A COMPARISON OF DIFFERENT SOFTWARE SOLUTIONS FOR 3D MODELLING

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Autodesk ReCap 360

Autodesk ReCap 360 is a free online service provided by Autodesk Company. This software exists even as a standalone commercial version, with an optional trial/student version. Principally, the user uploads a 'photo-set' on Autodesk servers where all the data are processed and the user is subsequently informed via email about the process being completed. The use of this software is, in general, not recommended, as there are only limited possibilities to design the results. All possible options are presented on the project's start page. Besides the 'Project Name', it is possible to choose 'smart cropping' (allows to ignore areas 'behind' cameras) or 'smart capturing' (this option should improve resulting texture; it is currently in the beta-testing phase); measurement units are available only for "rcs" format (ReCap native format), but the final model can be viewed or downloaded in several other formats (obj, rcm, fbx, ipm, rcs and ortho). The service is limited to a maximum of 250 photos per task (based on ReCap1). Whilst the upload time is unavoidably influenced by the internet connection quality, the processing time cannot in any way be predicted. Usually it takes up to several hours, depending on the server connectivity, workload and the size of the photo-set.

For the presentation of the resulting 3D models created by ReCap 360, the CONPRA secondees prepared nine different models that were, in some cases, post-processed in Meshlab (Meshlab1). 'Model 1' was created from 99 photos of the 'Vinča set' (see chapter 'Data Acquisition'). The final textured result in "*.obj" takes up more than 1.1 GB of space and it is in any way fit to be used by 'ordinary computers'. The result includes a lot of gaps, probably

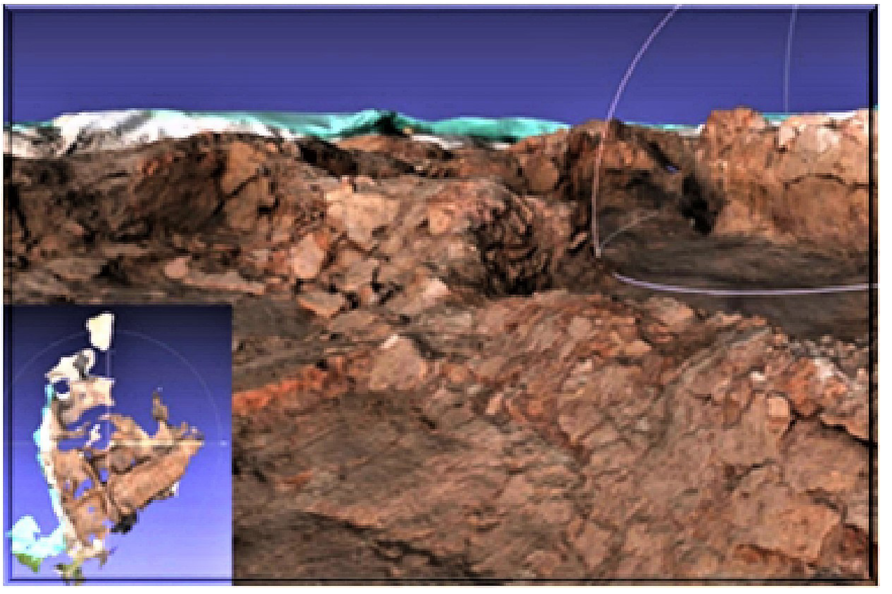

Figure 16. ReCap 360, Model 1 (photos by A. Žitňan, Via Magna).

due to the processing algorithms that were not able to stitch and properly reconstruct the dense point cloud and the final mesh. Figure 16 shows the preview exported from Meshlab. A detailed examination of result allows me to state that the final resolution and level of detail are satisfying, but errors in the model as a whole cannot be overlooked.

The next example is composed of 101 photos from the same photo-set and its size is about 1.05 GB. The model focuses on details of a Neolithic kiln and it can generally be observed that the result is much more satisfying when the redundant parts are removed in Meshlab. Nonetheless, the gaps still disrupt the result and render it unsatisfying and non-usable as, for example, a form of archaeological documentation (Figure 17).

The model presented on Figure 18 is composed of the entire photo-set (249 photos). It had the size of 1.53 GB before redundant parts were trimmed off. Unfortunately, such a large file was very difficult to process, so it confirms the impression that working with 3D models requires a powerful computer. The main parts of the model seem to be of relatively good quality and there are no gaps. Based on this, it can be concluded that the gaps in the previous two models were caused by the insufficient number of photos used, or an unsuitable photo-set. There was absolutely no problem in the service itself. But, the bad quality of the model outside the central parts of feature is another issue (see Figure 19).

'Models presented on Figure 20 are composed of 18 photographs (approx. 0.122 GB both) of original Roman tile photographed in the exhibition area of the Museum of Novi Sad. Because of the indoor light conditions, higher ISO values (1000) had to be used, so the photos are slightly disrupted by the high ISO noise. Nonetheless, this model can serve as an illustration of the differences between the automatic model creation and the use of the above-mentioned 'smart cropping' and 'smart capturing' options. It can be stated that, the model created with default settings came out without gaps in the texture and there is also no visible difference in the texture quality. Further, the 'smart cropping' option was of no importance.

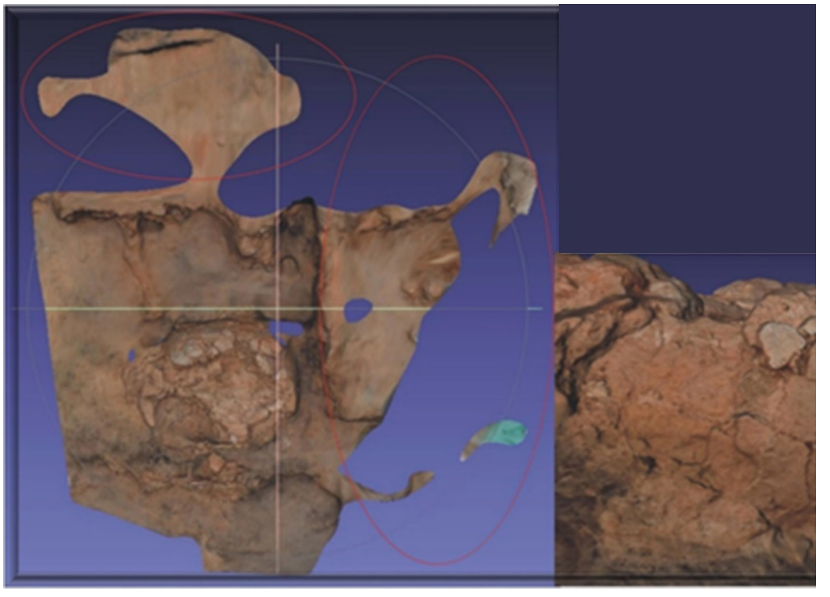

Figure 17. ReCap 360, Model 1 (photos by A. Žitňan, Via Magna)

Figure 21 shows model 6 (ca. 0.08 GB) which was sufficient to create a relatively good model and all errors and imperfections or deficiencies result from the input pictures. The blue background is inappropriate as it reflects blue undertone to the texture; moreover, it is too bold, so the service had to use blue texture as filling for the holes that represent missing potshards.

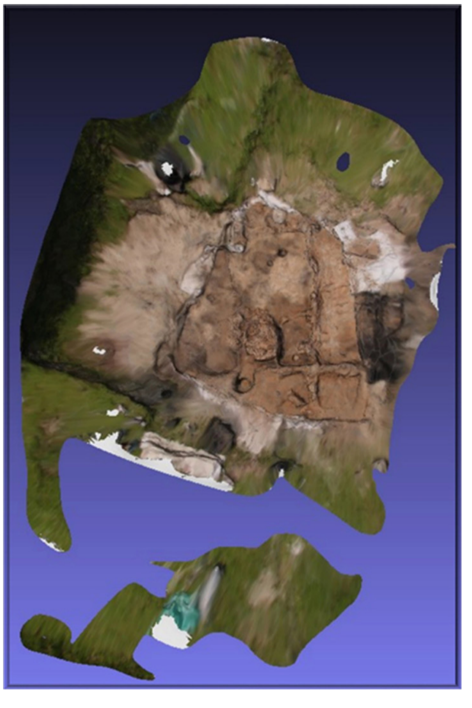

Figure 18. ReCap 360. Model 1 (original result; Photos by A. Žitňan (Via Magna).

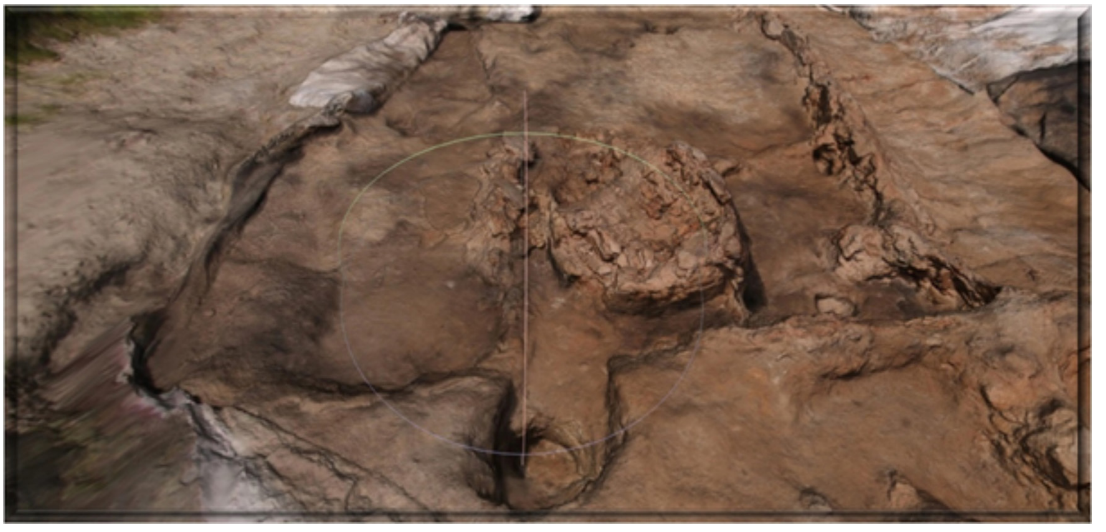

Figure 19. ReCap 360, Model 1; good quality central parts and bad quality of areas along the edges (e.g. lower left; photos by A. Žitňan, Via Magna).

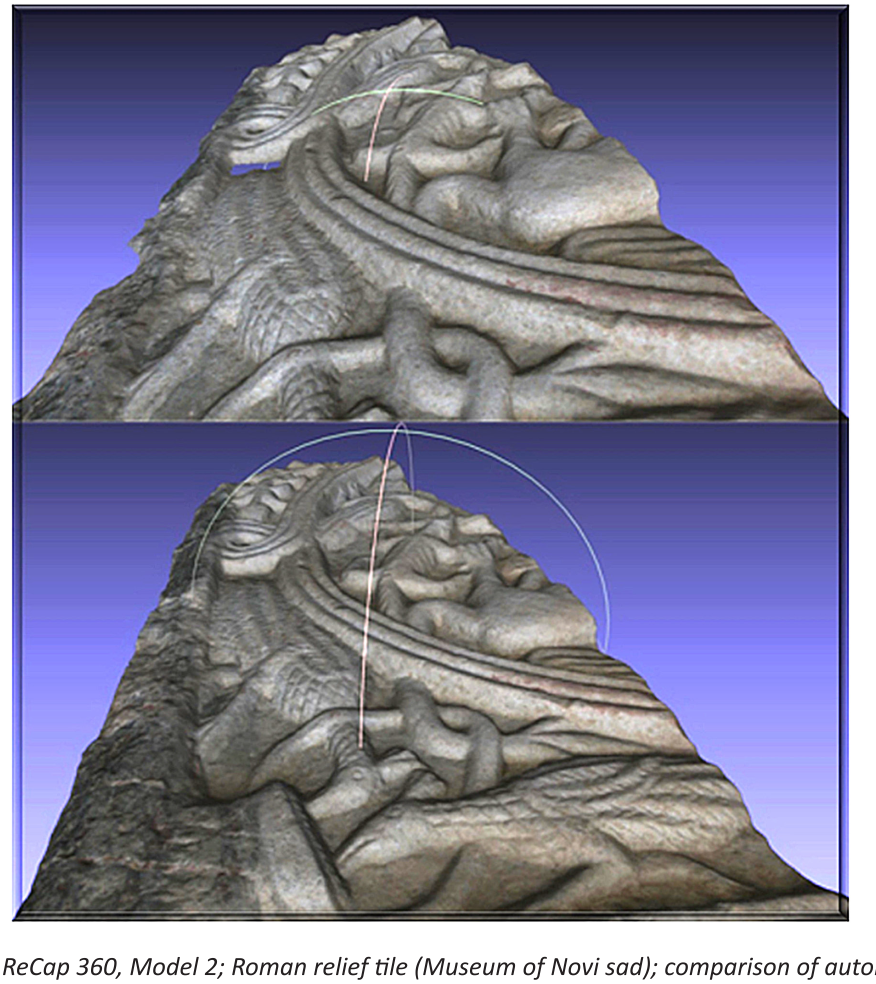

Figure 20. ReCap 360, Model 2; Roman relief tile (Museum of Novi sad); comparison of automatic/no adjustments (down) in recap 360 options and 'automated cropping' and 'smart capturing' option.

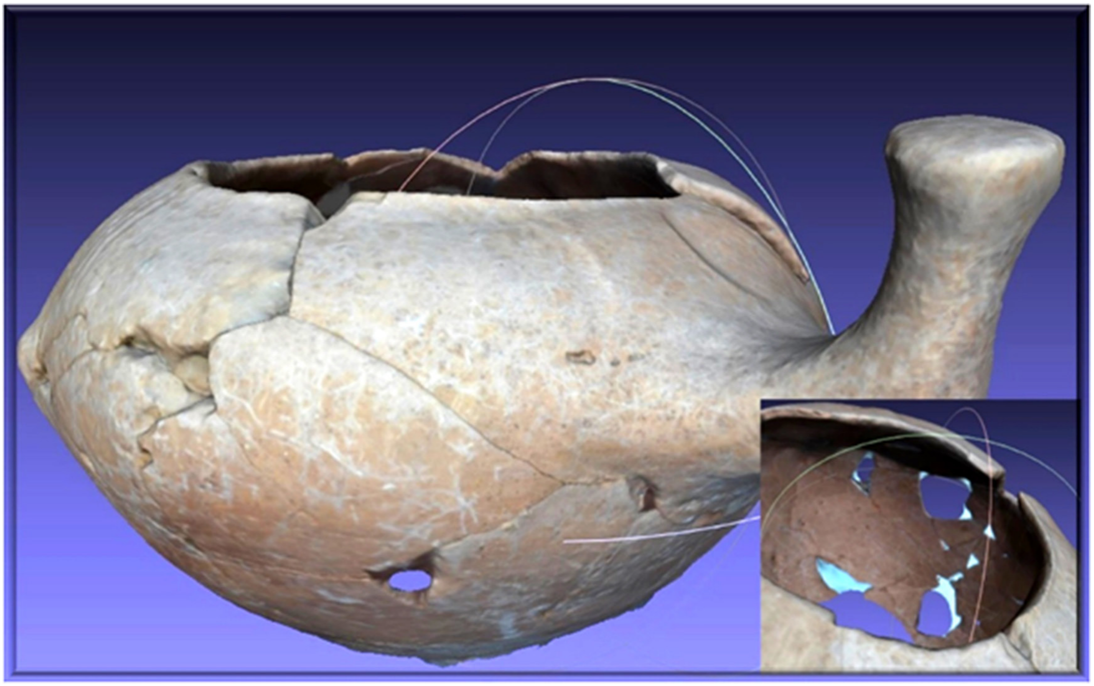

Figure 21. ReCap 360, Model 6 (photos by Z. Rejdovianová, Via Magna).

Figure 22. ReCap 360, Model 7 (photos by Z. Rejdovianová, Via Magna).

Figure 22 shows model 7 (another vessel from the Bronze Age Vinča) created from 49 photos. This model suffers from the same imperfections as the previous one. The miniature (lower right corner in the figure) proves the influence of bold blue background on the final texture. The texture imperfections are most certainly caused by the quality of the photos. Also, it can sometimes happen that the input surface has not enough of alignment points (Figure 23).

Figure 23. An example of the input picture for model 7 with indicated problems and errors (photo by Z. Rejdovianová, Via Magna).

Figure 24. ReCap 360, Model 8 (texture detail; photo by Z. Rejdovianová, Via Magna).

The vessel (model 8) was created from 31 photos (0.056 GB) and is shown in Figure 24. This model is used merely for presentation purposes since it illustrates well the quality of texture that is possible to gain via the web service. The rest of the vessel (its inner parts) is not modelled well because of the blurred photos.

Summing up 'Autodesk ReCap 360 web-service', it can be stated that this is quite a useful service, able to provide quality outputs. This is, perhaps, not so evident in the presented examples, but the outputs are highly influenced by the quality of photos. The gaps in model 9 are the only errors which cannot be explained. Similar to the other considered services (see below), it requires fast internet connection, but the server response (the speed of modelling) is very satisfying (in that view, it does not differ from commercial or free standalone software).

Autodesk 123D Catch

Autodesk 123D Catch is a web-based service similar to the one described above. It offers creation of 3D models, their cloud storage and download; moreover, the commercial version enables direct 3D printing. In contrast to ReCap, this service is limited to 70 photographs per model (Windows version; 123DCatch).

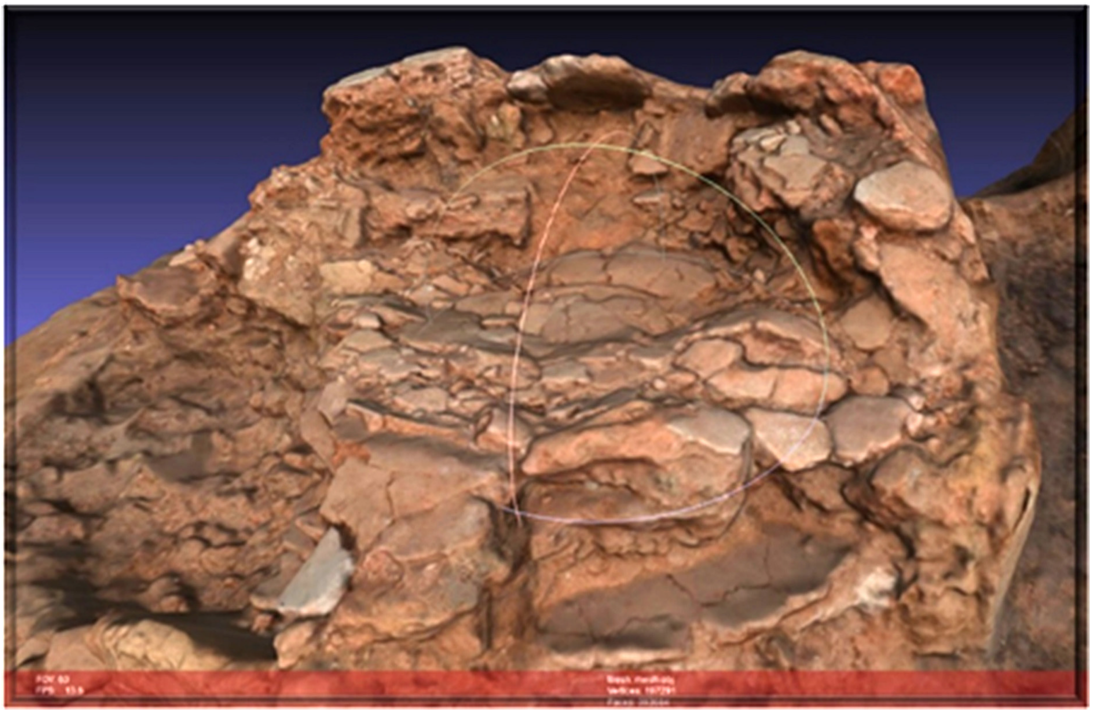

Figure 25. 123D Catch, Model 10 (photos by A. Žitňan).

Figure 26. 123D Catch, Model 11 (Roman tile and details).

The model labelled as model 10 was intended to use this service to produce a detail (kiln) using the 'Vinča site' photo-set (Figure 25). At first sight, there are no fundamental differences between this and the ReCap model, but, because of the service's limitation to 70 photos that can be used, it is not suitable for large models. Moreover, when zoomed-in to the maximum detail, it is clear that the texture detail is not high. Regardless of this, the mesh itself is useable.

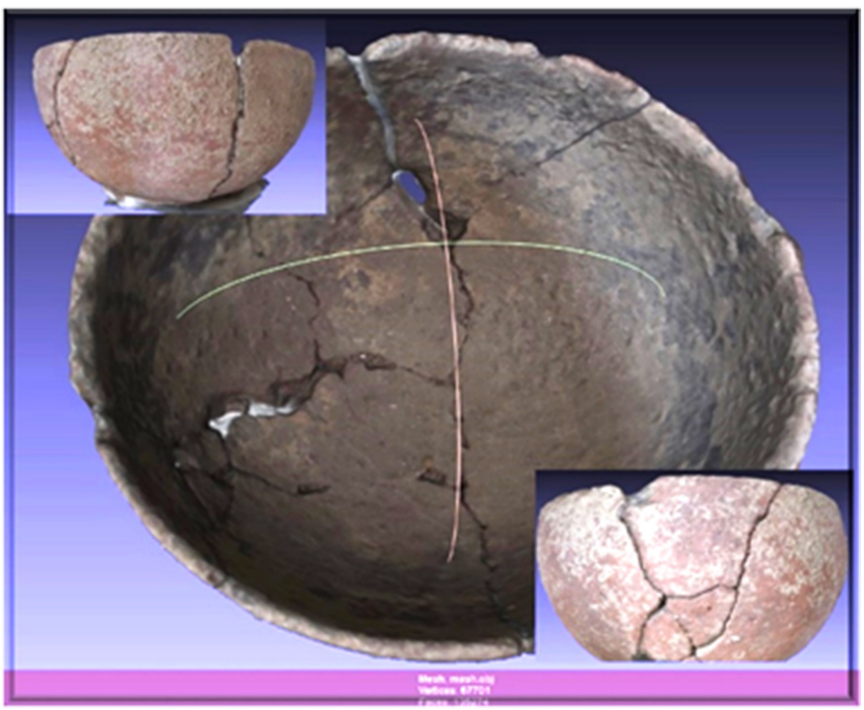

Figure 27. 123D Catch, Model 6, the Starčevo culture bowl.

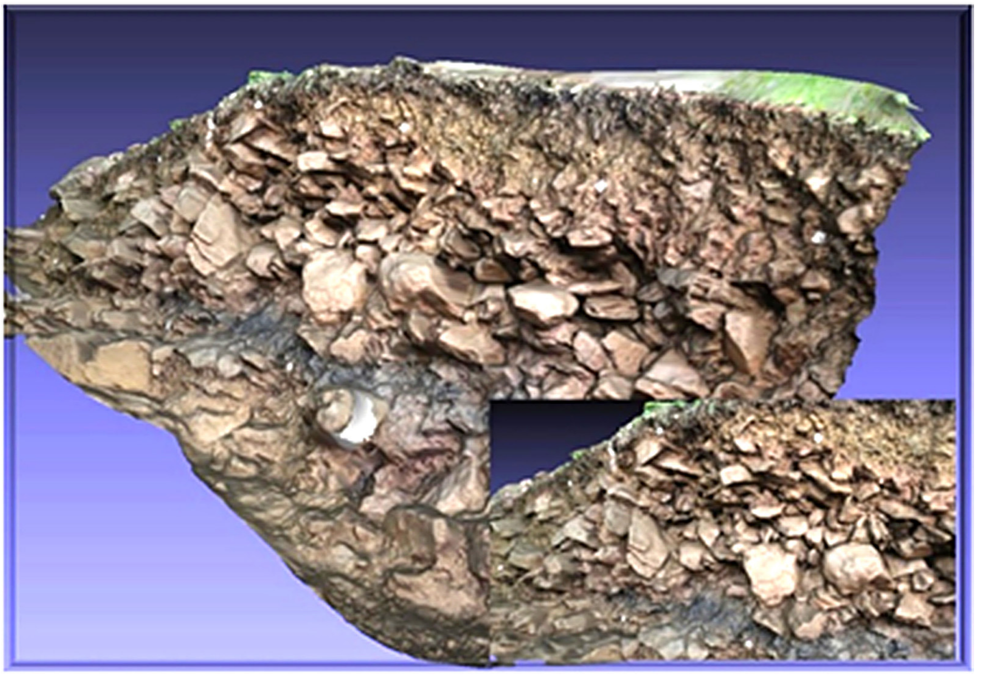

Figure 28. 123D Catch, Model 7, Vrcovice, trench (photos by D. Hlásek, TerraVerita).

Model 7 visualizes a trench profile from the site of Vrcovice (a hillfort in south Bohemia; ADC2010) and consists of 32 photos that were not initially created for 3D modelling (Figure 28). Nonetheless, the result is quite satisfying and presentable; the use of geo-referenced GCPs3 allows adding measurements, etc.

In conclusion, this application provides very good results for small features (e.g. artefacts, limited sections of the terrain). The important aspects are the service limitations: 70 pictures per photo-set and limited free download from Autodesk server (ten downloads per month).

Arc 3D 3 Ground Control Points

Arc 3D is a web-based group of tools allowing users to upload digital images to servers, where then a 3D reconstruction of the scene is performed. Similar to 123D Catch, there is a downloadable application. This application allows uploading and pre-processing of the pictures. The 3D reconstruction is based on the principle of auto-calibration, feature detection and correspondence, dense multi-stereo reconstruction and point cloud generation.

'ARC' has developed software to compute the reconstruction over a distributed network (cloud) of computers. This should make the procedure faster and more robust. Depending on the size, number and quality of the uploaded images, a typical job may take from 15 minutes to 2 or 3 hours (Arc 3D).

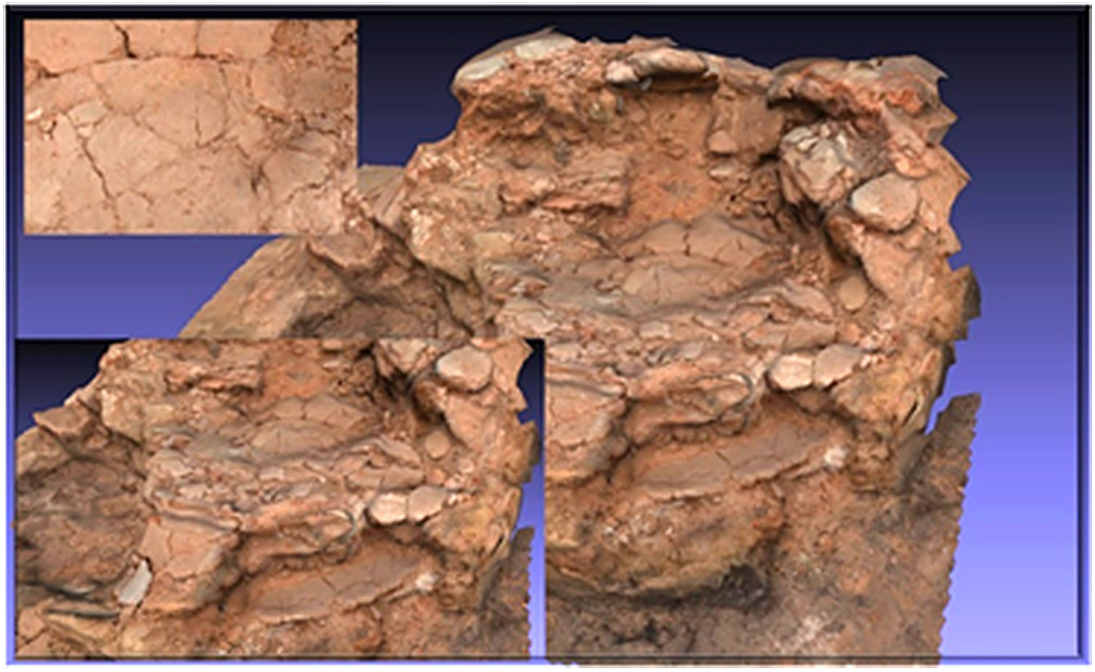

Figure 29. ARC 3D, Model 1 (photos by A. Žitňan, Via Magna).

Figure 30. ARC 3D, Model 2, Roman tile.

Figure 29 visualizes a detail of the Vinča kiln (0.035 GB). When compared against the 123D Catch result for the same kiln, Arc 3D provided more photo-realistic texture, but also more visible errors in places where the alignment and mesh reconstruction were not successful. The previously mentioned model of the Roman tile is of very bad quality (Figure 30). The team could not find a plausible explanation for the mesh and texture errors in this case. Similarly, model 7 from Vrcovice also came out with a lot of mesh and texture errors (Figure 31), but also with a very photo-realistic texture of significant quality. These results do not rank Arc 3D high, although several successfully completed projects (not only archaeological) indicate the potential of this service. During the testing of the service, it was noted that it crashes frequently (for related information see Vergauwen, Van Gool 2006; Tingdahl, Van Gool 2011; Cignoni et. al. 2008).

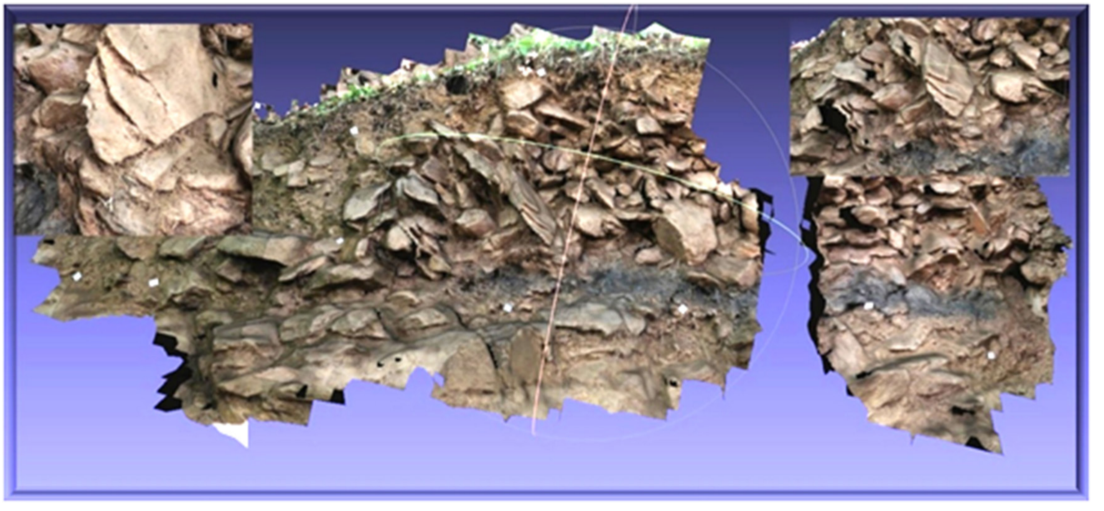

Figure 31. ARC 3D, Model 7 (photos by D. Hlásek, TerraVerita).

Standalone software solutions for 3D modelling

The following lines are devoted to standard software applications that are operational without the internet connection or secondary remote server services. An indisputable advantage is their self-sufficiency; on the other hand, they require powerful, high-end computer set that is able to run the whole process of 3D model creation (e.g. Photoscan2). Visual SfM (PMVS/CMVS) is a GUI application for 3D reconstruction using Structure from Motion.

The reconstruction system integrates several previous projects: SIFT on GPU (SiftGPU), Multicore Bundle Adjustment and Towards Linear-time Incremental Structure from Motion. Visual SfM runs fast by exploiting multicore parallelism for feature detection, feature matching, and bundle adjustment.

For a dense reconstruction, this program integrates the execution of Yasutaka Furukawa's PMVS/CMVS tool chain. The SfM output of Visual SfM works with several additional tools, including CMP-MVS by Michal Jancosek, MVE by Michael Goesele's research group, SURE by Mathias Rothermel and Konrad Wenzel, and MeshRecon by Zhuoliang Kang (VSfM1). In short, this open-source software package provides first steps of '3D-model creation': alignment, sparse and dense point cloud (with CMVS/PMVS extension; VSfM2) and computing. The subsequent steps must be carried out using Meshlab and Blender software (mesh and textured model). The first example shown here visualizes a trench profile from the site of Vrcovice as a compiled orthogonal photo (ICE1) with a final dense point cloud in the upper left corner (Figure 32). Figure 24 shows the reconstructed 'sparse cloud' from one of the vessel photo-sets (composed of 67 photographs). The other examples created from photo-sets of different size (49 and 31 photographs) are visualized in Figures 33, 34 and 355. The exemplary process is visually demonstrated in the following figures and accompanying text .

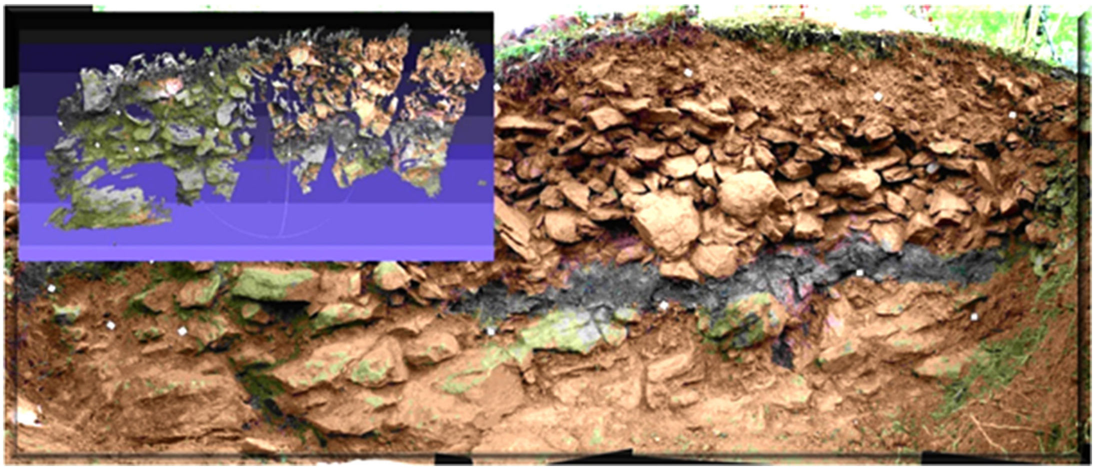

Figure 32. 'Ice' and 'Visual structure-from-motion', Model 7 (photos by D. Hlásek, TerraVerita).

The team has attempted to create a 'cost-free' model from the available set of photographs of the 'Roman relief tile'. The first step was the creation of 'sparse cloud' from the original photographs using Visual SfM. Then, the resulting 'sparse point cloud' was transformed into 'dense point cloud' using CMVS/PMVS algorithms of Visual SfM. Until this stage it was possible to work with Visual SfM GUI. Unfortunately, this software is not capable of creating 'meshes' from 'dense point clouds', so it was necessary to use another open source program – Meshlab. In summary, one has to import 'sparse and dense point clouds', create 'Poisson Mesh Surface' and 'parametrise' previously prepared pictures (during CMVS/PMVS procedure) to create the texture.

Figure 33. Visual SFM (sparse cloud), Model 4 (photos by Z. Rejdovianová, Via Magna).

Figure 34. Visual SFM (sparse cloud), Model 5 (photos by Z. Rejdovianová, Via Magna).

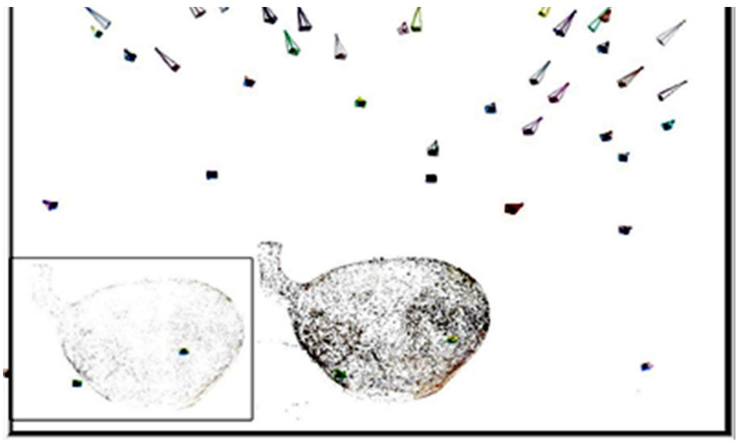

Figure 35. Visual SFM (sparse cloud), Model 3 with camera positions and a detail of the sparse cloud point model; photos by Z. Rejdovianová, Via Magna).

Figure 36 shows the final mesh surface that is based on 'dense point cloud' created by Visual SfM and Figure 29 visualizes the following step, i.e. the parametrized texture over the mesh. The models created with Agisoft Photoscan and presented here (see relevant figures) used the legal version of the software (provided by A. Žitňan, Via Magna) or a 30-day registered trial version (Photoscan). There is no need for an in-depth analysis of this software since it has been discussed before, including examination of its application in archaeology (e. g. Plets et al. 2012; Sapirstein 2014; Thanaphattarapornchai 2012).

During the CONPRA secondments, the team created several models using this software which I comment on here. Figure 37 shows a high-quality mesh model of the Vinča site; the pictures that follow present the medium- and low-quality models in order to highlight different results produced under different software settings (Figures 37,38). 'Model 1' is shown once again in Figure 39, where only 'sparse point cloud' was used as a base for computing the mesh and the texture. At a first sight, it is clear that the final textured model is not of good visual quality, but it seems that this 'shortened' procedure may be suitable for less detailed or flat features (details of the site are visualized in Figures 40, 41).

Figure 36. Meshlab (mesh), Model 2 created by Visual SFM (dense point cloud) and Meshlab (mesh).

Just as a comparison with the previously mentioned software, Figure 28 shows a model of the Vrcovice trench profile. Further features that the team has tried to create 3D models for are artefacts: the Roman tile – 'model 2' and the Vinča vessels – 'models 3-5'. and so on. Figure 44 visualizes a detailed overview of the Roman tile and the relief; it is characterized by a high level of relief details and texture. Figure 43 shows one of the Vatin culture vessels from Vinča. The model suffers from the same errors noted and discussed for models shown in Figures 8, 9. The need for high-quality photographs

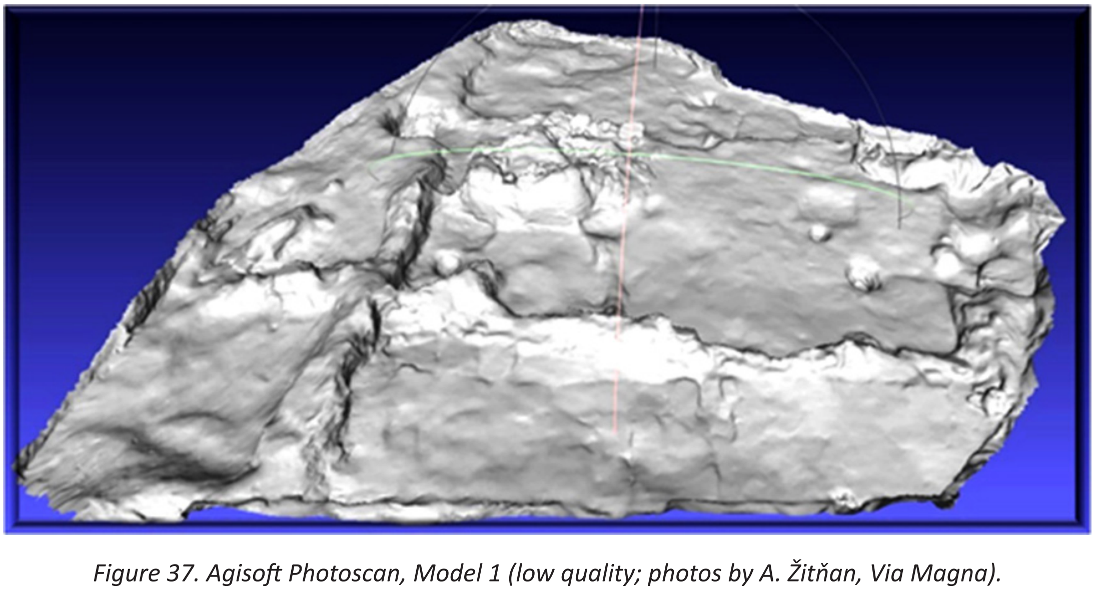

Figure 37. Agisoft Photoscan, Model 1 (low quality; photos by A. Žitňan, Via Magna).

and their pre-processing is illustrated in Figure 39. The ‘Vinča mask’ model is characterized by quality mesh and texture; moreover, the pre-processed photographs resulted in a clear model without disturbing elements of the background (46 Cameras/46 aligned (cropped); 35285 tie points; dense cloud 24 169 280 points; 3D model 4 861 512 faces). The same result is shown in Figure 45. Figure 46 shows in detail the aligned inner and outer surface of ‘model 5’; it was possible to create the whole model (model, surface chunks alignment etc.) using a single software.

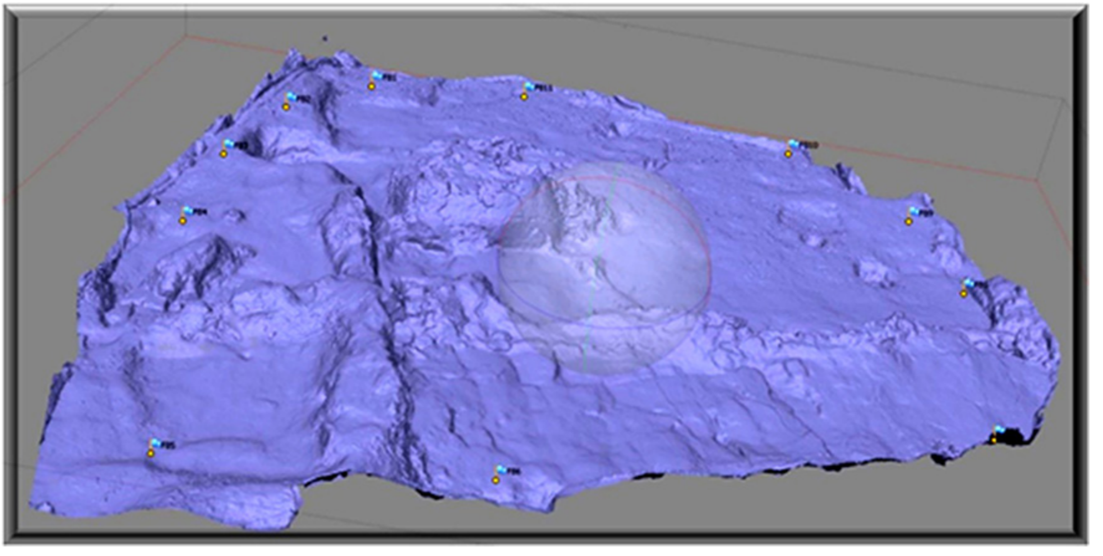

Figure 38. Agisoft Photoscan, Model 1 (medium quality; photos by A. Žitňan, Via Magna) with ‘GCPS‘.

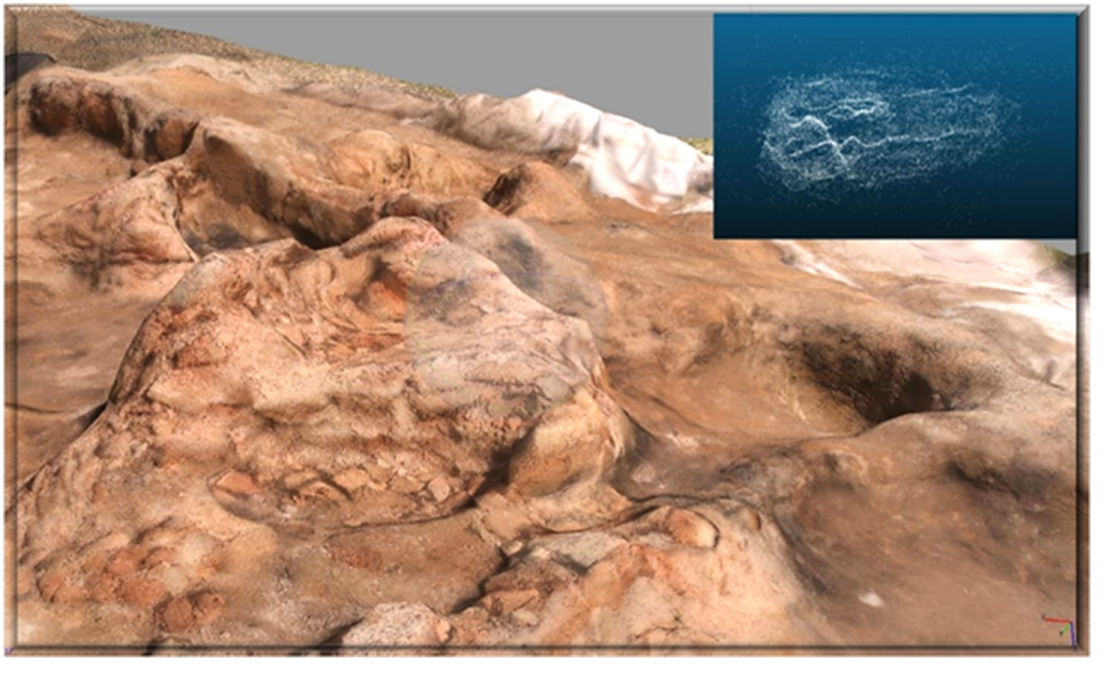

Figure 39. Agisoft Photoscan, Model 1 (model based on sparse point cloud; photos by A. Žitňan, Via Magna).

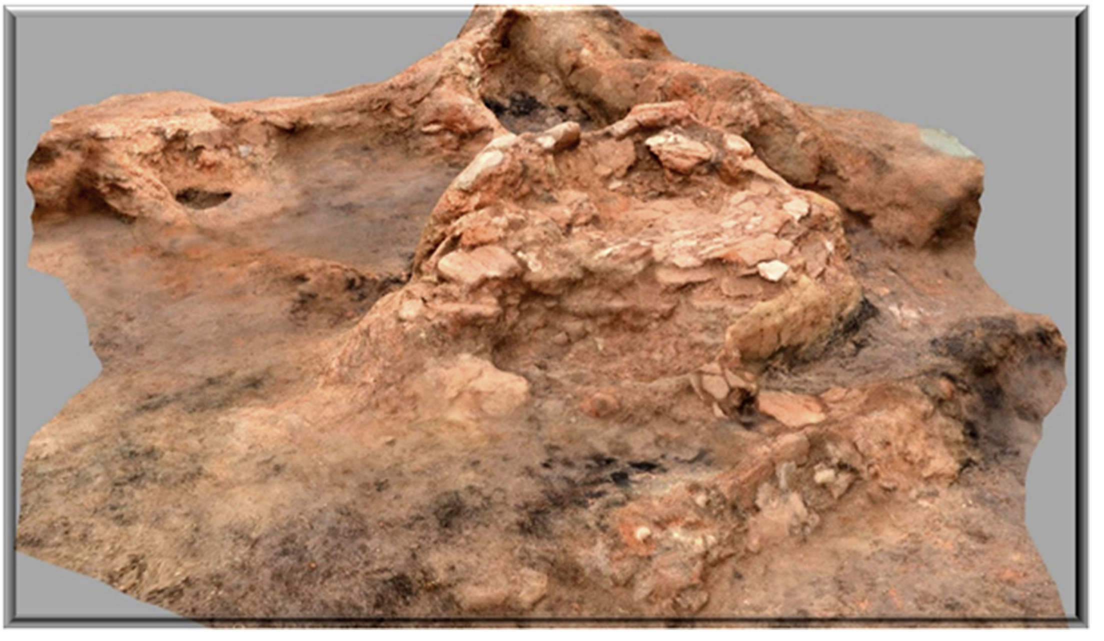

Figure 40. Agisoft Photoscan, Model 1 (detail of a kiln; low quality settings; photos by A. Žitňan, Via Magna).

Figure 41. Agisoft Photoscan, Model 1 (detail of a kiln; medium quality settings; photos by A. Žitňan, Via Magna).

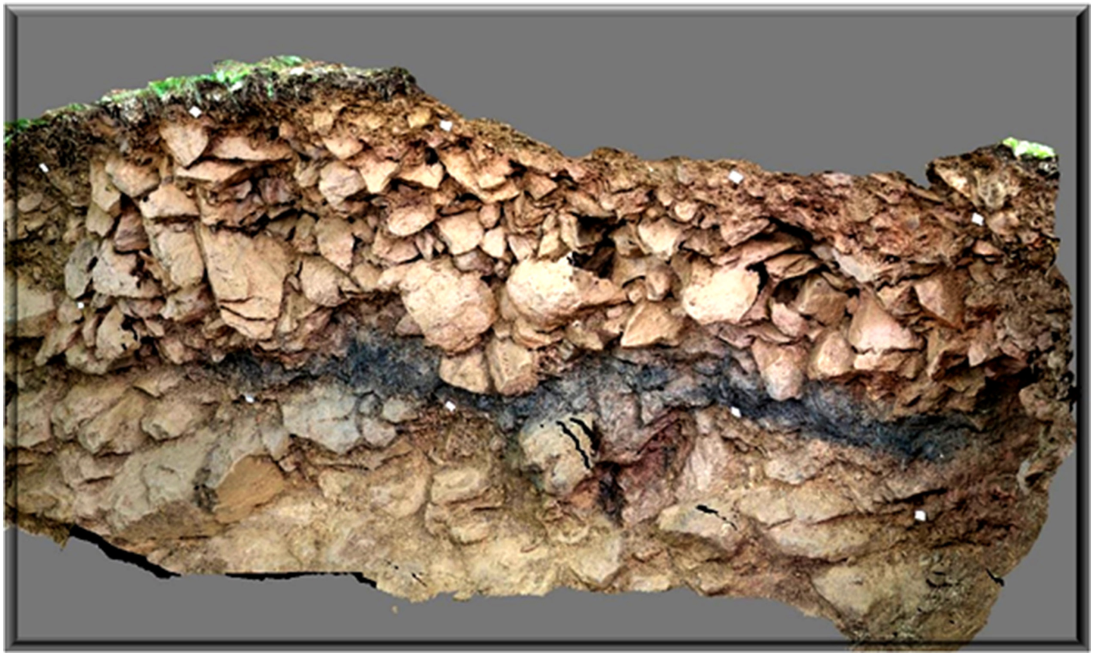

Figure 42. Agisoft Photoscan, Model 7 (photos by D. Hlásek, TerraVerita).

Figure 43. Agisoft Photoscan, Model 4 (photos by Z. Rejdovianová, Via Magna).

Figure 44. Agisoft Photoscan, Model 2.

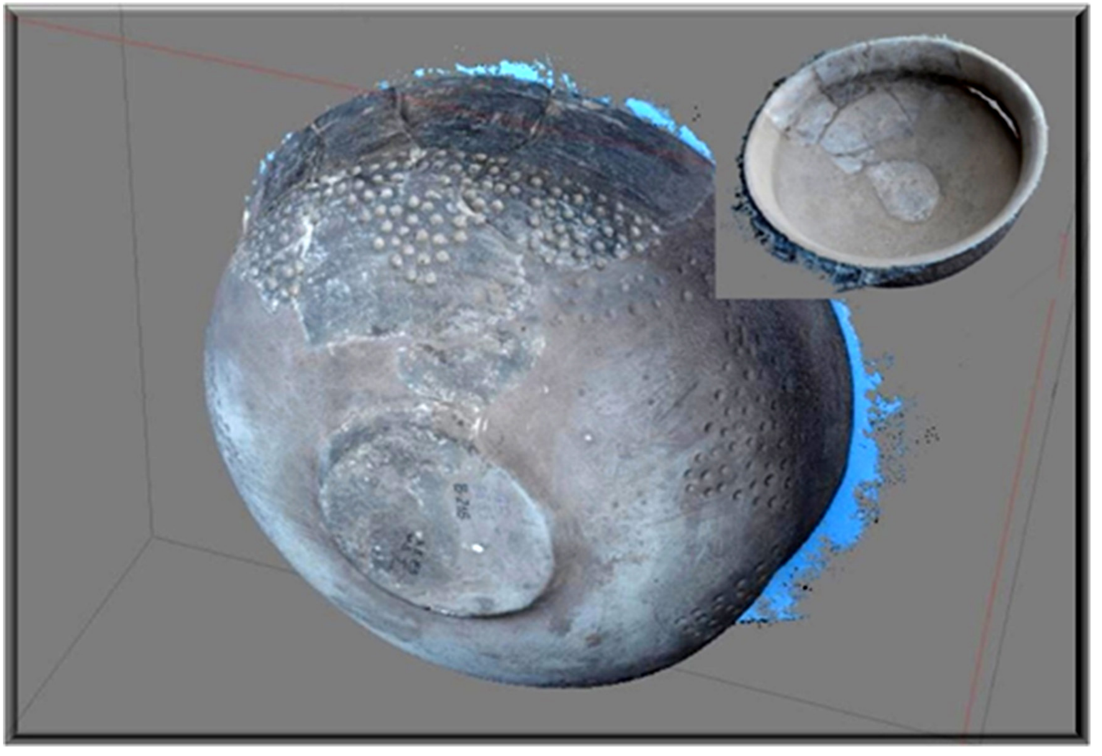

Figure 45. Agisoft Photoscan, Model 5 (photos by Z. Rejdovianová, Via Magna).

Figure 46. Agisoft Photoscan, Model 9 (photos by Z. Rejdovianová, Via Magna).

Software comparison: Conclusion

In general, it can be concluded that it is possible to use 'commercial' or 'open-source' software in the same manner. Both routes are capable of producing satisfying results. However, it is first necessary to obtain high-quality input photographs; it is also crucial to use high-end computer to reduce the processing time (regardless of the type of software used). Commercial software, like Agisoft Photoscan, is a powerful tool capable of conducting all of the steps in a single place (including geo-referencing), but the software must be purchased. Nonetheless, it is a well-suited and solution worth-investing in for professional use (even in archaeology). Open-source software is also useful. In this case, it is usually necessary to use some specific software solutions and one has to be prepared for frequent software crash and incompatibilities with some graphic cards (e.g. the tested software worked well on a powerful PC, but when a notebook used, the software kept crashing whilst importing dense clouds into Meshlab). There are a lot of possible reasons for this ill-performance which then hamper the work progress.

In sum, one option is to invest in professional software and be able to work without facing recurring problems, and the other is to invest time to test and learn the best way of operating open-source software. It is, ultimately, a question of how much time/funds one can set aside for this type of work and what outcomes are expected/satisfactory. It is our opinion is that the commercial software generates better results mainly in the last stage, i.e. the visual texture quality; as regards 'point clouds' and 'mesh' creating, both types of software give similar results.