# A FRAMEWORK FOR USING HANDHELD 3D SURFACE SCANNERS IN QUANTIFYING THE VOLUMETRIC TUFA GROWTH

## GEOMORPHOMETRY 2021, PERUGIA ITALY


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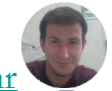
IVAN MARIĆ – University of Zadar, Department of Geography, Croatia, imaric1@unizd.hr 

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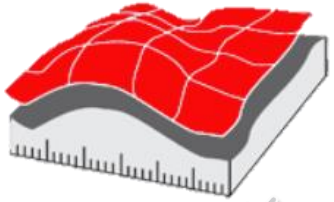

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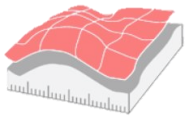
# INTRODUCTION AND BACKGROUND



- **Karst landscapes** are one of the most **complex** and **vulnerable** areas in the world (Van Beynen and Townsend, 2005, Ford and Williams, 2007, De Waele et al., 2011, Brinkmann and Parise, 2012).
- The most spectacular forms of universal **scientific** and **aesthetic** values in these landscapes are considered to be **tufa** (Cukrov and Lojen, 2010, Qiao et al., 2016) and **travertine** cascades (Ford and Pedley, 1996).
- These deposits can be found worldwide* (Viles and Pentecost, 2007), often are **protected** areas (Pentecost, 2010) and **popular** tourist destinations.
- **Tufa** is **localized**, **highly porous**, **mainly monomineral** rock (Capezzuoli et al., 2014) formed in freshwaters (Ford, 1989) of **ambient** to near-ambient temp. usually including the remains of **micro-** and **macrophytes**, **invertebrates**, and **bacteria** (Barešić et al., 2021).
- **TFD** - quantification of the tufa **growth** and **erosion** rates (Viles, Pentecost, 2007), expressed as the **mass**, **volume** or **height** accumulated or eroded at some period per unit area.

National Nature Reserve Jiuzhaigou, **China**

Mono lake, **USA**

Havasupai canyon, **USA**


Naukluft Mountains, **Namibia**

Dunn's River Falls, **Jamaica**

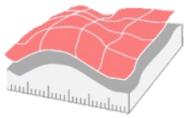
Hierapolis-Pamukkale, **Turkey**

Huanglong National Park, **China**

National park Una, **Bosnia and Herzegovina**

National park Krka, **Croatia**

- Sources: (Alexandrowicz, 2004, Carthew et al., 2006, Viles and Pentecost, 2007, Qiao et al., 2016, Liu, 2017)
- 88 tufa and travertine Quaternary deposits are located only in China, most of which are still active (Pentecost and Zhang 2001; Viles and Pentecost, 2007).

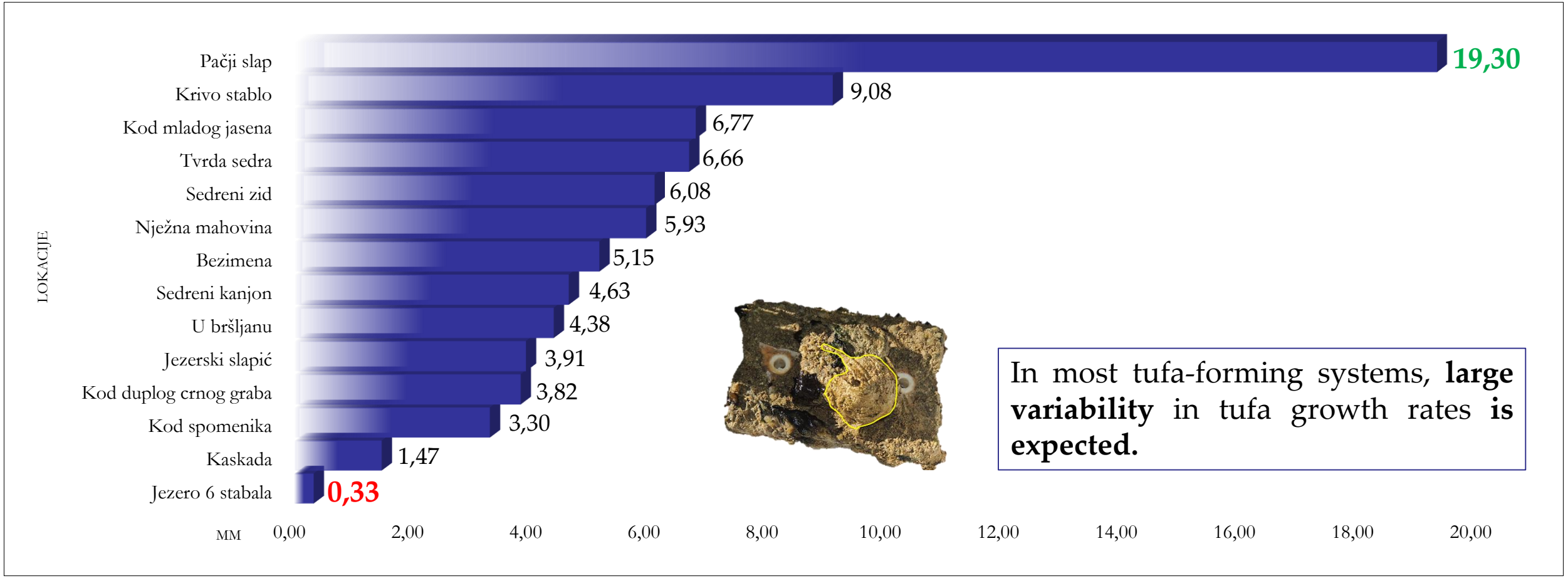


- Accurate determination of TFD is important because:

1. It addresses the fundamental geomorphological question of the **individual element evolution** in the karst landscape;
2. Differences in the TFD may indicate on the **changes** in the tufa environment (eg. the **tufa degradation process**) (Liu, L. 2017).
3. TFD is the result of biohydrochemical parameters on the basis of which the **characteristics** of the tufa-forming system are determined.

- However, achieving satisfactory measurement accuracy **is not easy** given that the average annual TGR is **around a few mm**.
- Despite the fact that recent advances in sensors have revolutionized the ability to **quantify the Earth's surface** at different **scales** (Smith et al., 2016, Verma et al., 2019) until now, to our knowledge, TFD has not been measured using **handheld 3D surface scanners**!

- **Example of Tufa Growth Rates at Skradinski buk, National Park, Krka**






In most tufa-forming systems, **large variability** in tufa growth rates **is expected.**

Marić, I., Šiljeg, A., Cukrov, N., Roland, V., & Domazetović, F. (2020). **How fast does tufa grow? Very high-resolution measurement of the tufa growth rate on artificial substrates by the development of a contactless image-based modelling device**. *Earth Surface Processes and Landforms*, *45*(10), 2331-2349.


OBJECTIVES

1. Test the **applicability** of *Artec Eva* in the measurement of small limestone plates (PLs) used in TFD analysis.

2. Propose a **framework** for using the 3D surface scanners in the quantification of tufa growth and erosion rates.

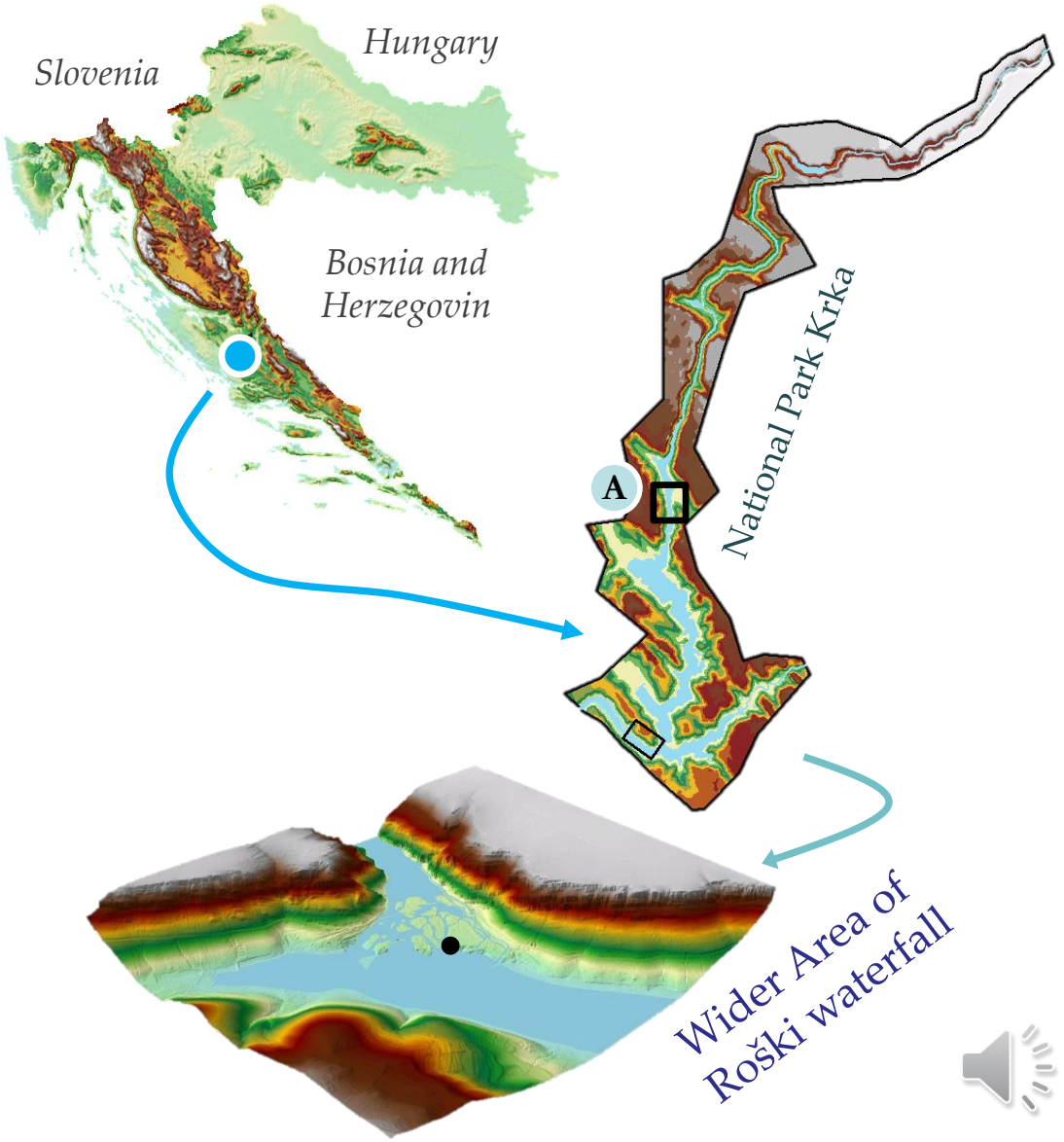
3. Determine the **average tufa volumetric growth** at Roški waterfall (National Park Krka, Croatia).

Roški waterfall, National Park Krka, Croatia



RESEARCH AREA

- The research area was the **Roški waterfall** at National park "Krka" (NPK) located in *Šibenik-Knin County* (Croatia).
- It is one of the **most famous landmarks** of the NPK.
- The beginning of the tufa barriers is made up of a series of **small cascades** (called a **"necklace"** by the locals).
- The length of the barrier is nearly **650 meters**, with a total difference in altitude of 22.5 meters.



# MATERIALS AND METHODS

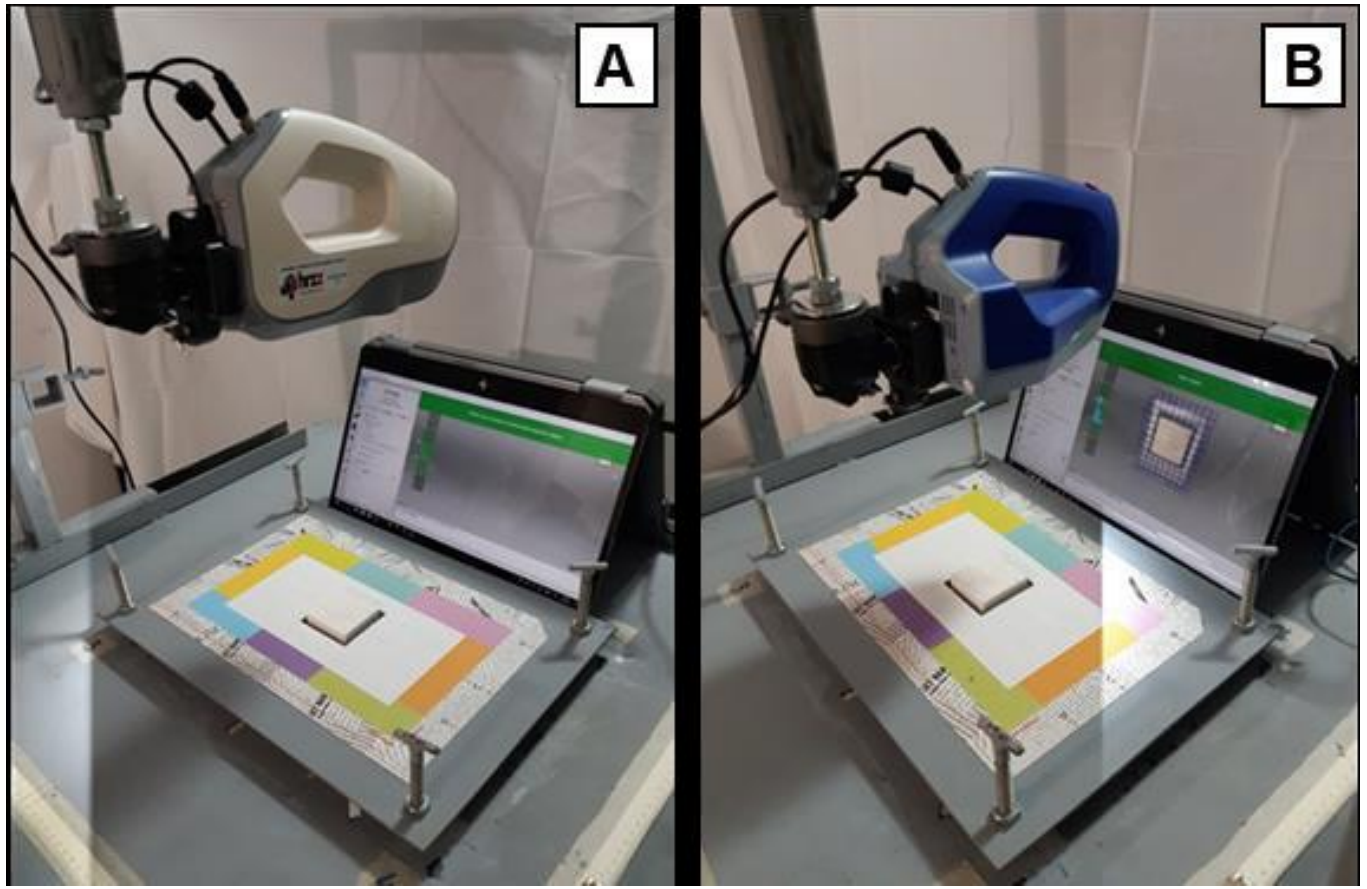
# Comparison of *Artec Eva* and *Space Spider*



- The **applicability** of *Artec Eva* in the measurement of small objects was examined using the ***Artec Space Spider.***

- ***Space Spider*** is a newer 3D surface scanner designed for measuring small objects (3D resolution up to 0.1 mm, 3D point accuracy up to 0.05 mm and a working distance of 0.2 – 0.3 m.)

- ***Artec Eva*** is a compact and lightweight 3D scanner (3D resolution is up to 0.5 mm at a working distance of 40 cm to 1 m, 3D point accuracy is up to 0.1 mm).




Measurements of the test PL using the ***Artec Eva*** and ***Artec Space Spider*** in created **local coordinate system (LCS)**

LCS eases the adjustment of the 3D model position onto one of the coordinate plane.

# Comparison of *Artec Eva* and *Space Spider*





- The **volume** generated using ***Space Spider*** was used as the **benchmark (true)** data.

- ***S***cans were processed using the **same workflow process**.
- Two 3D models were imported into one ***Artec Studio project*** and **align using LCS**.

- The accuracy of the *Eva* is then expressed with **absolute (AE)** and **relative error**.
- AE = difference between the "true" (*Space Spider*) and the measured value (*Eva*).

- Also, the accuracy of *Artec Eva* is analyzed through the **surface-distance map** from which the **RMS** and **MAD** were calculated.

- **Surface-distance map** enables the comparison of two 3D models and assesses the deviation of their forms. It is often used as **quality control** measure.

# Installation of limestone plates (PLs)



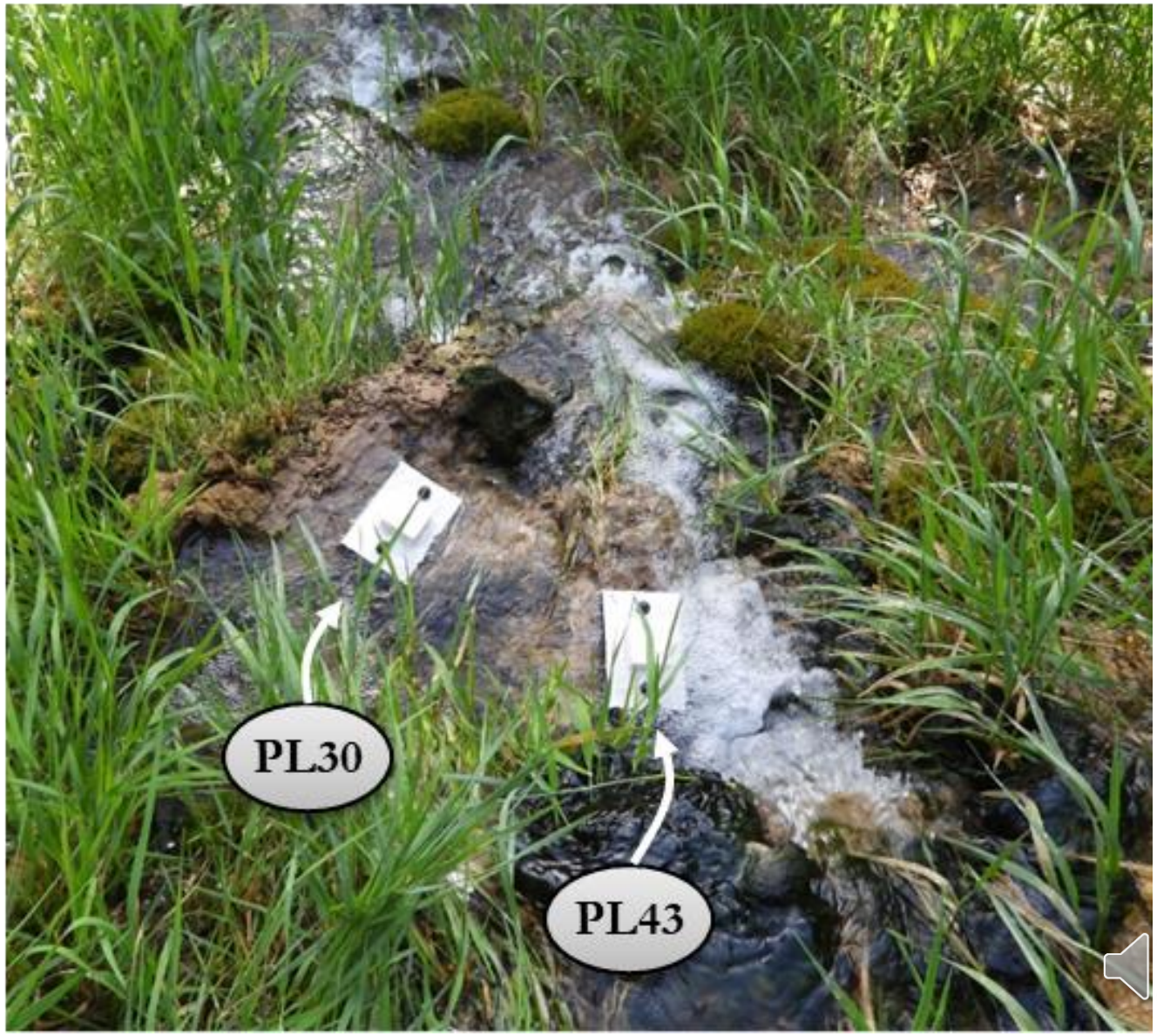
- Tufa volumetric growth was measured on the upper surface (25 cm²) of two limestone plates (PLs).
- The PLs were positioned in the immediate surroundings of the **Roški waterfall.**
- **Specific code** was engraved beneath each PLs and unique **ID** and **name** were assigned to a location.
- Each PL was measured using *Artec Eva* before installation in the tufa forming watercourse.
- PLs were fixed with **two stainless steel screws**. Before the second measurement, which was done after **six months**, they were left drying at room temperature for 4 days.

Installed PLs near Roški waterfall

Example of code engraved beneath PL

# Installation of limestone plates (PLs)

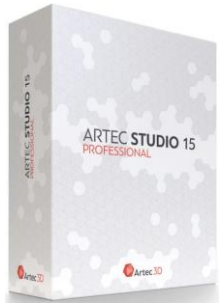


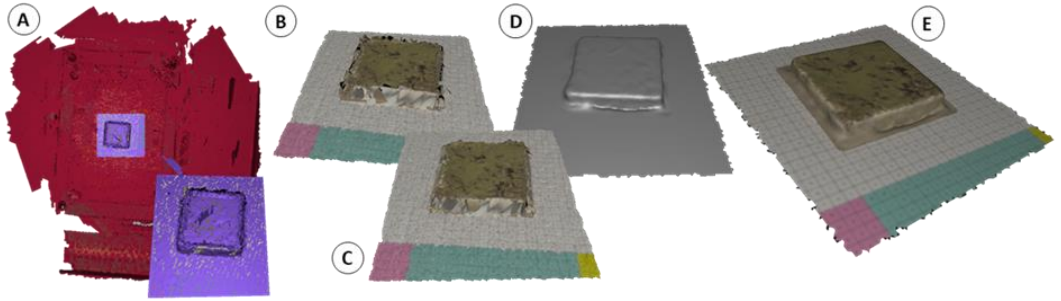



# Data Processing of Scans



- Scans of the initial and final PLs were processed in ***Artec Studio 14 Professional***. It is an industry-recognized software designed for advanced 3D scanning and data processing.
- No scan segmentation occurred during the scanning therefore processing workflow included **five steps**.



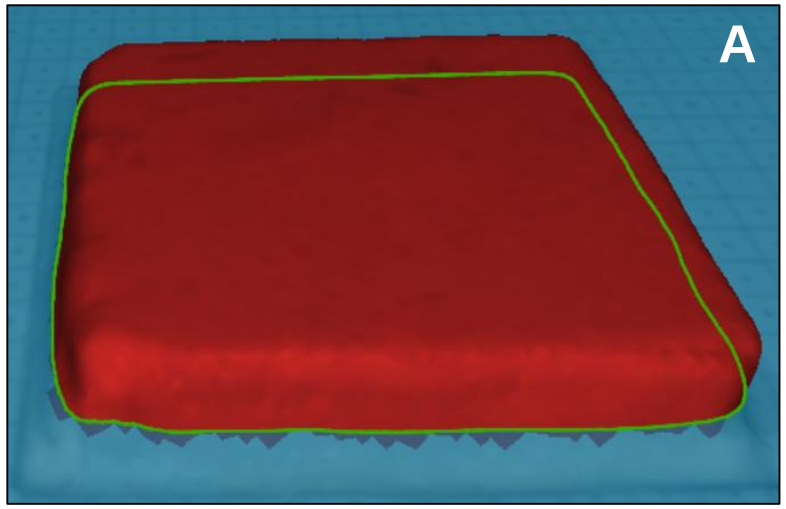

1. ***Crop surroundings***
2. ***Global registration*** - algorithm converts all one-frame surfaces into a single coordinate system
3. ***Outliner removal*** - eliminates noise or larger errors on the scans.
4. ***Sharp fusion*** - creates a unique model surface with respect to the initial input.
5. ***Apply texture*** - acquired by integrated 1.3 MPx camera.

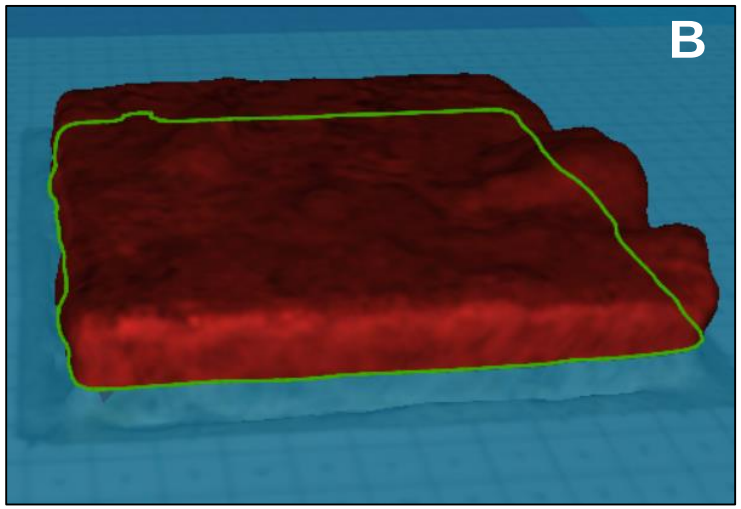
# Calculation of Volumetric Tufa Growth

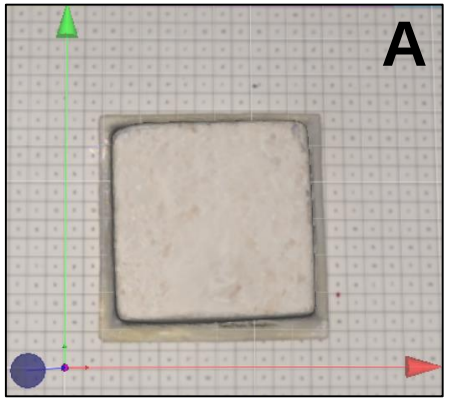


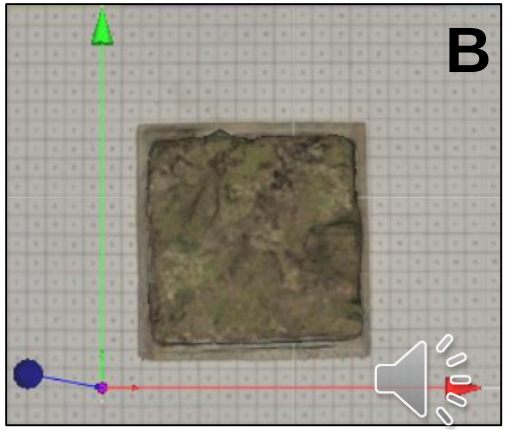
- The volume of PLs and formed tufa was calculated from derived 3D models using the ***Measure - Section*** tool.
- Volume was calculated above the **specific plane of the** (LCS).
- The initial and final 3D models were aligned using the **LCS.**

- The **volumetric (mm³) tufa growth** was calculated as the **<u>difference</u>** between the volume of the (B) final model and the volume of the (A) initial PL model.



# RESULTS AND CONCLUSION

# Applicabilty of *Artec Eve* in small object scanning



- Volume of PL32 measured with *Artec Eva* and *Space Spider* was compared.
- The AE of measurement with Artec Eva was **904,66 mm³.** Respectively, Artec Eva **overestimated the PL volume** by 904.66 mm³, or **6.38%**, which is expected since it is intended for scanning the smaller subjects

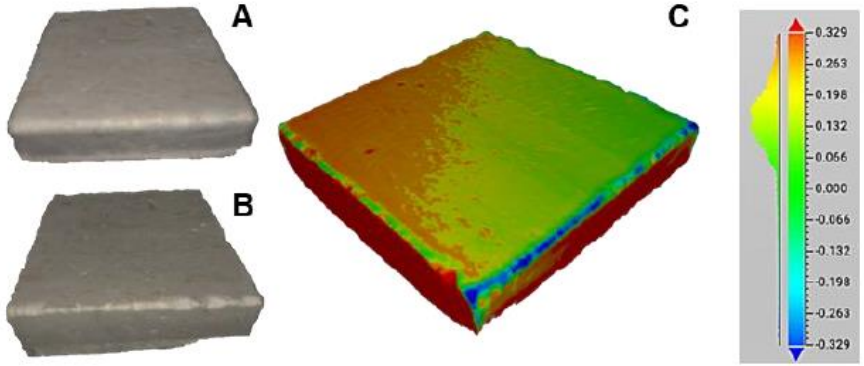



**Table 2.** PL volume (mm³) calculated in *Artec Studio* for *Artec Space Spider* and *Artec Eva*

| PLCODE | Volume (mm³) | |
|---|---|---|
| | *Artec Eva* | *Artec Space Spider* |
| PL32 | **15077.14** | **14172.48** |

- **<u>Surface-distance map</u>** is a colored rendering on the particular regions of surfaces. Corresponding values of distances and their distribution can be read from the graduated scale with the histogram.

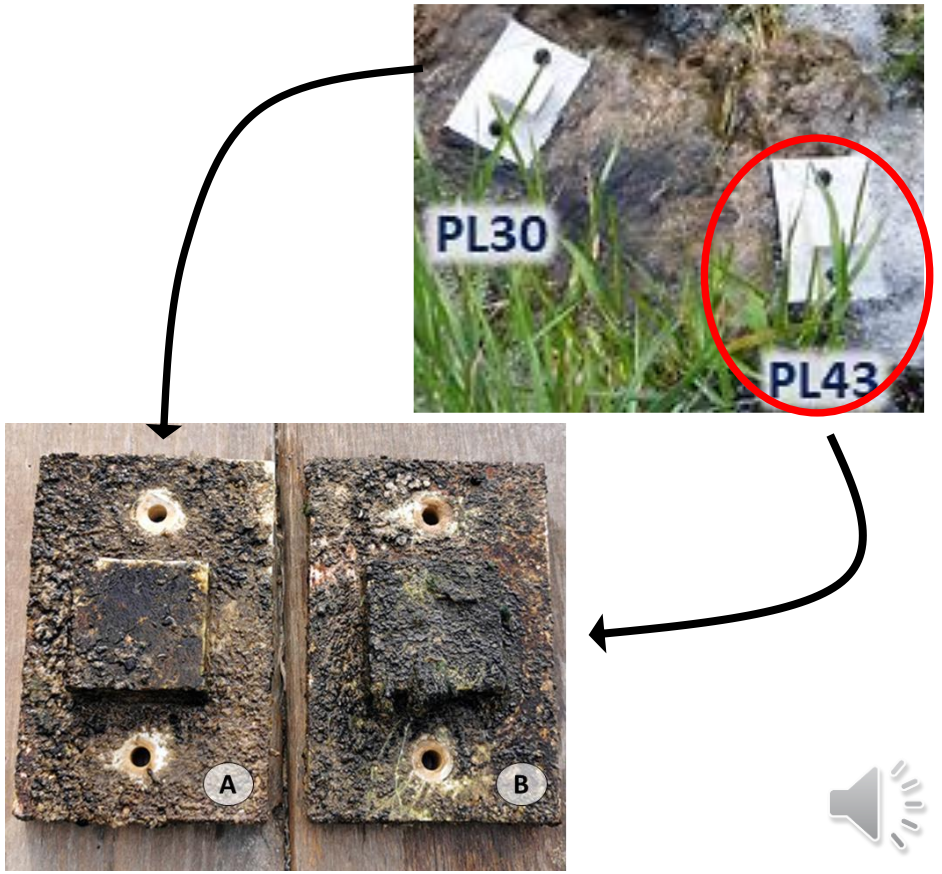
- Blue color corresponds to negative distance while red represents positive distance. **RMS was 0.259** while MAD was **0.281 mm.**

# Volumetric Tufa Growth at Roški waterfall

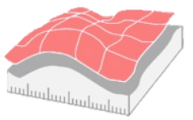


- The PLs were removed from the site on 10th January, 2020, after around six months spent in water.
- Despite the fact that the PL30 and 43 were placed in a flow at a distance < **30 cm**, volumetric TG for **PL43 was 791,70 mm³** larger than on the **PL30.** This is due to the characteristics of the PL43 **micro locations**.
- The PLs are set at a similar slope, but the PL43 is more exposed to the **water spray zone** than the PL30.
- The mean volumetric TG for a location was **1490,02 mm³.** The data obtained show that the tufa grew **7,72 mm³** per day.

| PL CODE | Volume (mm³) | | Volumetric tufa growth (mm³) |
|---|---|---|---|
| | Initial state | Final state | |
| PL30 | 14070,08 | 15164,25 | **1094,17** |
| PL43 | 15258,66 | 17144,53 | **1885,87** |
| MEAN | | | **1490,02** |




CONCLUSION



- We have demonstrated a framework for using handheld 3D surface scanners in quantifying the volumetric tufa growth. The **mean volumetric tufa growth** for Roški waterfall was **1490,02 mm³** in six month period on an area of 25 cm².
- Although *Eva* is not intended for measuring small objects (eg. surface area of 25 cm²), it can be can provide somewhat reliable volumetric tufa growth results if the dimensions of the artificial substrates (PLs) are **slightly bigger**.
- In this case, *Artec Eva* overestimated the PL volume INITIAL STATE by **904.66 mm³**, or **6.38%.**
- The reason is the **small size of the scanned object** and the fact that **no tufa was present** at the upper surface of the PL while determining the accuracy.
- If possible, we suggest using ***Artec Spider*** in monitoring the TFD when the artificial substrate is small limestone PL.


Thank you for attention!