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# Survey and Photogrammetry: Retrieving and Modeling Lost Data

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## **SURVEY AND PHOTOGRAMMETRY: RETRIVING AND MODELING LOST DATA**

In 2013, an exceptional discovery was made in the Fontainebleau Forest near Paris (France). On a boulder at Vallée au Noirs a never seen before figure representing a human figure framed by two boats with steering oars on one side and a crook-hafted axe with a ring on the other side. The engraving is partially buried which maybe delated its discovery but also protected it from degradation. It is known that this specific boulder is one of the most popular climbing rock of the area and the axe is often used as a fulcrum. The artwork has been totally cleared and recorded then the survey has been refilled. This article focuses on the process to record each step of the survey in order to virtually recreate all elements of the stratigraphy. This allows then to measure, weigh, and precisely locate all discovered artifacts. In this example, the clearing of a site during excavation work is photographed and modelled for each important stage. In addition to the step-by-step monitoring and the archiving possibilities entailed, this method also allows for generating additional data, such as removed cubatures or the precise shape of the studied strata. Those are operations that are carried out on both filled and empty spaces.

*Keywords:* Photogrammetry, 3D recording, 3D stratigraphy, retro modeling.

### **Prolegomena**

Facing the main car park of the rock climbing area, the boulder is a 16 m high decorated with a 3 and a half meter human figure dominating two boats and an axe. This discovery was made in the Massif of Fontainebleau, south of Paris, during a campaign focus on the recording of engraved Neolithic axes for the Jade program. This boulder was not listed as a major object except for climbers for its difficulty to be overcome. It's only because the sunset just lit the rock at the right moment that we identified an axe shape like that occurred to be the most visible figure of the entire composition. A first recording was made in 2013 of the visible elements. Then, a second survey revealed the entire composition a year later. The axe emerged only 30cm above the ground and is clearly a Bégude type axe with a handle. Two boats were then revealed with a grazing light, a smaller one in a near central position and a larger one with a shape that suggests a paddle. But the main surprise has been the identification an impressive anthropomorph set be-

tween the axe and the boats. This human like figure benefits the overhang of the rock and is characterized by flaming hair or feathers above the head and shoulders and details that may brought accurate information concerning clothes. This fascinating discovery is not the aim of this article which is purely a technical walkthrough to enlarge the possibility of photogrammetry during the survey. All details and issues regarding the “Rocher aux Noirs” and its figures are listed in the bibliography bellow.

### Procedure and installation

The systematic recording of the excavation steps is both a testimony, a way to document the evolution of the site, and the opportunity to measure, layer after layer, the quantities of extracted sediments, the deduction of the sedimentary layers' configuration and the opportunity to extract orthophotographs of the faces as a whole. The process benefits from the site's installation apparatus. The orthogonal grid, on a one-meter frame on the ground, enables the measuring and the appreciation of the digital reconstruction's potential distortions. Here, an axis is given on the abscissa along the rock and parallel to its most linear face. Orthogonally, the frame spreads from the rock outwards on a five-meter distance.

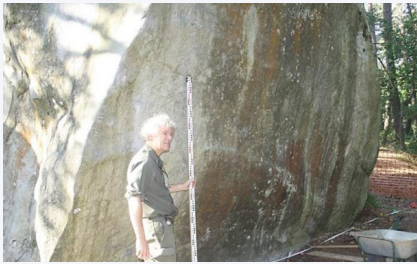
The threads making the grid are marked at their intersection with a coloured capsule, secured to the ground by a nail. It will be very easily detected by the reconstruction programmes, and will be used as markers. Coloured balls highlight the angles and delineate the installation's maximum perimeter.



Horizontal marks, positioned thanks to a laser level, are arranged in a belt shape on the rock.



A survey on the site's level establishes the big proportions and gives the levels of the horizontal marking, the rock's height and the distance at the base from a point on the grid. These measures will represent as many control points of the 3D model.



### Photographs

The photographs were taken either with a pole to remain perpendicular to the subject, or by hand. The first method implies a delayed shutting action, while the second entails occasional acrobatics. For the big and high objects, the pole is paramount.



For each shooting session, the marks should rigorously include the horizontality markers, fixed, which will facilitate the placing of the 3D model and the scale marks, which will give the geometry's right proportions.



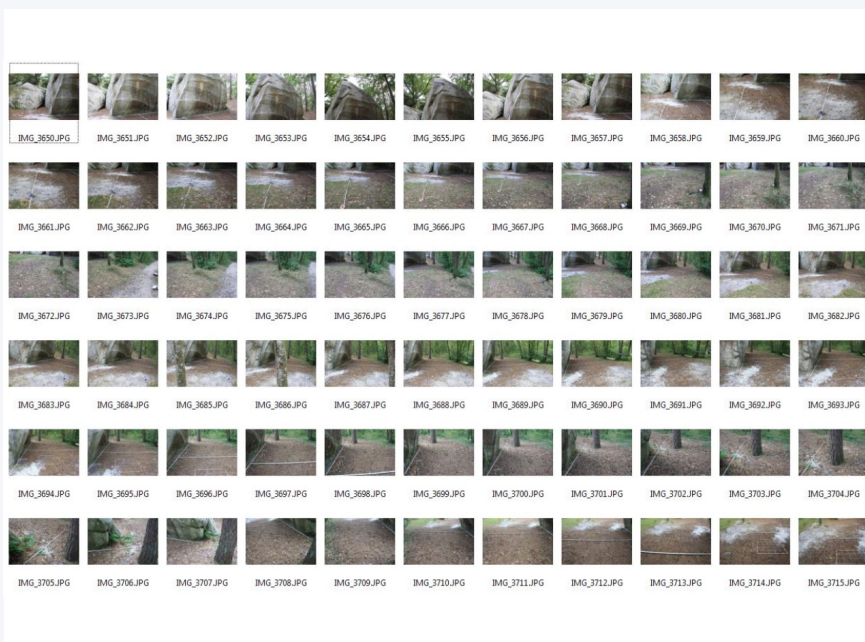


## Part 1. Data collection

*Step 0: site established, area cleared, but not yet excavated*

An initial round of 136 photographs is carried out before the beginning of the first level of excavation. The photographs are taken in 18mm with a Canon 1000D. A systematic paving is performed in order to cover the surface as a whole, and the base of the rock is also shot to set the vertical lines in order to have an intangible surface, which will later be used to readjust and superimpose the following surveys.

An excerpt from the photo collection gives an idea of the coverage undertaken.



The paving should follow a rigorous, continuous, linear and uninterrupted route. It is usually necessary to rehearse it before the beginning of the shooting, in order to anticipate the potential problems that might occur.



Here, the cloud is made of 11 million points and should be cleaned on the approaches. The vegetation and the peripheral elements around the targeted area should be eliminated.

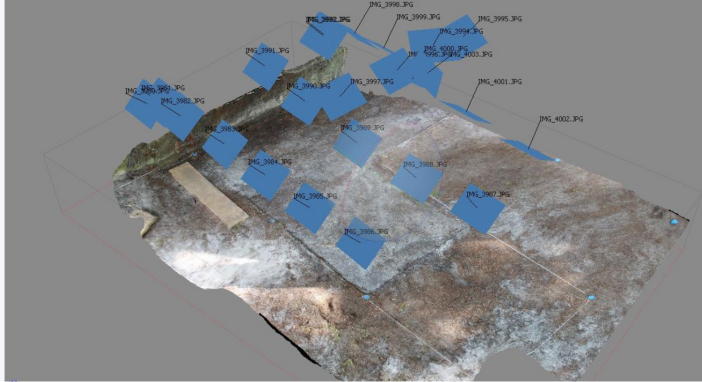


*Step 1: first pass*

For the first step of the excavation, a series of 24 photographs (18mm, F/16) is taken. The little differentiation of the ground surface and the quantity of information to record being relatively small, it is possible to stay

at around one meter from the ground while scanning the surface with an approximate  $45^\circ$  angle of incidence. An important element is to have a density of information in relation to the subject that we are looking to record. First and foremost, it is here a question of measure, in order not to miss any detail, but also not to over-detail and produce incidental effects in terms of treatment, storage or discrimination of meaningful elements.

There is little depth information here. We should note that the excavated surface is not affected by the sun.



### Step 2

The second step of the excavation is recorded via a series of 34 photographs (18 mm, F/4), at a much smaller distance and with the use of the





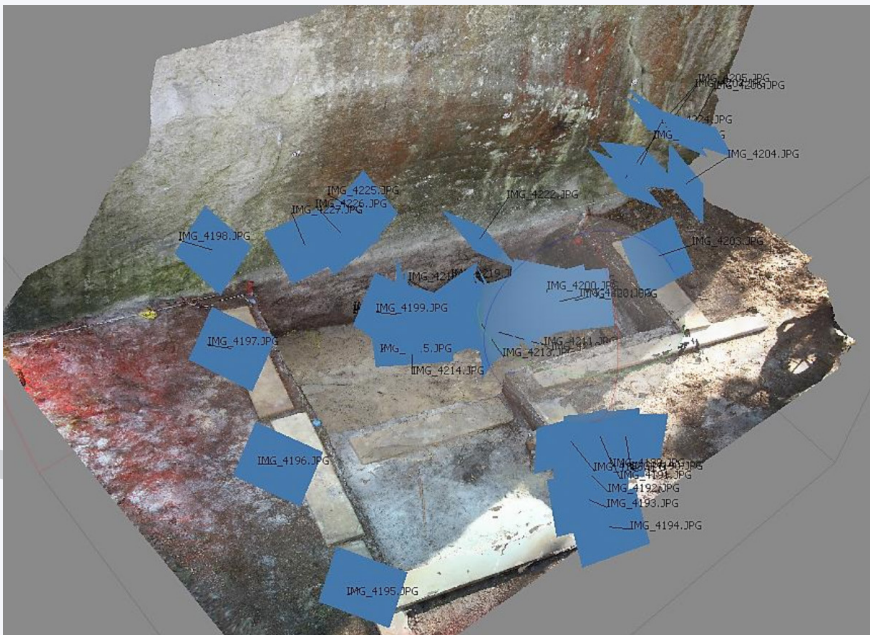
flash. The flash is justified by the particularly dark shade of mould in section, and by the significant backlight during the shooting. Moreover, it balances the differences in natural light exposure, and moderate the differences in tonalities, due to the colorimetric variations in the photos, taken during different moments of the day.

400'000 points are extracted, the texture calculation in orthophoto (Photoscan) enables a faithful restitution of the sections' aspect.



*Step 3: detailed explanation of the procedure*

The step 3 explains the walkthrough in Photoscan in order to get a perfect photogrammetry. This can be found at the following page: <http://keris-studio.fr>





#### Step 4

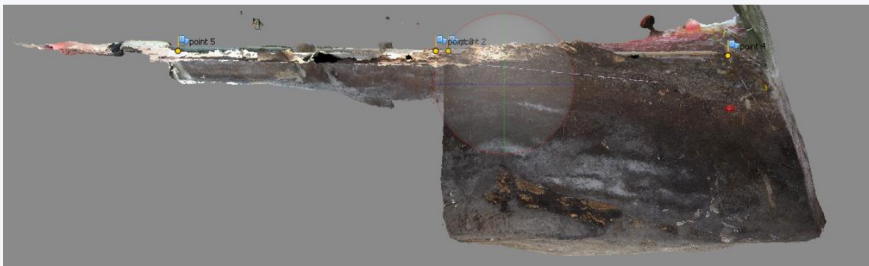
The fourth step follows the same protocol. The excavation pit becoming deeper, it is necessary to create closer views. 40 photos (18 mm, F/4) are taken with the flash.

At this stage, the 3D model shows a section of the excavation.



#### Preparation of the orthoview

Throughout the descent, the question of the stratigraphic section becomes more and more important. To create an orthoview, in preparation for an orthophoto, it is necessary to set the model properly, as explained in step 3, and most importantly to make a texture as clean as possible.



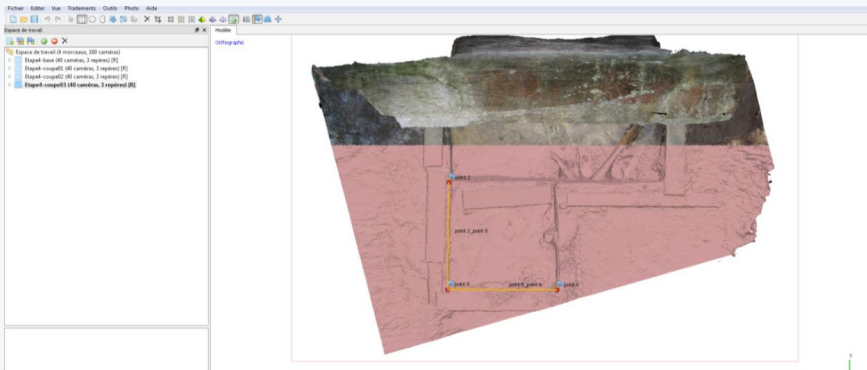
The quality of the texture is doubled with the possibility of producing two maps instead of one.

From then on, the materials' rendition is particularly detailed. It will not be possible to keep the calculation for real time. It is a preparation for orthoviews.

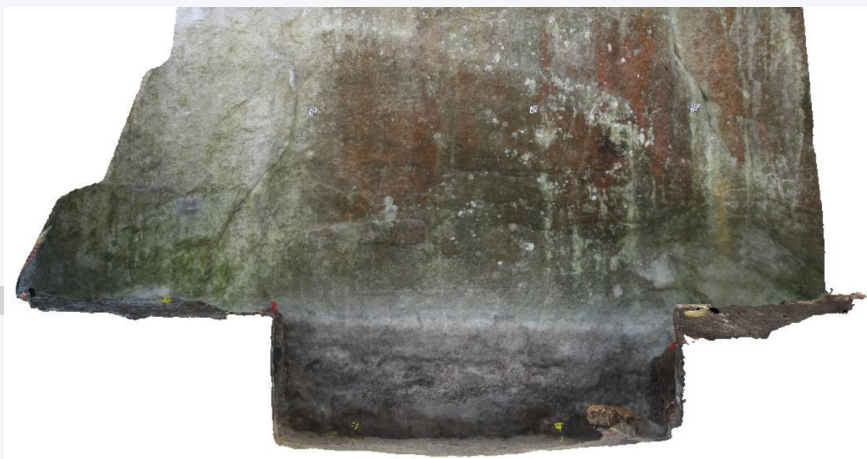
To create the views, parts of the model will have to be erased. It is thus important, first, to duplicate the geometry before cutting it.

The model is cut with a simple selection and cancellation. The "5" key enables the passage to the orthogonal view, and the "7" key to the plan view. Use the rectangular selection.

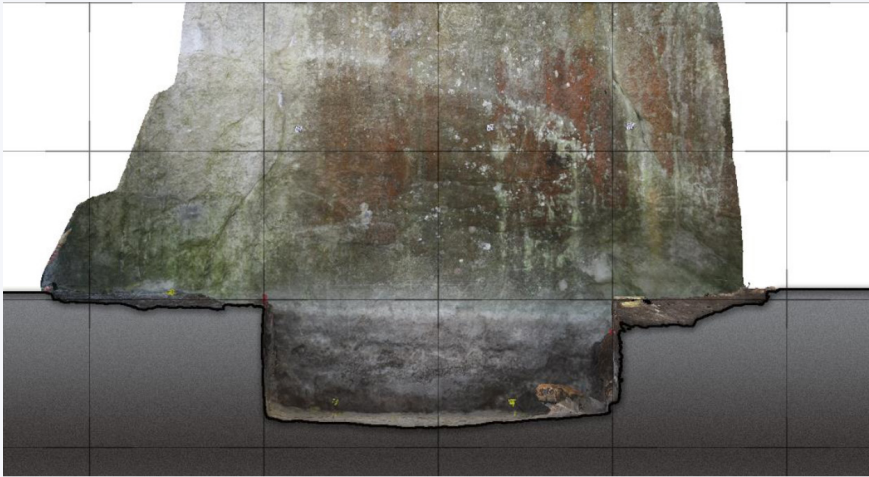
Delineate a big rectangular selection to determine one of the first sections.



Press 1 to see the front elevation.



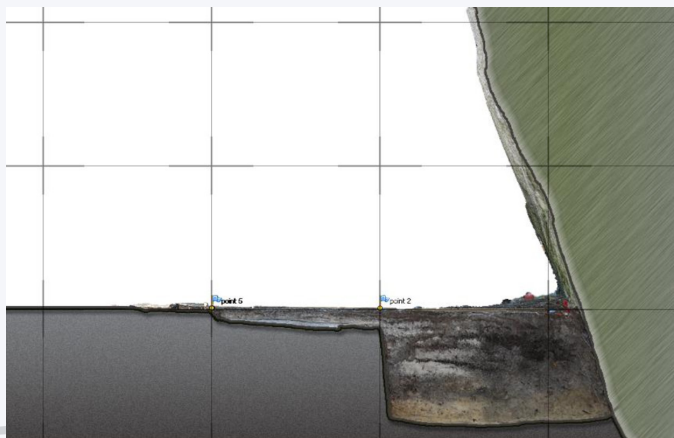
Once prepared, the section fits the orthophoto's requirements.



We proceed in the same way for the other elevations, the right view...

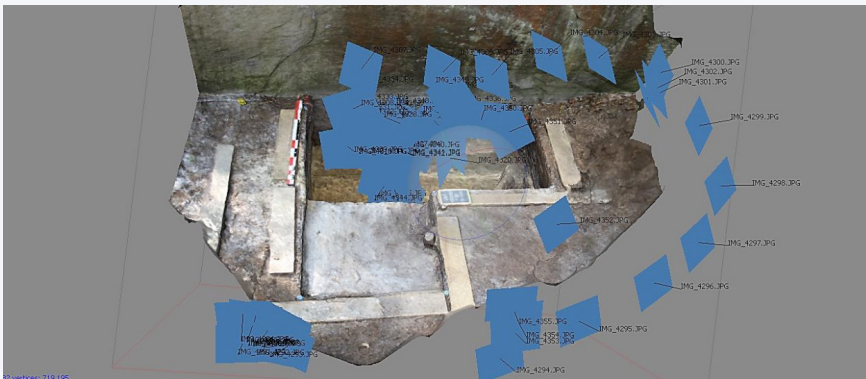


... then the left view, after graphic processing.



*Step 5*

The next step represents a 30 cm descent in the extraction sampling of a sterile and perfectly homogeneous layer of sand. The shooting strategy asks for an even more rigorous organisation, with the site's entrance and exit that need to be rehearsed beforehand. For this step, it is necessary to collect more details on the stratigraphy, and thus to take more photos while standing closer. The first views compose the ensemble and place the scene within its limits. Then, they focus on the details, with a paving realised at around 30 cm, with an almost perpendicular incidence. 72 views (30 mm, F/4) were taken with the flash, even for the remote positions.



Flash photography reveal the shadows and all the details in the section.

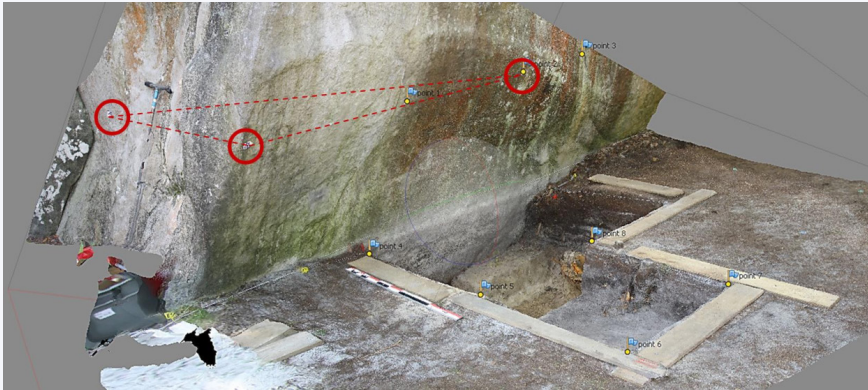


*Step 6*

Throughout the excavation descent, the precision needed becomes increasingly important, in particular on the stratigraphy's face. At this step, 74 photographs are taken (18 mm, F/4) with the flash, in a movement that encompasses the site as a whole, then in spiral towards the significant details, and finally reversing the movement.



The 3D base is ensured by the points of reference placed on the rock, as mentioned above. The triangle formed by the points gives the horizontal line.



Horizontal plate set with the laser level.

#### Step 7

The seventh step is characterised by the clearing of the hard ground on top of which the previous step had ended. 56 photos (18 mm, F/4) are taken with the flash, according to the route described above. The redundancy of the geometric information from one shot to another allows us to set the models relative to one another, and to further develop calculations on volumes of sediments and geometry of strata.



We can see in the model's detail, also expressed with mesh, that the photos resolution ( $3888 \times 2592$ ) enables a model with more than 1 million faces. The re-mapped texture, calculated in 4K in orthophoto, provides an easy reading of the details. The number of pictures taken allows for the large augmentation of the details level by producing a 4K orthophoto, not for the geometry as a whole, but for each face, for example.

*Step 8*

The eighth step follows the same principle, with 74 photographs taken under the same conditions (18 mm, F/4) with the flash. The method's consistency stabilises the models produced, making them coherent.

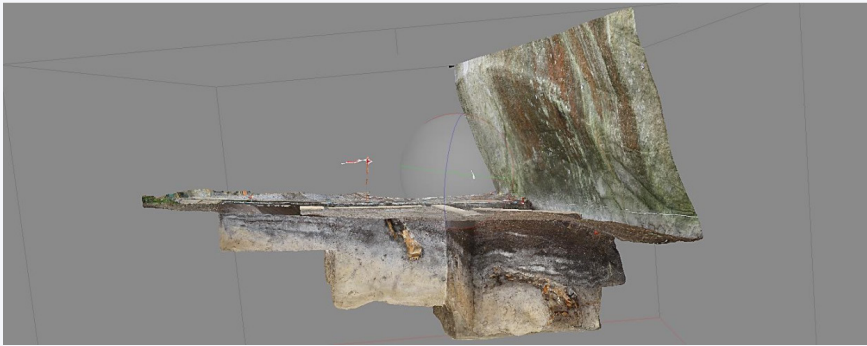


Diagram of the shots and axonometry of the model and the section.  
Subsequent steps from 9 to 12.

As the excavation becomes deeper, it is necessary to set the vertical lines, even if it is redundant with the horizontal panel that is set to the rock. A plumb line, fitted with coloured balls, is suspended above the pit. That way, this element, which is not in contact with the rest of the subject, can be easily removed from the 3D once the verticality is ensured.

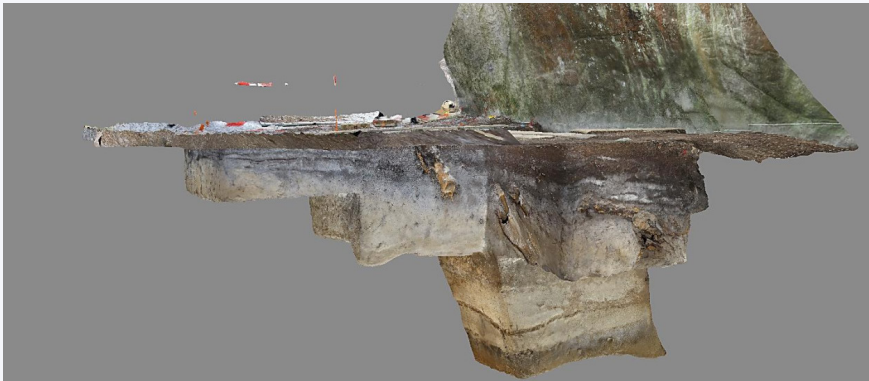
In that setup, the balls are exactly 50 cm apart. Most programmes used for the mesh reconstruction know how to spot the spherical objects as parts of a measuring or detection device, and not as part of the recorded subject. The cleaning is thus done rather easily.



The risk with this excavation work was the landslide of the walls. The very fluid sand, even held up by strata of hard ground, could crumble from the vibrations coming from the team walking around the pit alone.



Step 9

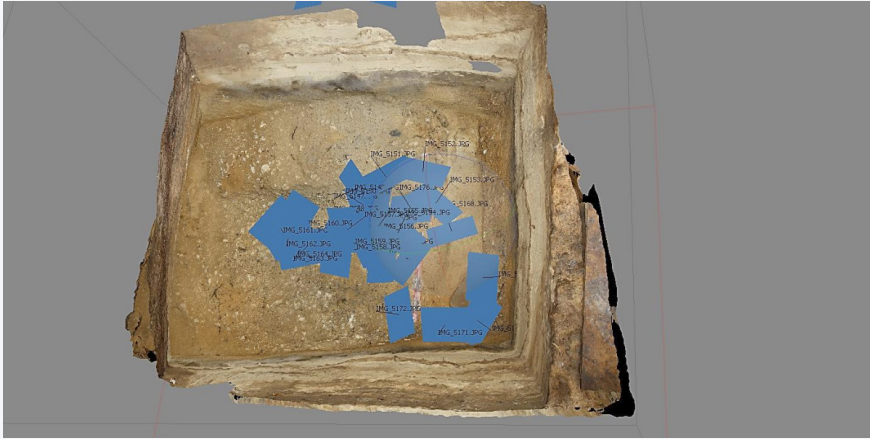


Step 10





*Step 11*

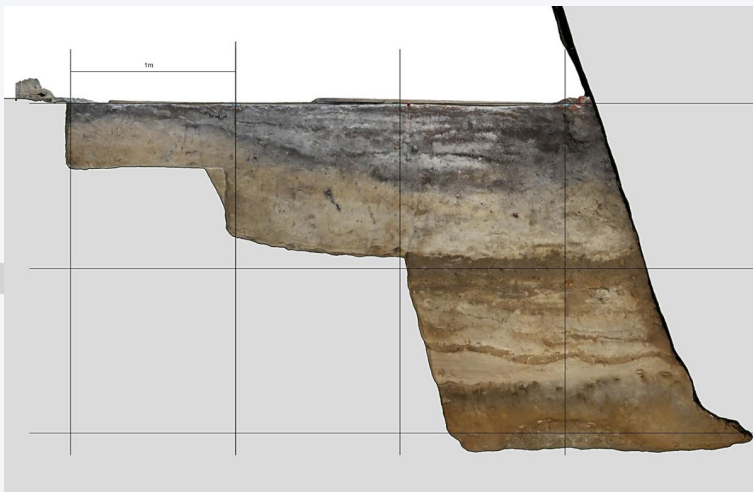


*Step 12*

Step 12 represents the detailed recording of the stratigraphy. With 147 views, a very fine paving of the section was produced.

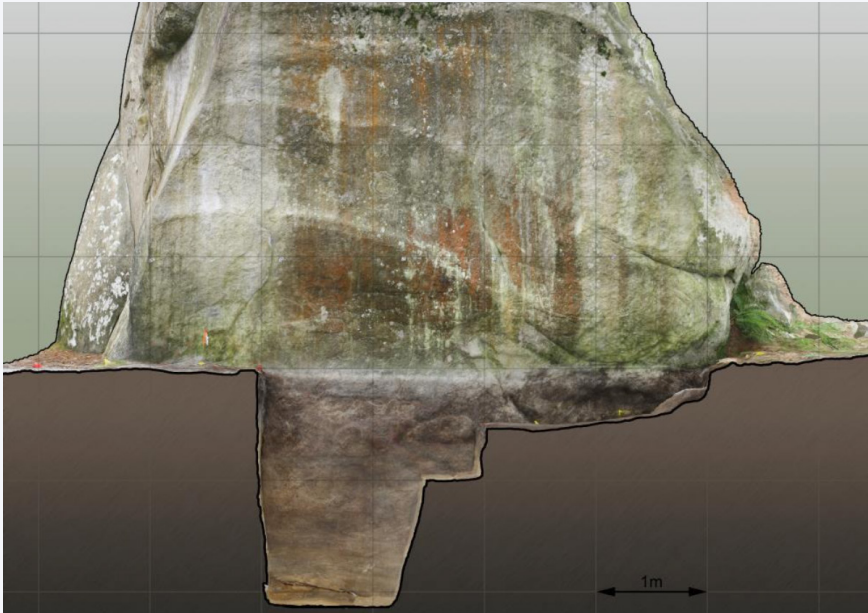


From this model was yielded an interior elevation of the site, helping the preparation for the stratigraphic analysis.





The exploitation of the perpendicular section will be the base of the engraving's interpretation.



To produce this elevation, the model was prepared with Photoscan, with the section as explained above and recalculated with a very high definition texture ( $4 \times 4096$ ) in order to get as many details as possible. The Photoscan model offers a rather neutral, homogeneous light, which is ideal for future graphic exploitations, as shown below.



*Step 13*

Step 13 consists in a collection of the model in its setting. The excavation work did not progress further from the previous step, but the new shots encompass the whole context. 342 photos are taken for a segmented re-modelisation in successive models, which will then be put together. We can see in the picture above a lateral view of the rock, and below the excavation site as a whole.



It may be noted that the whole site is very complex, with many plants, mould covered with dead leaves and an entanglement of blocks in the background.

**Final step, end of the excavation work, filling**

The steps occurring after the excavation work are also recorded.

A first series has the aim to preserve the site without the surrounding building site's elements. With a lesser definition (50 photographs), the model reproduces the edges of the site and shows well the thickness of the mould.

The final recording is a testimony of the site's filling and cleaning of all signs of intervention.



## Part 2. Data exploitation

The recording of the successive stages of the excavations not only enables the conservation of traces of each sequence, allowing us to refer to them in case it is needed, but also opens many possibilities for the visualisation of the strata and quantitative analyses on thickness, volumes and mass of extracted sediments.

To be brief and caricature the situation, it is a question of structuring the information between this state:



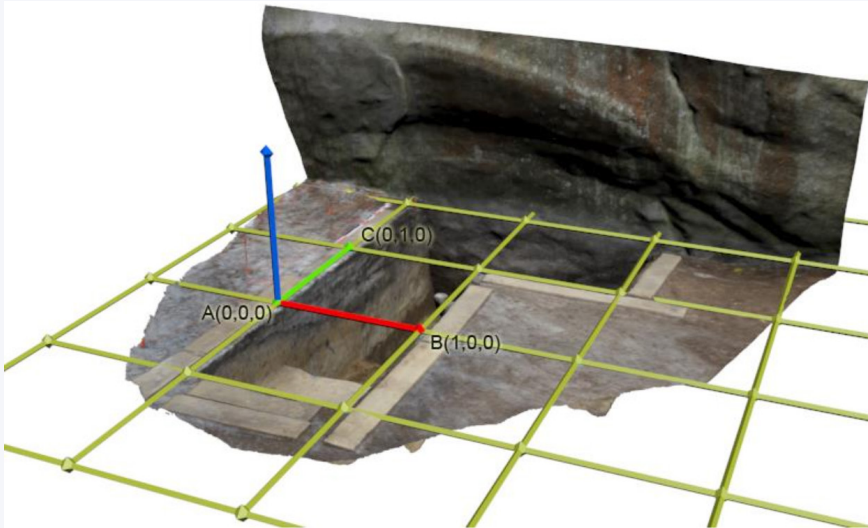
... and this one.



In the first part of the work, we paid special attention to position the modelisations within the same system. A special point detected on field is identified as the  $(0,0,0)$  point for the whole apparatus. Two other points,  $(0,1,0)$  and  $(1,0,0)$ , delineate the base of an orthonormal system, from which the site's geomatric information are organised. The measurement base is the metre.



Following this protocol, all files superimpose perfectly, making further processing easier.

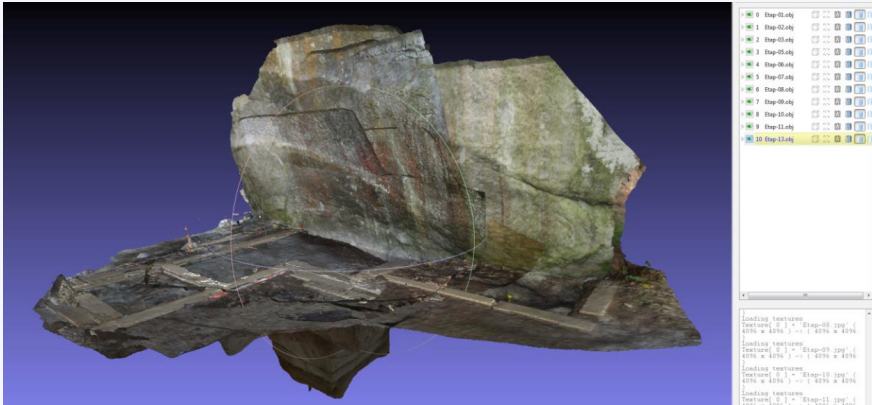


*Simplification and export from Photoscan.* The continuation of the work does not require that the geometry be in high definition. Storing files containing millions of polygons would penalise the processing time, without adding any significant precision. The discrimination happens within Photoscan to keep the setting markers. However, this operation could also happen in the host program.

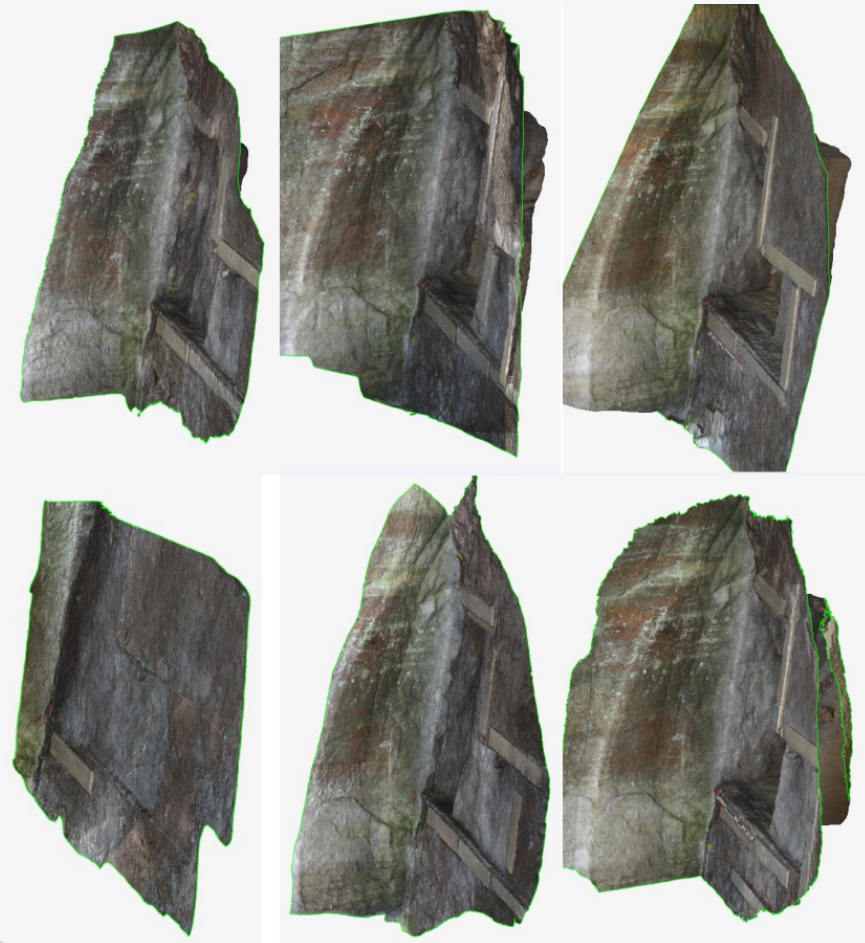
First, we duplicate the existing geometry in order to preserve the model in high definition. Within the workspace, select the current chunk and right click to see the contextual menu and the “duplicate” command. There are now two chunks, that it is possible to rename. The first one will remain in high definition, and the second in low definition for the export. The chunks, are renamed. While ensuring that we are in the low-definition chunk, we then click on “Tools/Mesh/Decimate the mesh”. The ratio is of 10 %. The model loses definition, but gains easy processing. It is necessary to recalculate the texture for this new definition. The model then needs to be exported: “File/Export the model”. The OBJ format, for example (one of the most universal formats) is chosen. We keep the default settings.

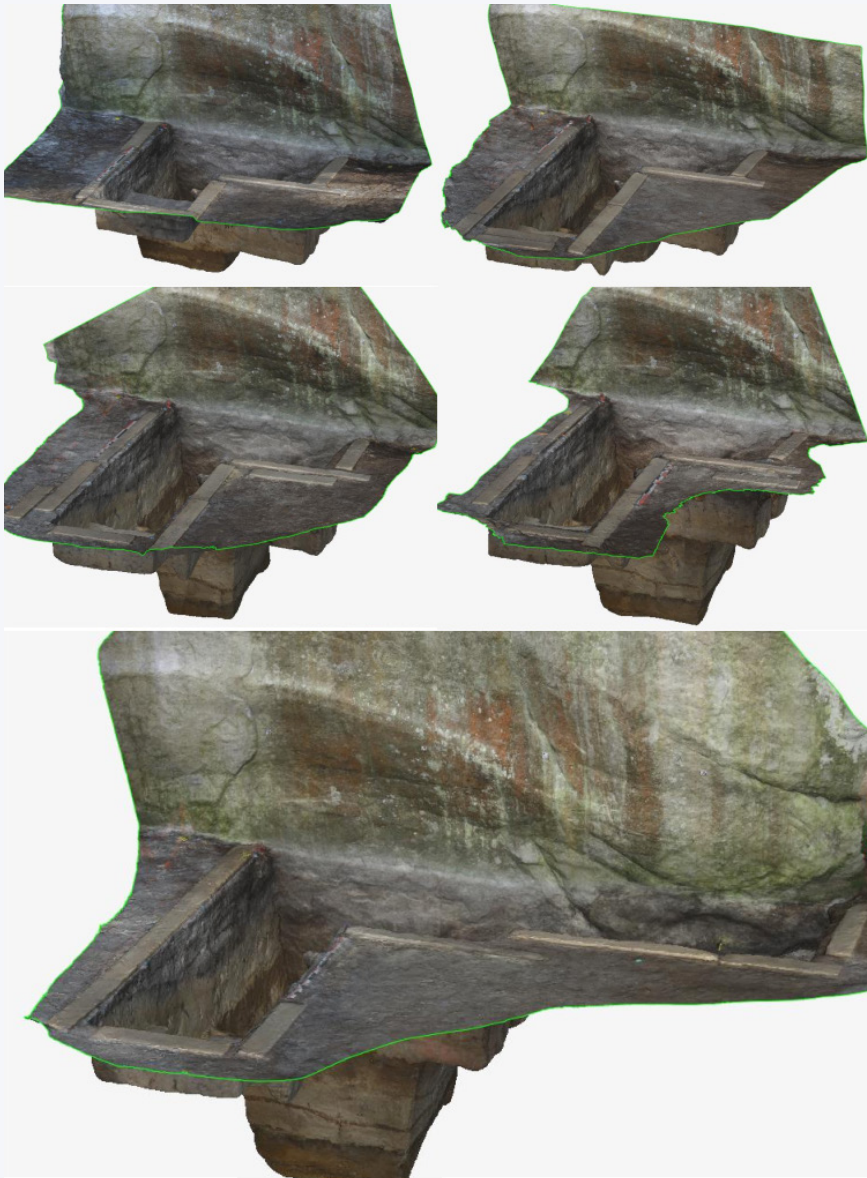
The superimposition of the strata looks like the following:





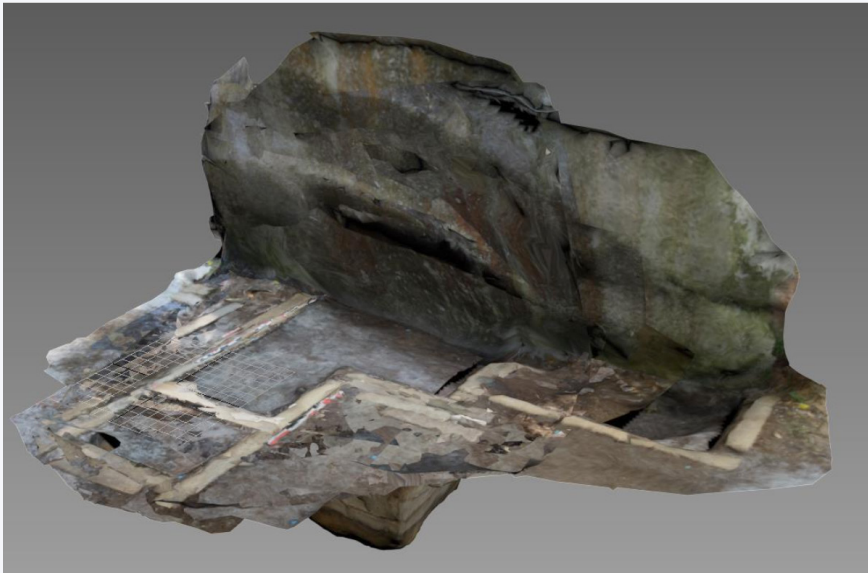
The step-by-step decomposition is visible below.





### **Superimposition of files and visualisation of the site's evolution**

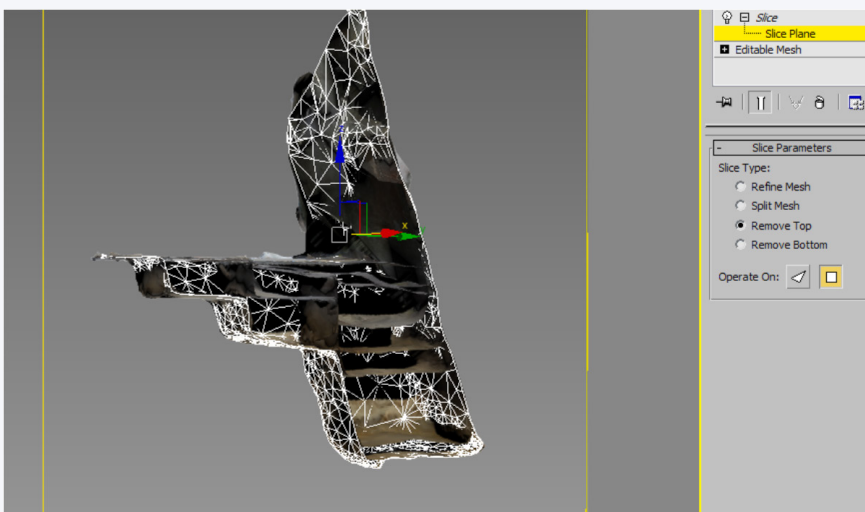
The demonstration will take place in 3DsMax, Autodesk's software, but the features are similar to any other 3D software, such as Blender, Maya, Cinema 4D or Modo.







The different steps, in OBJ format, are imported, and we check the scales.

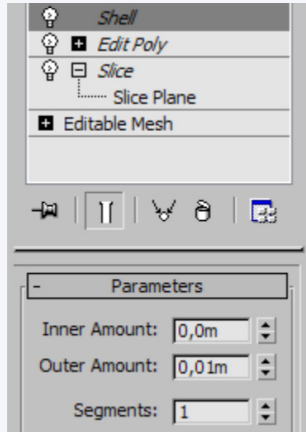
The objects arrive with separated geometry, to enable action on all the objects at the same time. They should be grouped. The modifiers will thus act on all the polygons at the same time.





Once the geometries are grouped, we click on “Modifiers/slice”. Click then on the function’s (+) to unfold the “Slice Plane”. We rotate the plane to put it in the section’s direction. Depending on the orientation, we will choose either “remove top” or “remove bottom” to perform the section.





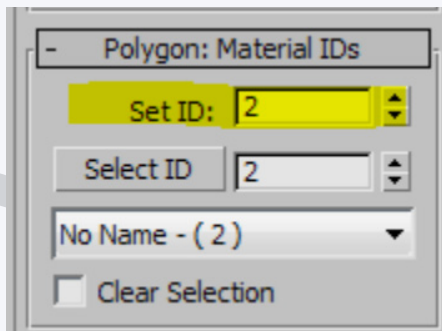
We then add an “Edit Poly”   *Edit Poly*   *Slice*, in order to apply a “shell”. The shell will bring thickness to the sections, making them more visible.



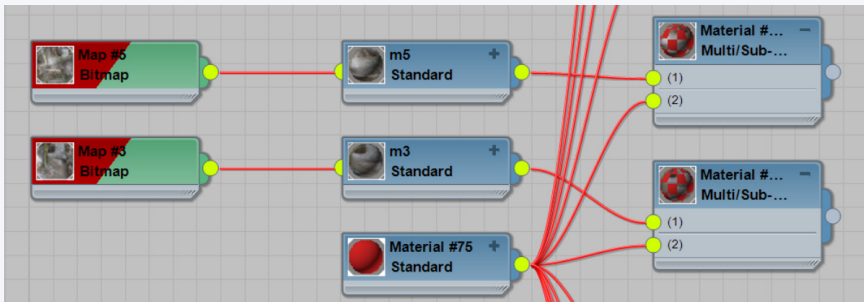
Another “Edit Poly”   *Edit Poly*   *Slice* is needed to modify the function’s slices’ colour. We then switch to the Poly mode to select the slices’ polygons, with the “By angle” function (with a value of 75) activated.



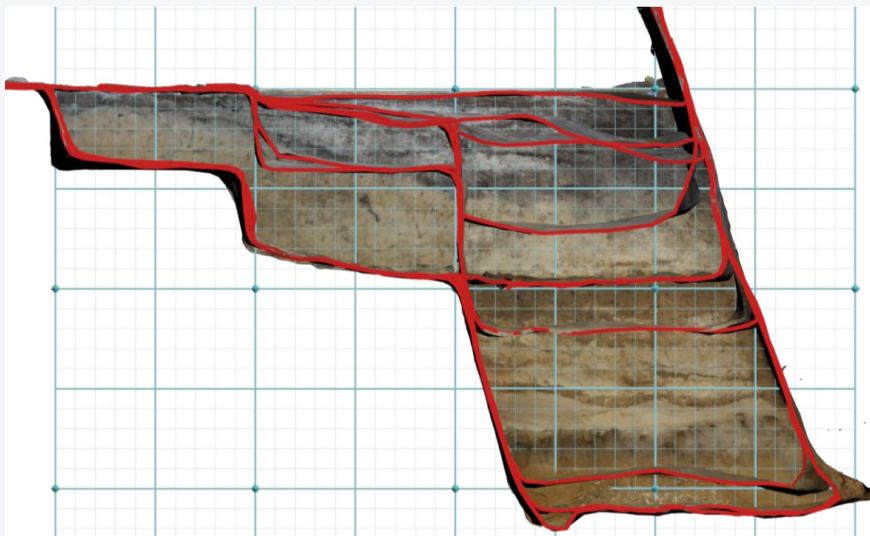
When the slices’ polygons are selected, a “Material ID” value is needed, for example of 2. From then on, we will be able to assign a texture that is different from the surface’s one to the cut slice, and highlight the cut line (sections).



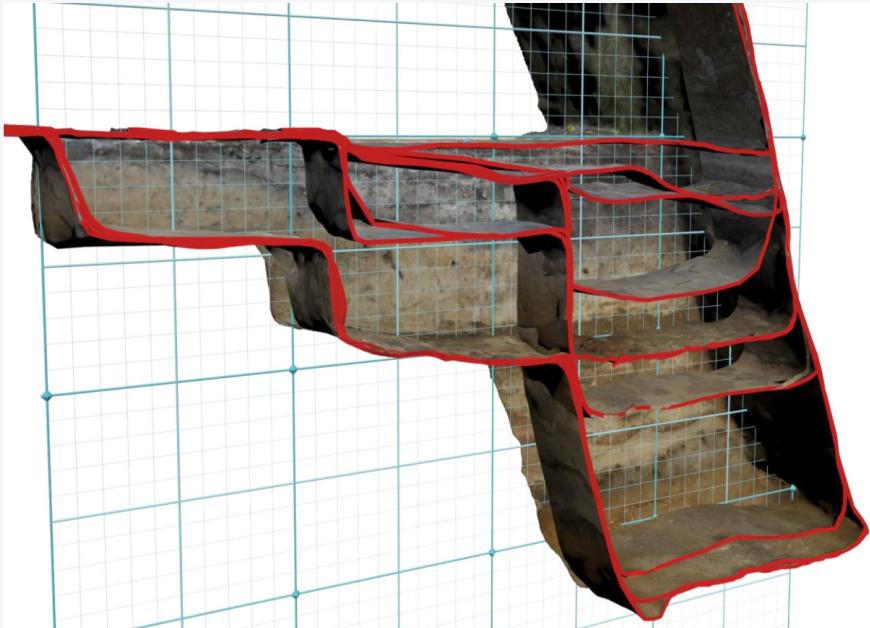
The materials will have to be worked on some more to obtain a structure such as the one in the sample below. Each section is composed of a “Multi-sub Object” texture with, in Slot 1, the original texture and, in Slot 2, the section’s colour, which can be shared between the different textures.



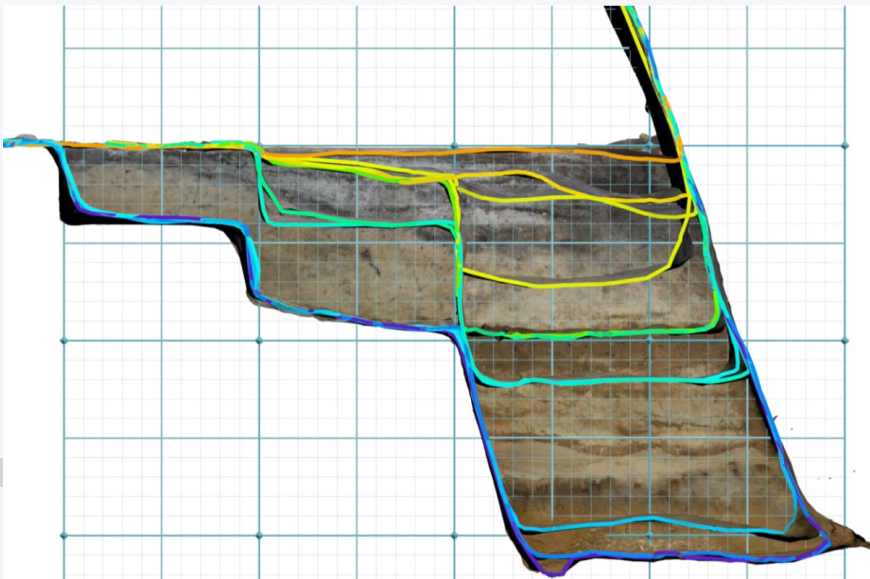
The result in perspective is as such.



Given that the elements here have been made using 3D. A high-definition model was used to provide a clear vision of the textural elements, and thus follow the strata’s level, depending on the nature of the site. The montage in perspective:

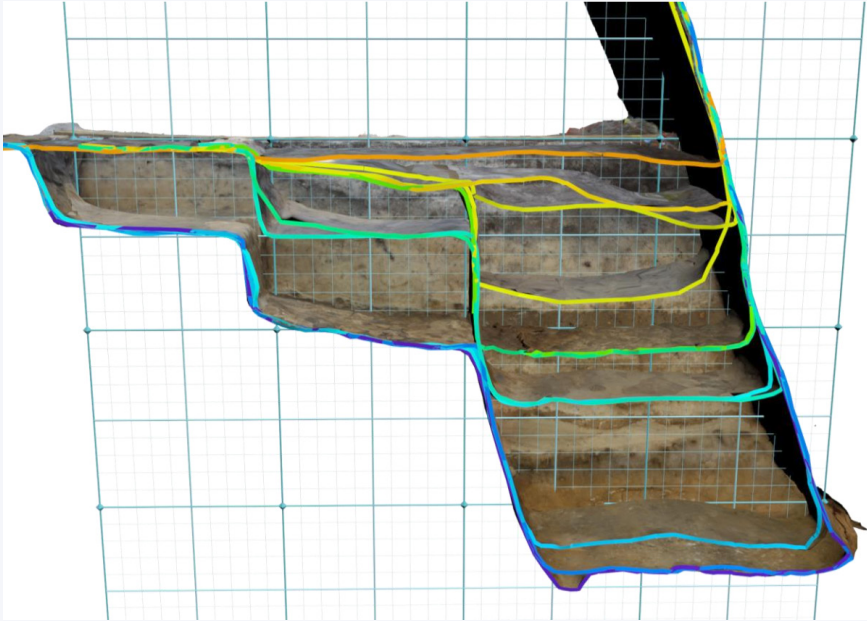


We can also identify the strata via a coloured figuration of the chronology, helping the reading of each stage of the excavation.



In perspective.





### Definition of the extracted volume

By working with the empty spaces, and no longer with the filled ones, it will be possible to determine the quantities of extracted materials.

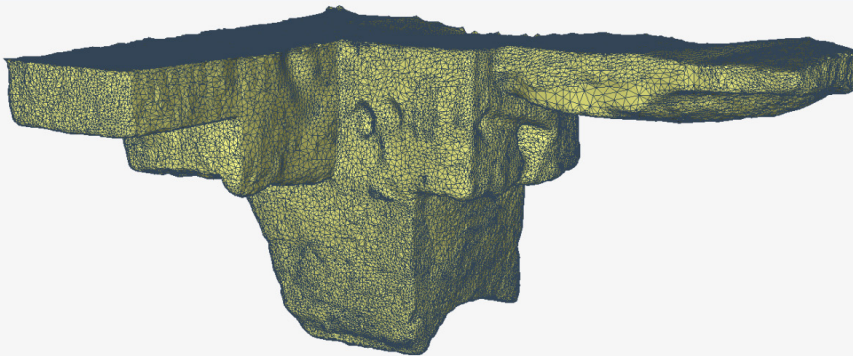
It represents the easiest calculation, as it does not require to work on several geometries. The last modelisation will deliver this information very easily. The following operations can be carried out on any 3D tool. The file is uploaded. It is then a question of removing everything that does not correspond to the site's border.



Only the pit remains.



The upper part is filled to create a filled space.



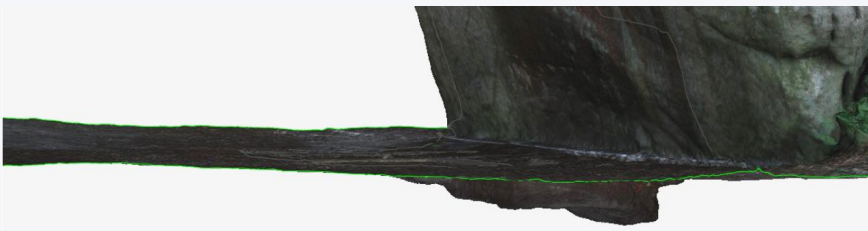
The evaluation of the extracted volume equals thus 6.63m<sup>3</sup>.

**Calculation and definition of each step of the excavation work**

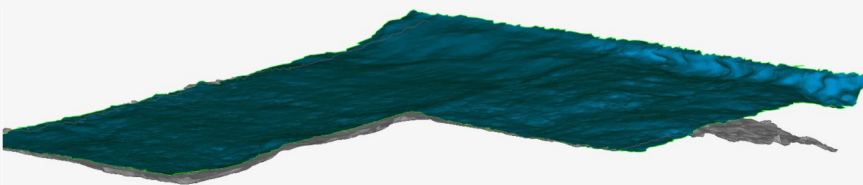
The strata will be added one by one, starting with the file showing the site before the intervention.



Below, visualisation of Step 0 and Step 2 to see how Step 0 will be used as a “lid” for the pit in the following stages.



The “lid” is cut out according to the bottom of the site. Before assembly, attention must be paid to the faces’ orientation. As the idea is to create a closed volume, the vectors need to be directed towards the outside. This is the case of the “lid”, but not for the site’s bottom, which will work in reverse.



Steps 1 and 2 are assembled, and the reading of the geological strata is easy.

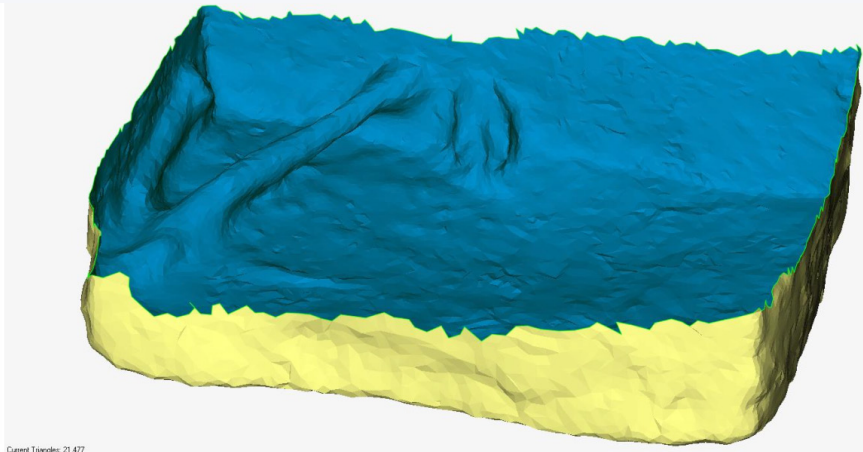




Next step:



Explanation of the “empty space”, which is the root’s way.



Next step:



Next step with highlight of the hard layer.



Last intervention

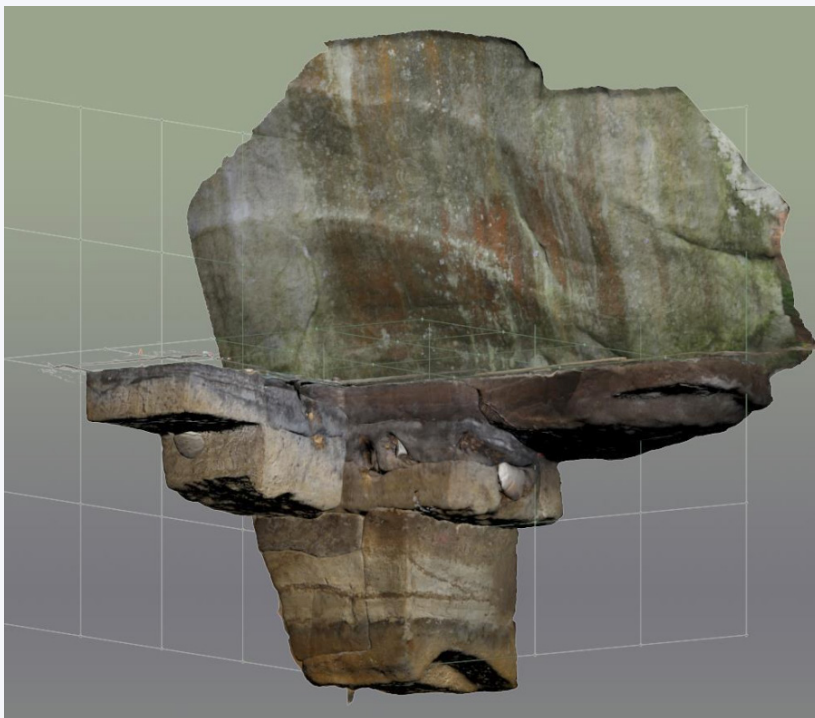
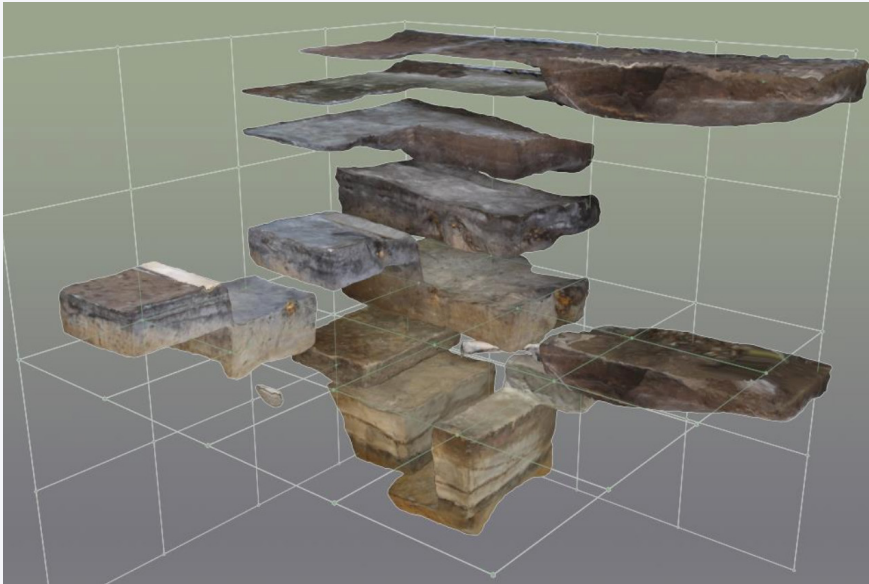


And visualisation of the chunks as a whole.

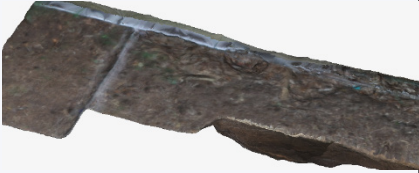


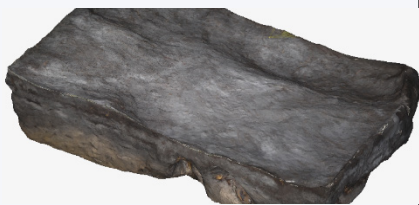
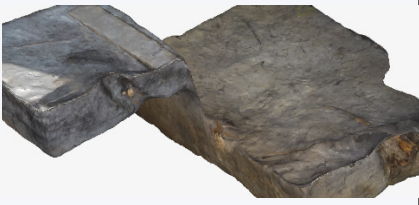





Scattered vision and linked to the base of the rock.



Note: the difference in volume with the previous result comes from the accounting of the volume of leaves and mould from the site's upper layer.

Strate	Volume (m <sup>3</sup> )	Altitude Sup (m)	Thickness (cm)	Nature
	1,16	0,00	0,01-> 0,50 max	Leaves and humus
	0,16	0,00	0,01-> 0,15 max	Leaves and humus
	0,69	-0,03 -0,20	0,04-> 0,28 max	sand
	0,88	-0,28	0,40	
	0,69	-0,10 -0,71	0,28 0,32	
	0,35	-0,96	0,19	Hard layer

	0,86	-0,01 -0,40	0,40 0,48	
	0,98	-1.17	0,68	
	1,63	-0.03 -0.65 -0.96 -1.89	0,38max 0,31 1,09 0,24	Humus sand
	0,02	-0,61		Roots and wood
total	7,49			

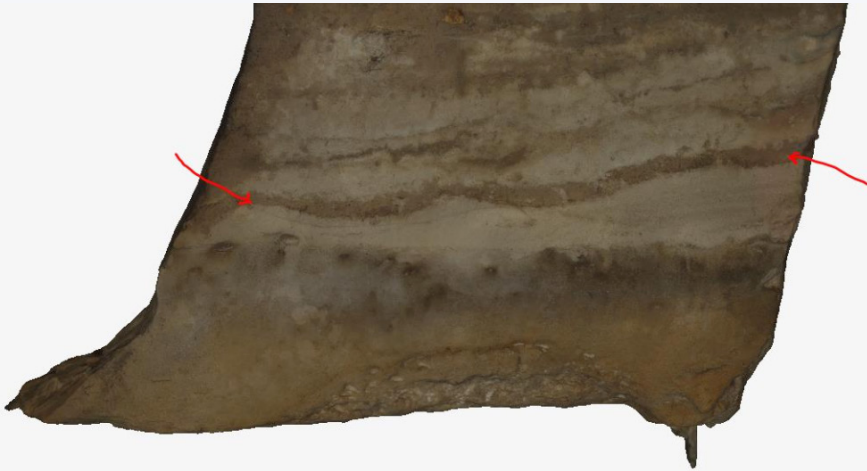
### Deduction of each layer's geometry

The excavation work has followed a removal logic according to the soil's nature, but also an archaeological logic that identifies the layers rich in materials, compared to the ones that are poorer in that regard. It is however possible to deduce the geological strata depending on the traces. As we have deposit lines on at least three faces of the site, it is thus easier to recreate the volume characterising the layer. It is about working with the empty space, rather than the filled one.

Several methods can be used. The first consists in retracing a 3D outline on each face, then in assembling the splines in one volume. The other solution aims at selecting the polygons and assembling them. The latter will be shown here. Once again, any 3D software works.

For the detailed operation, this stratum is chosen:

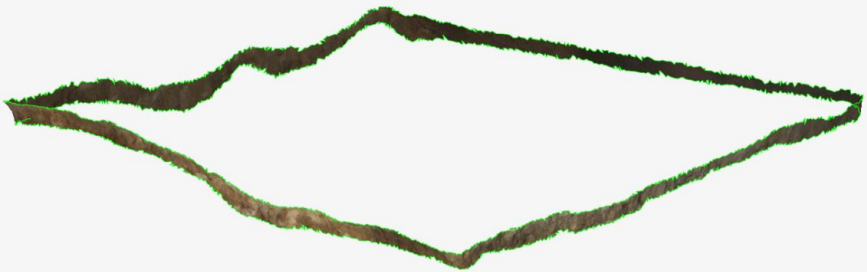




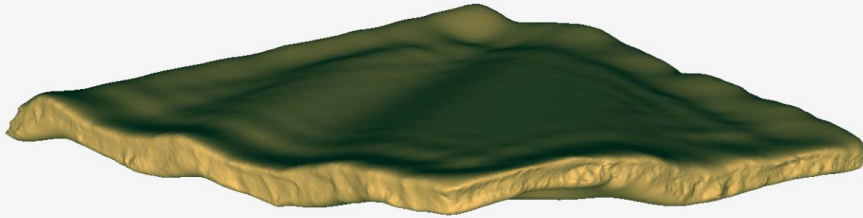
We must first start by reversing the faces in order to get the normal ones towards the outside. The selection is done face by face, leaving polygons on the border.



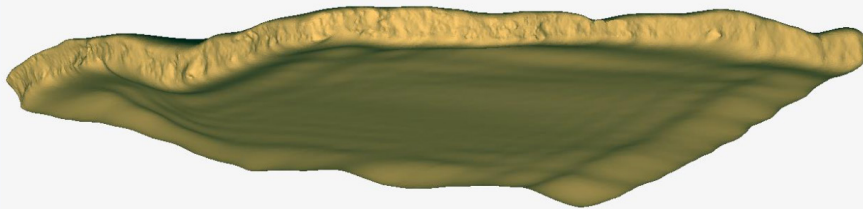
The layer is isolated. Only remains to “put a lid” on the upper and lower faces.



The filling is done:



From another angle:



The volume is at 0.1534m<sup>3</sup> and the altitudes are at -1.47 for the upper face at the centre and -1.57.

The development is as follows:



angles actuals : 37.404  
angles selectionnés : 0  
4.0730 m  
3.3091 m  
0.6332 m



Each stratum is cut out. When we separate each stratum from the others, it looks as follows:



Here again, each element can be measured and qualified.

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