahko po naravni poti preoblikoval v tako simetrično koničasto obliko, in potrdil, da je bil odkrit leseni predmet povsem premišljeno - umetno preoblikovan.[4]

Od odkritja konice so v strokovnih krogih arheologov in muzeologov potekale intenzivne razprave o načinu konserviranja in zaščiti konice pred posledicami njene izločitve iz pogojev *in situ.* Izoblikovani so bili različni predlogi (ohranitev v pogojih in situ v posebni kapsuli ipd.). Prevladalo je stališče, da se konica zaščiti s tradicionalno metodo konserviranja mokrega lesa, tj. z melaminsko smolo. Po postopku konserviranja in zadnjih volumetričnih meritvah je bila izmerjena dolžina konice 15,01 cm (16 cm – analogno izmerjena dolžina ob odkritju), širina 4,9 cm (5,1 cm) in debelina 2,3 cm (2,5 cm). Spremenila pa se je tudi oblika konice (močan upogib spodnjega dela in vrha). Opazne so tudi površinske razpoke.

Po odkritju konice leta 2008 sta bili opravljeni dve analizi (2018 in 2020) in izdelanih pet 3D modelov. Prvi je bil izdelan leto dni po odkritju (2009) in po opravljenih volumetričnih meritvah ni pokazal pomembnih odstopanj od originala. Naslednji trije 3D modeli so bili izdelani na začetku in na koncu postopka konserviranja z melaminsko smolo. Zadnji model pa je bil izdelan ob prevzemu konice leta 2018 z µCT snemalnikom. Primerjava vseh petih 3D modelov je opozorila na pomembne površinske spremembe artefakta (izrazitejše razpoke, upogib nasadnega dela in vrha konice, močno zmanjšani volumen).[5] Po postopku konserviranja sta volumetrična analiza in primerjava (Tabela 1) vseh petih 3D modelov opozorila, da je dolžina konice krajša za 6,8%, širina manjša za 7,3%, debelina za 21,3% in prostornina za

3. Preventive survey of the Ljubljanica river bottom at Sinja Gorica and two photographs of the Palaeolithic wooden point. / Preventivni raziskovalni pregled struge reke Ljubljanice pri Sinji Gorici in dve fotografiji paleolitske lesene konice. (left photo: O. Musić / right photo: S. Olić, Arhos d.o.o)

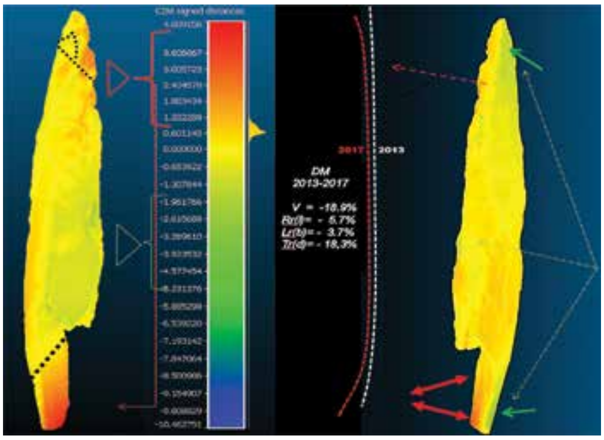
method; >43,970 years - Beta-252943 and 38,490 ± 330 BP OxA-9866) confirmed that the age of the artefact was about 40 thousand years and the object represents a yew[3] point that was a part of a composite hunting weapon.
The wooden point was made and used at the transition from the Middle to the Late Würm period, at a time when Neanderthals were slowly becoming extinct and the first anatomically modern humans were already on their way to Europe. The Ljubljanica River near Sinja gorica thus joins eight European sites with remnants of treated wood from older Stone Age. The length of the object at the time of its discovery was 16 cm, width of 5.1 cm and thickness of 2.5 cm.

After the public presentation of its discovery, some doubts in the interpretation of the artefact by the discovery team arose in parts of the professional public. Some archaeologists hypothesized that the said "point" is a naturally reshaped piece of wood that has taken on its current form through hydrogeological processes. The documentation of the point was therefore sent for further assessment and comparison to Switzerland. Dr. Niels Bleicher (Labor für Dendrochronologie - Zürich) ruled out any possibility that wood could be naturally transformed into such a symmetrical pointed shape and confirmed that the discovered wooden object has been deliberately and artificially shaped. [4]

20,6%. Spremenila se je tudi oblika konice. Ugotovljen je močan upogib spodnjega nasadnega dela in manjši upogib vrha konice. Ugotovili smo, da se je prostornina oz. volumen konice med letoma 2009 in 2013 povečal za 13,8%. Predvidevamo, da je bila celična struktura lesene konice pred odkritjem leta 2008 tisočletja izpostavljena zunanjim pritiskom sedimentnega okolja, ki je vplivala na to, da se je celična struktura stisnila. Po odkritju je bila konica razbremenjena pritiska sedimentnega okolja in je bila hranjena v vodi vse do začetka konserviranja leta 2013. Ker les ni bil več izpostavljen nobenemu dodatnemu pritisku okolja, je celična struktura dobila svojo naravno obliko in prostornino.[6] V letih 2019 in 2020 smo pridobili še dva 3D modela konice. Primerjava kaže, da se je tri leta po postopku konserviranja upočasnil in stabiliziral proces deformacije konice (Sliki 4 in 5). Postopek deformacijske analize 3D modelov konice izdvajamo periodično. S tem želimo pravočasno preprečiti nepopravljive spremembe in ohraniti dragoceni arheološki artefakt.

Z nepopolno volumetrično informacijo površinskih 3D modelov smo bili soočeni že pri primerjavi petih površinskih 3D modelov lesene konice.[7] Primerjava je opozorila na volumetrične površinske spremembe predvsem po opravljeni konservaciji konice. Sklepanje o nastalih spremembah in njihovih vzrokih je bilo zato lahko le pogojno. Za celostno analizo je bilo treba pridobiti informacije tudi o notranji strukturi konice. Ta

3 The analysis of the sample of the found wooden object was performed by the Department of Wood Science of the Biotechnical Faculty of the University of Ljubljana (Ing. Martin Zupančič). The analysis of the sample indisputably confirmed that it is a common yew (*Taxus baccata*). / Analizo vzorca najdenega lesenega predmeta je opravil Oddelek za lesarstvo Biotehniške fakultete Univerze v Ljubljani (ing. Martin Zupančič). Analiza vzorca je neizpodbitno potrdila, da gre za navadno tiso (Taxus baccata).
4 Gaspari, Erič, Odar 2011. / Kavur 2012.



4. Changes of the point during the conservation phase 2013 - 2017 / Spremembe konice med postopkom konservacije. (By: E. Guček Puhar)

Since the discovery of the point, intensive discussions have taken place in the professional circles of archaeologists and museologists on the method of conservation and protection of the point from the consequences of its exclusion from the in situ conditions. Various proposals have been made (i.e. preservation in in situ conditions in a special capsule, etc.). The decision that the point should be preserved by a traditional method for conservation of waterlogged wooden artefacts, i.e. with melamine resin, has prevailed at the end. After the conservation procedure and the last volumetric measurements, the current dimensions of the point are as follows: length 15.01 cm (was 16 cm when found, using traditional measurement), width 4.9 cm (5.1 cm), thickness 2.3 cm (2.5 cm). The shape of the point has also changed — there is a strong bent of the lower part and a lesser one at the top of the point. Several surface cracks are also visible.

After the discovery of the point in 2008, two studies (2018 and 2020) of five 3D models were performed. The first 3D scan was made a year after the discovery of the point (2009) which did not show significant deviations from its original state. The following three 3D models were acquired at the beginning and at the end of the melamine resin conservation process. The last model was acquired with a microtomographic recorder in 2019 when the point was again taken over by the local museum. The comparison and deformation analysis of all 3D models highlighted important changes to the artefact.[5]

After the conservation procedure, volumetric analysis and comparison (Table 1) of all five 3D models showed that the current point length was shorter by 6.8%, its width was reduced by 7.3%, its thickness by 21.3%, and its volume by 20.6%. The shape of the point has also changed — there is a strong bending of the lower part and smaller bending at the top of the point. As can

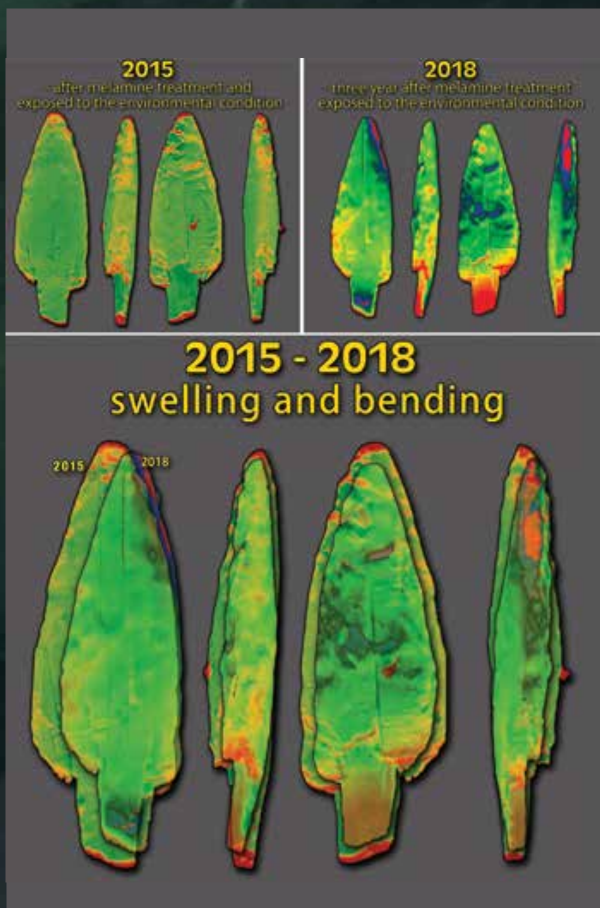
5 Guček Puhar et al. 2020. / Solina 2018.

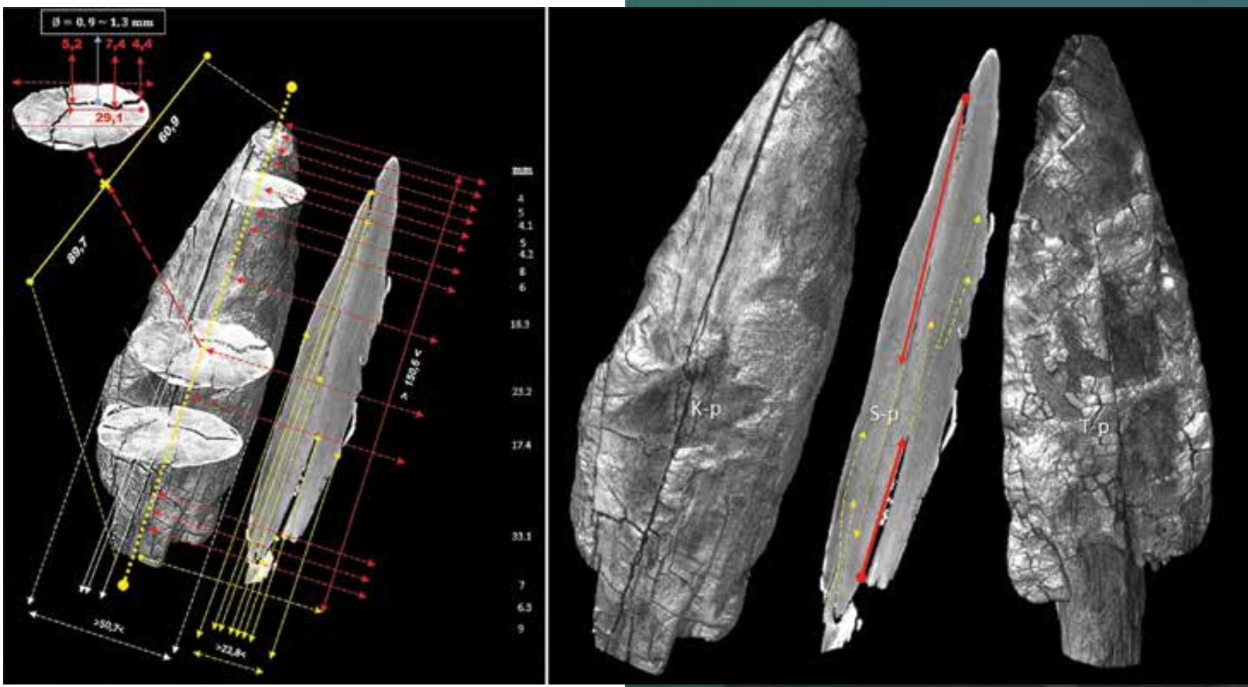
je edina lahko celoviteje pojasnila nastale spremembe, na katere je opozorila površinska volumetrična analiza primerjanih 3D modelov. Ker je bila konica v letih 2018 in 2019 skenirana z mikrotomografskim snemalnikom,[8] smo razpolagali z dragocenim naborom mikrotomografskih slik. Iz njih smo rekonstruirali dva prostorninska 3D modela konice in ju primerjali. Na ta način smo pridobili dodatne informacije za celostno arheološko obravnavo trenutnega stanja konice, ki je le ena od osmih podobnih lesenih ostalin paleolitika v Evropi.

S prostorninskim 3D modelom smo nesporno identificirali, raziskali in dokumentirali notranjo strukturo predmeta. Spremembe in deformacije (razpoke, lomi, luknje, odprtine, tvegana mesta razpada ali zloma) so jasno vidne in locirane (Slika 6). Na modelu smo identificirali kritične točke notranje strukture artefakta (Slika 7). Ugotovljeni sta bili dve izraziti notranji deformaciji: daljša razpoka in izrazitejši lom.

V zgornjem delu konice imamo opravka z razpoko, ki vse do sredine konice poteka po strženskem traku in sega

5. Visualisation of critical changes of the point shape between models from 2015 and 2018. / Vizualizacija pomembnejših sprememb oblike konice med modeloma iz let 2015 in 2018. (By: M. Erič)





6. Critical internal structure of the point .- 1 / Kritične točke v notranji strukturi konice - 1.
(By: E. Guček Puhar)

be observed from Table 1, the volume of the point has increased by 13.8% between 2009 and 2013. We assume that before its discovery in 2008, the cell structure of the wooden point was under external pressure by the sedimentary environment for thousands of years and the voids in the wood cell structure have compressed. Once the point was recovered, it was kept in water until the start of conservation in 2013. Since the wood was no longer exposed to any additional ambient pressure, the cell structure regained its natural shape and volume.[6] Surface cracks are also noticeable. In 2019 and 2020 we acquired two additional 3D point models. The comparison (Fig. 4 and 5) show that the process of point deformation decreased in the three years after the conservation process. The process of deformation analysis of 3D models will continue periodically. In this way, we would like to avoid irreparable changes and damages of the point.

When the surface 3D models of the Palaeolithic wooden point were compared we realized that we did not have enough information about the changes inside the wooden point.[7] The comparison drew attention to volumetric surface changes mainly after the point underwent melamin conservation.
Inference (deformation monitoring) about the resulting changes and its causes could only be made conditionally and not completely scientifically consistent. For a

s površine v globino od 2 do 22 mm. Štiri milimetre pod vrhom konice (prečno ob začetku zgornje razpoke) obstoji nevarnost prečnega odloma konice (Slika 7). Če bi se nadaljevala tendenca širjenja razpoke čez sredino konice po strženskem traku v smeri nasadnega dela (Slika 6) ali pa prečno v smeri ugotovljenega večjega loma (ta težnja širjenja razpoke sicer trenutno ni zaznana – op.) v spodnji in nasadni del konice, ki je od omenjene razpoke trenutno oddaljen 18 mm, bi se lahko soočili z nevarnostjo zloma konice. Primerjalna analiza 3D modelov iz let 2018 in 2019 ne potrjuje te težnje.

Glede na ugotovljeno stanje notranje strukture konice ocenjujemo, da je prostorninski 3D model jasno opozoril, da je največje tveganje za obstoj sedanje oblike konice lom in deviacije v spodnjem osrednjem delu (Slika 7 – z rdečim krogom omejeno območje). Deformacije v tem delu vplivajo na upogib nasadnega dela, ki ima (razen desnega začetnega dela) še vedno dokaj čvrsto lesno strukturo.

Notranja dinamika sprememb v tem relativno kratkem časovnem intervalu kaže tendenco umirjanja oz. stabilizacije. Ugotovljene izrazite spremembe na površinskih 3D modelih v letih 2009 in 2015 oz. 2017 so bile zato lahko le posledica različnih invazivnih postopkov, ki jim je bila konica izpostavljena v postopku konserviranja (faza spodbujenega intenzivnega nabrekanja in toplotne obdelave – sušenja).

Z računalniško tomografsko analizo 3D modelov smo želeli opozoriti na pomen uporabe računalniške tomografije v računalniškem in strojnem vidu, zlasti pa pri obravnavi posebno občutljivih in slabo obstojnih predmetov v arheologiji ter pri varovanju, predstavljanju

6 Effect of Osmosis on the wooden cells./ Vpliv osmoze na celično strukturo lesa.
7 Guček Puhar et. al. 2018.

comprehensive analysis, information on the internal structure of the point had to be obtained. Only knowing the internal structure of the point could clearly explain the resulting changes, which were only indicated by the surface volumetric analysis of the compared 3D models. Since the point was scanned with a microtomographic reader[8] in 2018 and 2019, we had a set of microtomographic images at our disposal. From them we reconstructed two volumetric 3D models of the point and compared them. In this way, we obtained additional information for a comprehensive archaeological treatment of the current state of the point, which is one of only eight existing wooden remains of the Palaeolithic in Europe.

With the 3D volumetric models, we indisputably identified, researched, and documented the internal structure of the artefact. Changes and deformations (cracks, fractures, holes, openings, risky places of disintegration or fracture) are clearly visible and located in these models (Fig. 6). The critical points of the internal structure of the artefact were thus determined and marked on the volumetric 3D model (Fig. 7). Two pronounced internal deformations were found: a longer crack and a more pronounced fracture.

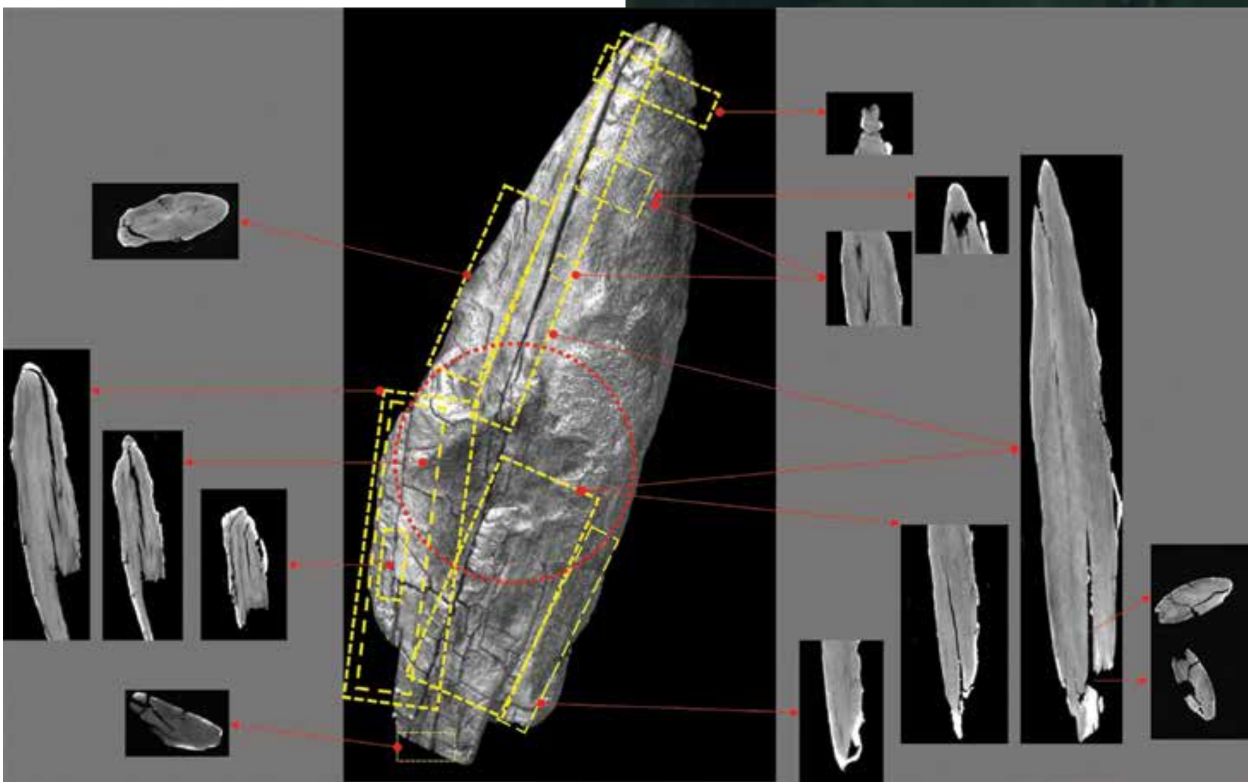
8 Microtomographic two-dimensional images of the Paleolithic wooden point and its surface 3D model were made with a microtomographic reader MicroXCT 400 Laboratory for Cement, Mortar and Ceramics, Institute of Civil Engineering of Slovenia, Dimičeva ulica 12, SI-1000 Ljubljana, http://www.zag.si/fig./ Mikrotomografske 2D slike paleolitske lesene konice in njenega površinskega 3D modela je z mikrotomografskim čitalnikom MicroXCT 400 opravila Lidija Korat iz Laboratorija za cemente, malto in keramiko, Inštituta za gradbeništvo Slovenije, Dimičeva ulica 12, SI-1000 Ljubljana, http://www.zag.si/fig

in ohranjanju ostalin kulturne dediščine.

S prostorninskim 3D modelom smo lahko natančno identificirali, raziskali in dokumentirali notranjo strukturo artefakta. Deformacije (razpoke, zlomi, razpad) so jasno vidne in locirane. Prostorninski 3D model je uspešno dopolnil vedenje o značilnostih in posebnostih sprememb ter revidiral pomanjkljive in z dejstvi ne povsem podprte ocene sprememb na podlagi površinskih 3D modelov.

Prostorninski 3D model - kot rezultat neinvazivne rentgenske tehnike - celostno dopolnjuje informacije o dragocenih arheoloških ostalinah. Z njegovo pomočjo in širokim naborom informacij, ki jih vsebuje rekonstruirani 3D model iz mikrotomografskih 2D slik, arheologija ne bogati le dokumentacijo o arheoloških predmetih, ampak pomembno širi vedenje o notranji strukturi in posebnostih artefakta, o preteklih tehnologijah, posreduje pa tudi natančnejše volumetrične podatke. Prostorninski 3D model skupaj s površinskim 3D modelom ponuja popolne informacije o trenutnem stanju izvirnika. Tak pristop lahko uspešno uporabimo pri pravilnem izboru tehnik konserviranja, analizi in vrednotenju, pri vizualizaciji prostorske predstavitve predmeta, aditivni arheologiji in pri pravočasnem načrtovanju postopkov za shranjevanje in zaščito ostaline. Pomen površinskih in prostorninskih 3D modelov ter računalniških prostorskih in površinskih 3D vizualizacij bogati standarde arheološke in kulturne dediščine, ki jih priporočajo Londonska listina, Seviljska

7. Critical internal structure of the point - 2. / Kritična notranja struktura konice - 2. (By: E. Guček Puhar)



In the upper part of the wooden point there is a crack, which runs all the way to the middle of the point along

the core strip and extends from the surface to a depth of 2 to 22 mm. Four millimetres below the tip of the point (transversely at the beginning of the upper crack) there is a risk of a transverse fracture (chipping) of the point (Fig. 7).

If the tendency of the crack to spread continues across the middle of the point along the core strip (Fig. 6) in the direction or transversely to the direction of the observed major fracture (note that this crack propagation tension is currently not detected) to the lower and planting part of the point, which is currently 18 mm away from said crack, we could face the risk of breakage of the point. A comparative analysis of surface 3D models from 2018 and 2019 does not confirm this trend.

Given the observed state of the internal structure of the point, we can estimate that the volumetric 3D model clearly pointed out that the greatest risk for the existence of the current shape of the point is the fracture and deviation in the lower central part (Fig. 7 - red circle bounded area). Deformations in this part affect the bending of the planting part, which (except for the right initial part) still has a fairly solid wood structure.

The internal dynamics of changes in this relatively short time interval shows a tendency towards stabilization. Significant changes found on the surface 3D models in 2009 and 2015 or 2017 may have been the result of various invasive processes to which the point was exposed during the dating and conservation processes (phase of stimulated intensive swelling and heat treatment - drying).

With the surface 3D models and the microcomputed tomographic analysis of the volumetric 3D model we wanted to draw attention to the importance of using computed tomography in computer and machine vision, especially in dealing with particularly sensitive and poorly stable objects in archaeology and for protecting, presenting and preserving cultural heritage.

With the 3D volumetric model, we were able to accurately identify, investigate, and document the internal structure of the artefact. Changes in deformation (cracks, fractures, decay) are clearly visible and located. The volumetric 3D model successfully complemented the knowledge about the characteristics and peculiarities of the changes and revised the deficient and not factually supported assessment of the changes based only on the surface 3D models.

A Palaeolithic Wooden Point from Ljubljana Moor (3D volumetric values / measurements)						
3D DIMENSION (Coordinate axes – x-y-z) (VOLUME)	In situ	Ex situ – 3D MODELS				
	DISCOVERY (2008)⁰	Ex situ (2009)	THE BEGINNING OF CONSERVATION (2013)	END OF CONSERVATION (2015)	Ex situ (2017)	Ex situ (2018)
	<0	1	2	3	4	5
	μm	μm	μm	μm	μm	μm
X	160000	155616	160958	152709	151768	150061
Y	51000	50014	52274	50594	50348	49073
Z	25000	25580	28810	23856	23585	22821
		μm^3	μm^3	μm^3	μm^3	μm^3
V		70654	80404	66382	65238	61348
V%-1		α - 1	+13,8%	-6.0%	-7.7%	-9.6%
V%-2			α - 2	-17.4%	-18.8%	-20.5%

⁰ - initiative traditional measurements; α - index base

Tab. 1. Volumetric comparison of 3D models of the Palaeolithic wooden point (2009-2018). / Volumetrična primerjava 3D modelov paleolitske lesene konice (2009 - 2018).

načela in ratificirane mednarodne pogodbe. Hkrati pa lahko računalniška tomografija in rekonstrukcija prostorninskih in površinskih 3D modelov iz tomografskih ali mikrotomografskih slik učinkovito prispeva k uveljavitvi Pravila 4 iz Dopolnitev UNESCOVE konvencije o zaščiti podvodne kulturne dediščine, ki državam podpisnicam priporoča uporabo nedestruktivnih postopkov in metod pri ohranjanja ostalin kulturne dediščine.

Primerno bi bilo, da arheološka stroka pogosteje kot doslej uporablja neinvazivno računalniško tomografijo pri obravnavi posebej občutljivih ostankov predmetov kulturne dediščine in vključi izdelavo prostorninskih 3D modelov v dokumentarne arheološke zbirke. Prostorsko in površinsko 3D upodabljanje iz 2D CT slik ne samo širi znanje o prikazanih predmetih, temveč omogoča nadaljnjo analizo, identifikacijo, razširja polje arheometrije ter omogoča bolj kakovostno 3D upodabljanje.

Arheologom, konservatorjem in restavratorjem računalniška tomografija, podprta z umetno inteligenco, globokim učenjem in drugimi novimi metodami računalniškega vida, lahko zagotovi tudi pravočasne in zanesljive dodatne informacije za načrtovanje, izbiro in izvajanje učinkovitejšega ohranjanja dragocenih ostankov lesene kulturne dediščine.

**Članek povzema rezultate več analitičnih študij in predstavitev uporabe računalniške analize in metod ali tehnik za rekonstrukcijo 3D modelov arheoloških predmetov. Predstavljene so bile na različnih mednarodnih konferencah in srečanjih med letoma 2017 in 2020 in objavljene v tujih virih (glej bibliografijo). S študijami in raziskovalnimi poročili želimo analitične raziskave in uporabo računalniških orodij približati strokovnjakom, ki si zelo prizadevajo pri terenskih izkopavanjih in iskanju učinkovitih metod in tehnik za ohranjanje ostankov lesene podvodne kulturne dediščine.

The volumetric 3D model comprehensively complements - as a result of a non-invasive X-ray technique - information on the valuable archaeological remains. With its help and a wide range of information contained in the reconstructed 3D model from microtomographic 2D images, archaeology not only enriches documentary information about archaeological objects, but significantly expands the knowledge about the internal structure and features of artefacts, past technologies, and provides more accurate volumetric data.

The volumetric 3D model along with the surface 3D model provides complete information about the current state of the original. The approach can be successfully used in the correct selection of conservation techniques, analysis and evaluation, in the visualization of the spatial representation of the artefact, additive archeology and in the timely planning of artefact storage and protection procedures. Surface and volumetric 3D models enriche the standards for documenting of archaeological and cultural heritage recommended by The London Charter, the Seville Principles and other ratified international treaties. At the same time, computed tomography and reconstruction of volumetric and surface 3D models can effectively contribute to the implementation of Rule 4 of the UNESCO Convention on the Protection of Underwater Cultural Heritage, which recommends that signatory states use non-destructive procedures and methods to preserve cultural heritage.

It would be appropriate for the archaeological profession to use non-invasive computed tomography more frequently for acquisition of volumetric 3D models in documentary archaeological collections. Spatial and surface 3D rendering from 2D CT images not only expands the knowledge of the studied objects by allowing further analysis and identification of materials, but also enhances the possibilities for their visualization.

Archaeologists, conservators, and restorers can benefit by computed tomography, supported by artificial intelligence, deep learning, and other new computer vision techniques, to provide timely and reliable additional information to plan, select, and implement more effective conservation methods of valuable wooden cultural heritage.

**The article is a summary of several studies and presentations on the use of computer analysis and methods for reconstruction of 3D models of archeological objects, which were presented at various international conferences and meetings between 2017 and 2020 and/or published in international journals (see bibliography). Through such studies and research reports, we aim to bring such analytical approach and the use of computer tools closer to the experts who invest great efforts in field excavations and in the search for effective methods and techniques for the conservation of underwater cultural heritage.

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