Photogrammetry at Lapa do Picareiro:
3D Modeling of a Middle and Upper Paleolithic Cave Site

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PURPOSE

To find accurate and affordable alternatives to LiDAR and other Laser Scanning Techniques for the collection and recording of spatial data. LiDAR resolution may be too fine for our purposes, resulting in bulky data sets and limited use file formats. LiDAR also requires expensive equipment that must be carried up and down the approach to the site. LiDAR also requires contracting out the scan collection and initial data processing.

HYPOTHESIS

Photogrammetry is capable of producing three dimensional models with resolutions as reliable as LiDAR and as useful. These models will be less expensive, requires less hardware, and less time to make than LiDAR.

BACKGROUND

Lapa do Picareiro is a Middle to Late Paleolithic site in central Portugal. The site sits inside of a cave on top of a low mountain, accessible only by goat paths. As the excavation removes more soil the true shape of the cave becomes more apparent. With complex stratigraphy and rapidly changing surfaces, the site requires a versatile method of recording space that can provide context to multiple different stages in the excavation. This context provides crucial information for the many faunal and lithic materials recovered each year.
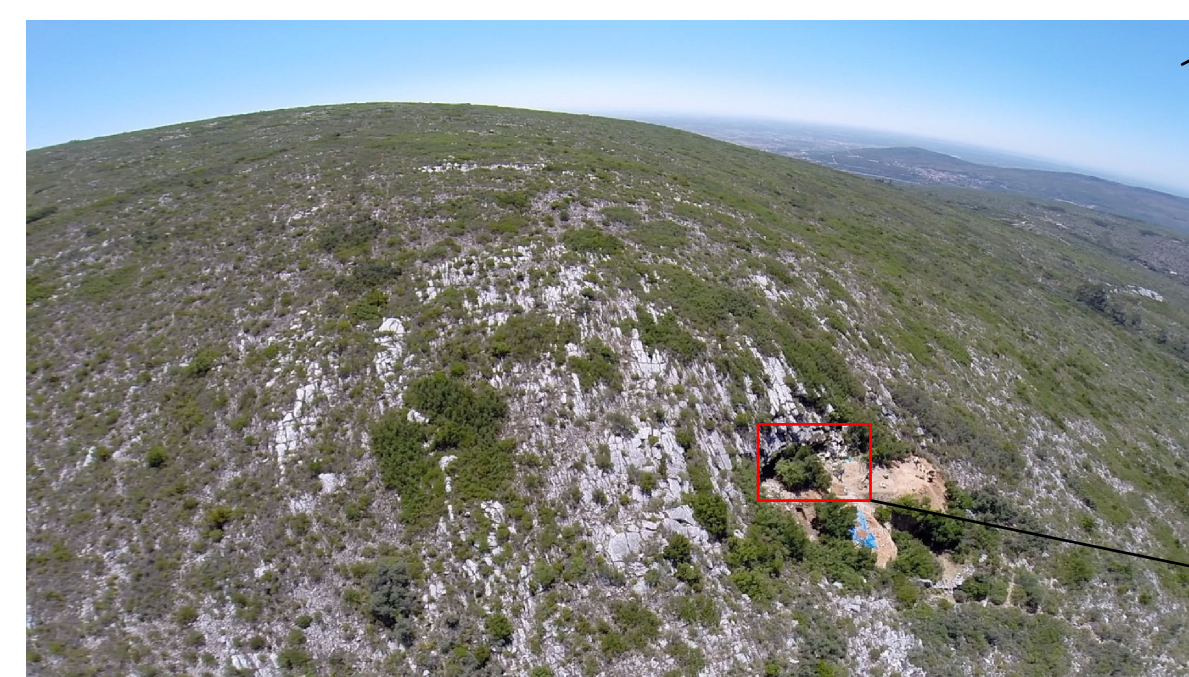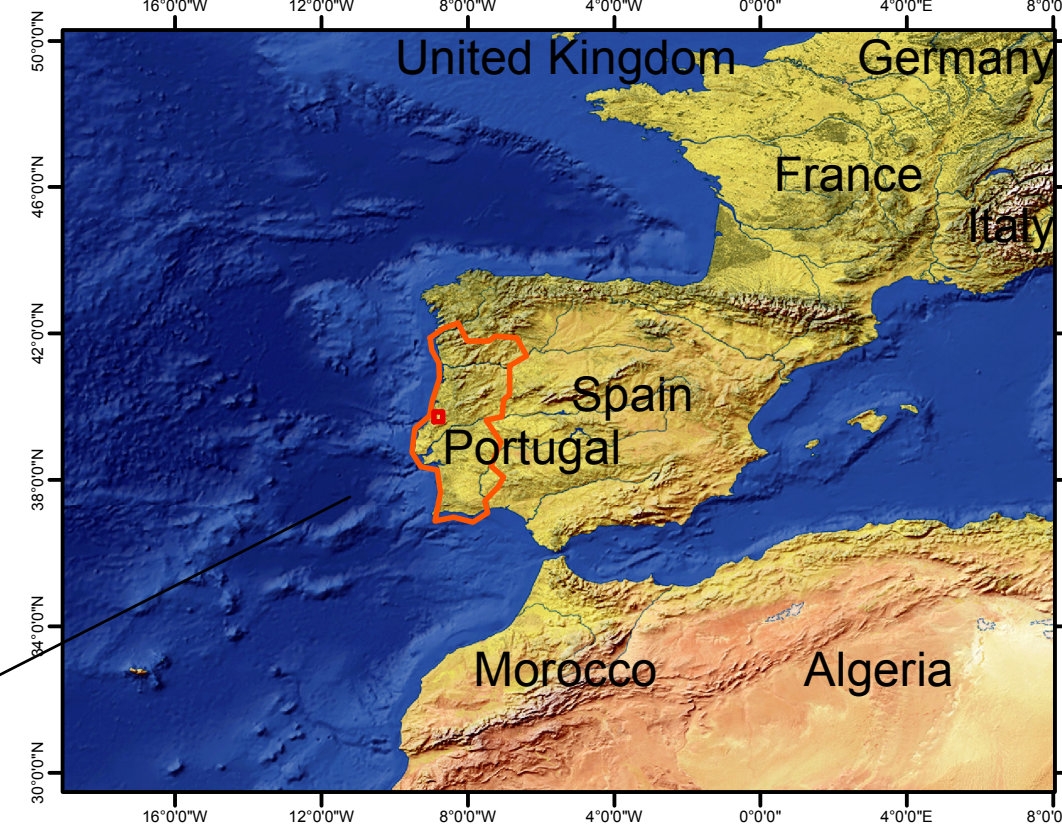
The mouth of Lapa do Picareiro with the back dirt piles and the approach path. Facing south. Footage captured using UAS technology.

Layer "T" Model Area
Back Room Model Area

In 2015 two areas of interest in the cave had models created of them using photogrammetry. A recently uncovered back room, which until 2014 was sealed off by unexcavated material, and a section of the geologic layer "T", a layer of large clasts. The back room was chosen because of a series of hearths excavated in 2015. The layer "T" section was chosen to fill gaps in the recovered material point cloud caused by clasts.

MATERIALS

All pictures were taken with a Nikon D3100 DSLR camera. Photogrammetric work was completed using Agisoft PhotoScan. Total station points were collected using a Sokkia CX-103 and the OldStoneAge.com EDMWIN software. Data were imported into ArcScene for visual rendering and manipulation.

METHODS

The general methodology described below was applied to each of the models created in 2015. This section covers the creation of the clast model of Layer "T".

Pictures were taken of the area starting parallel with the surface. The photographer rotated all the way around the area with each picture's field of view overlapping the next by thirty to sixty percent. This allowed the photogrammetry software to identify common points among the pictures. The camera was then raised by roughly fifteen degrees and photographs taken again around the entire area. This was repeated until the collective fields of view formed a dome of coverage around the area (Fig. A).

After uploading the pictures into Agisoft a rough model was made and the control points used to link the model to a known projection and coordinate system were added (Fig. B). This was done by manually adding the points to a picture, then adjusting the points once they had been identified by the software in the rest of the photographs. These control points still needed spatial data to be entered at this stage.
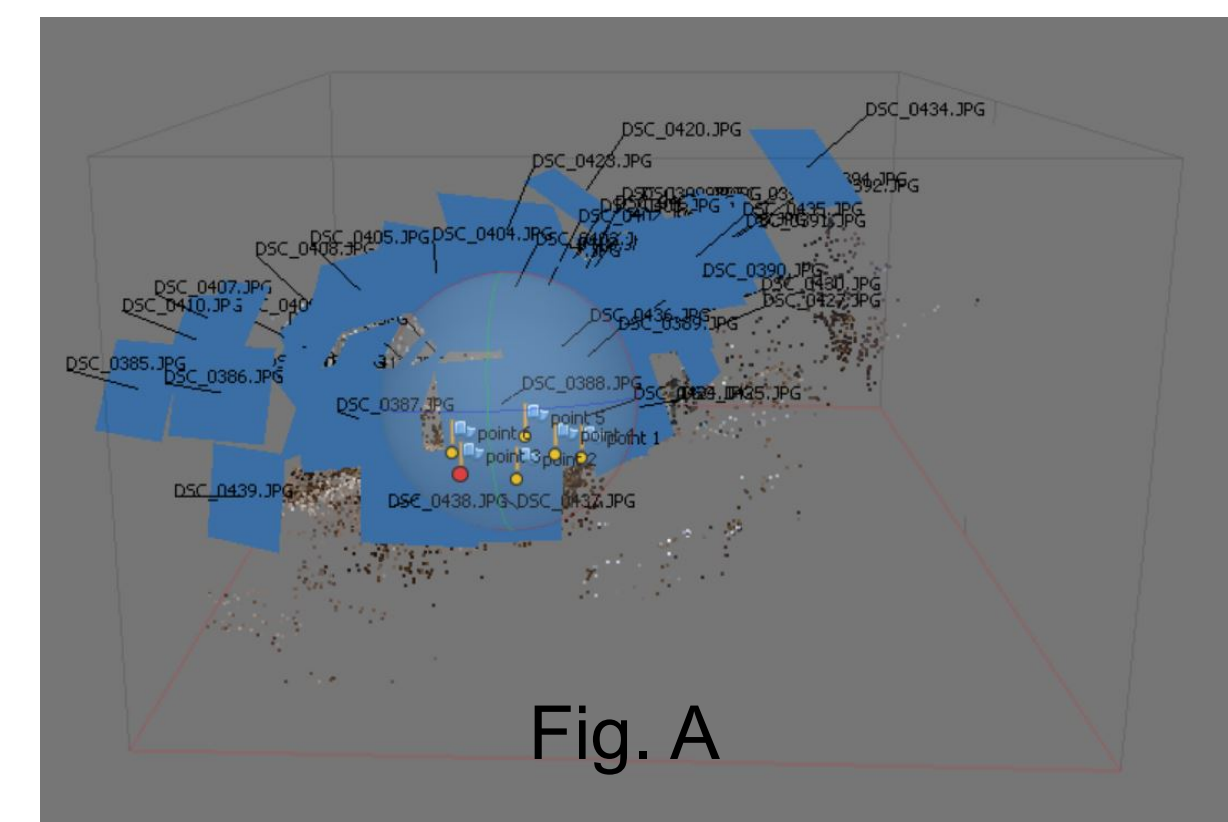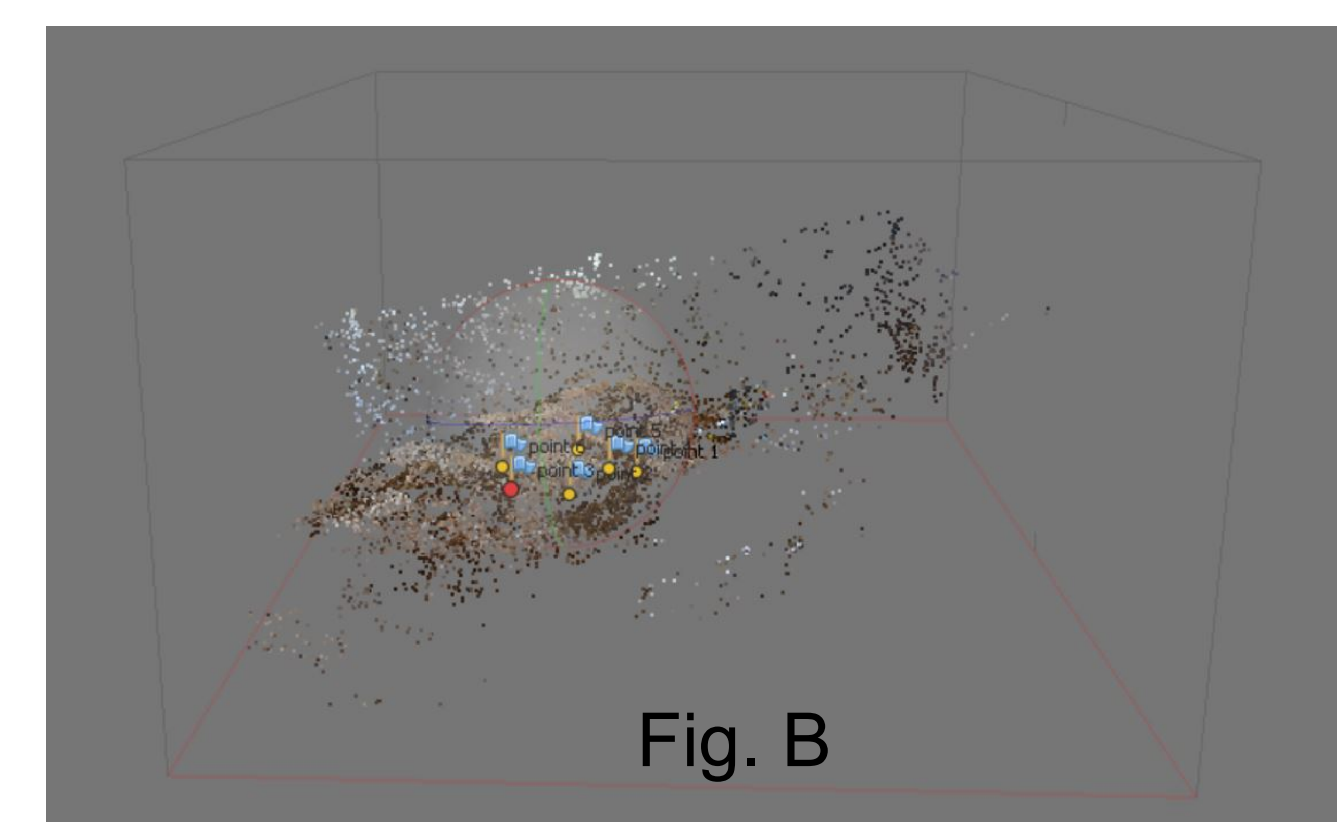

Fig. A

Fig. B

A dense point cloud, mesh, and texture were created and the software workflow was completed(Fig. C). To be used in other systems in conjunction with other spatial data, the specified control points needed x, y, and z data.

Piece plots were taken at changes of geometry on clasts in layer "T" using the total station (Fig. D). Control points were chosen because of their location at major changes in geometry and for the ease of locating them among the point cloud.
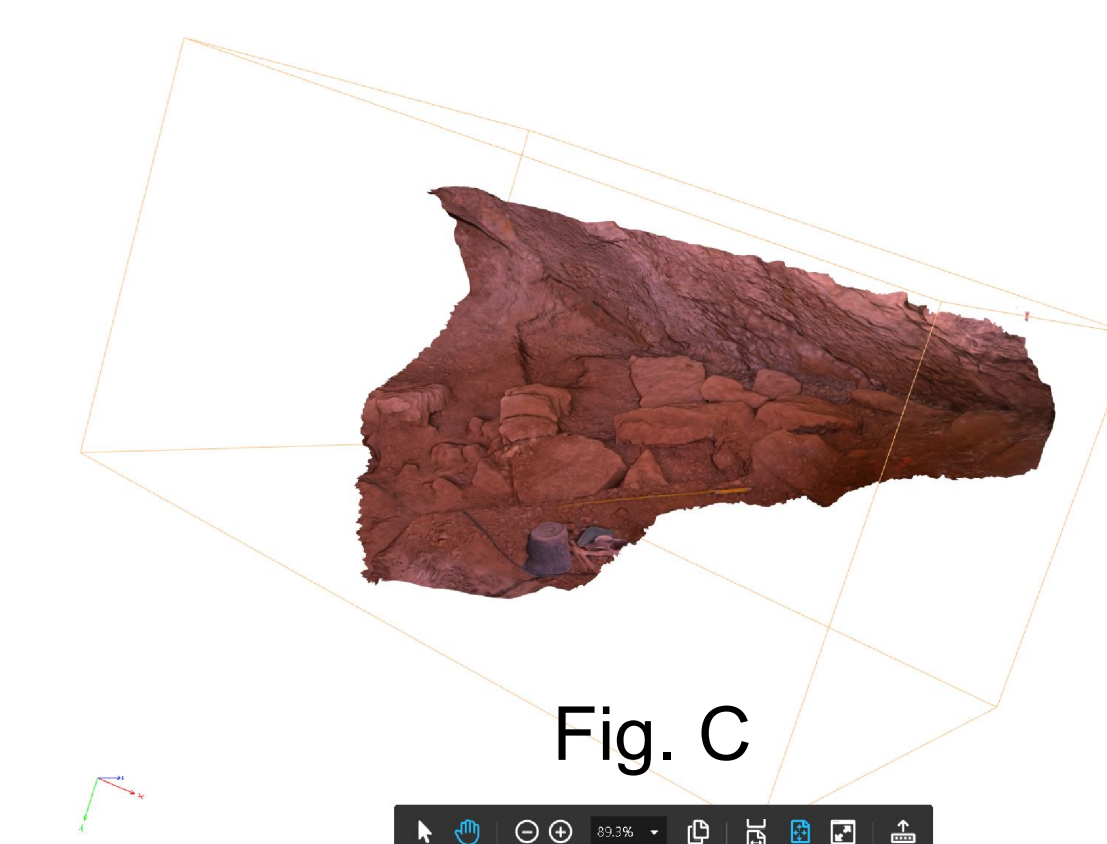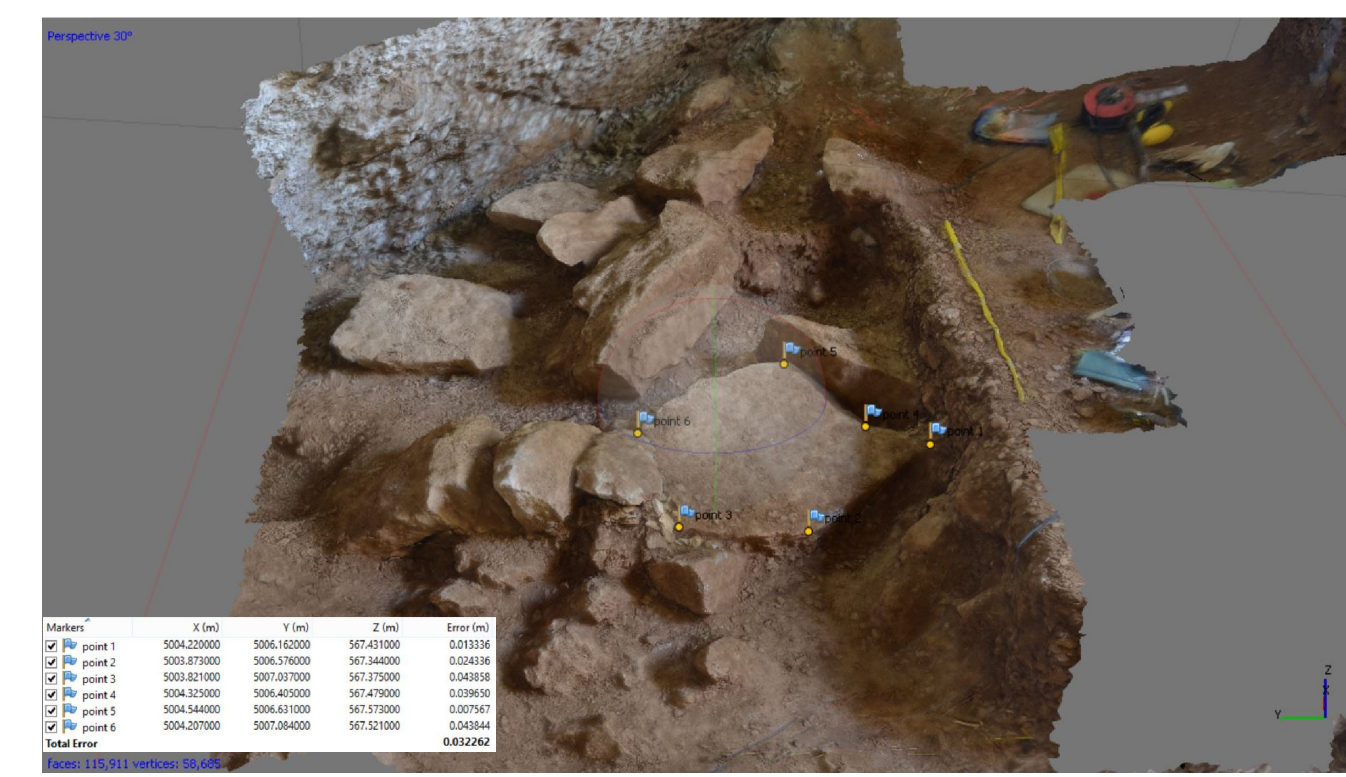

Fig. C

The x,y, and z coordinates assigned to the control points were inserted into Agisoft corresponding with the appropriate points in the model (Fig. E). At this stage, the bounding box reset to match the control points. This could have been done earlier in the process, before the dense point cloud was created. The bounding box did not always adjust and it was useful to align the model with a single axis in the excavation grid made visible by a physical boundary in the pictures used for the model.

Once the control points were added, the model was imported into ArcScene where the point cloud for the excavation aligned with those chosen as control points (Fig. F).
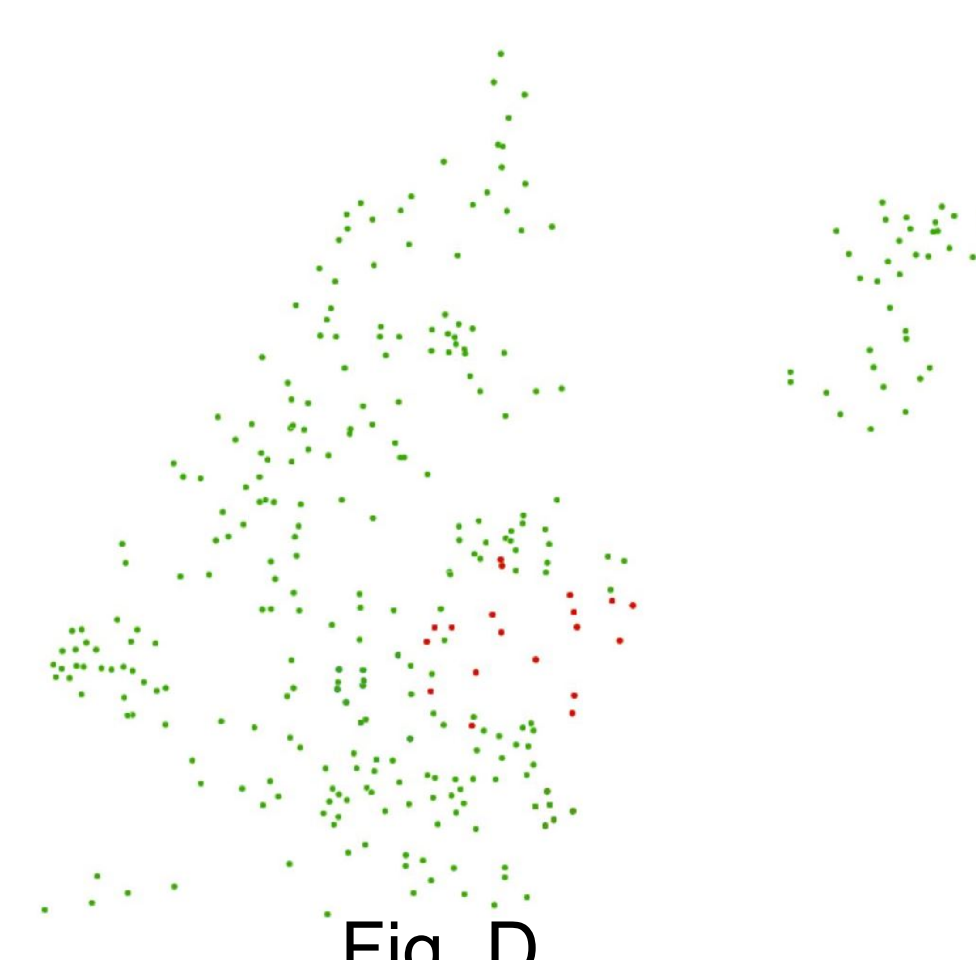

Fig. D

Fig. F

RESULTS

Multiple models were created. The lack of sufficient lighting in the cave presented some problems but served as a learning experience. The low resolution models were successfully aligned along the pre-existing axis in the cave and imported in ArcScene where they match the recovered material point cloud. The images below show some of the point selections chosen to pair with the models. Error in control point placement along all axis was less four centimeters. More lighting and more control points would decrease this error. The following images show that photogrammetric models can be integrated into point clouds using less equipment, time, and money than LiDAR.
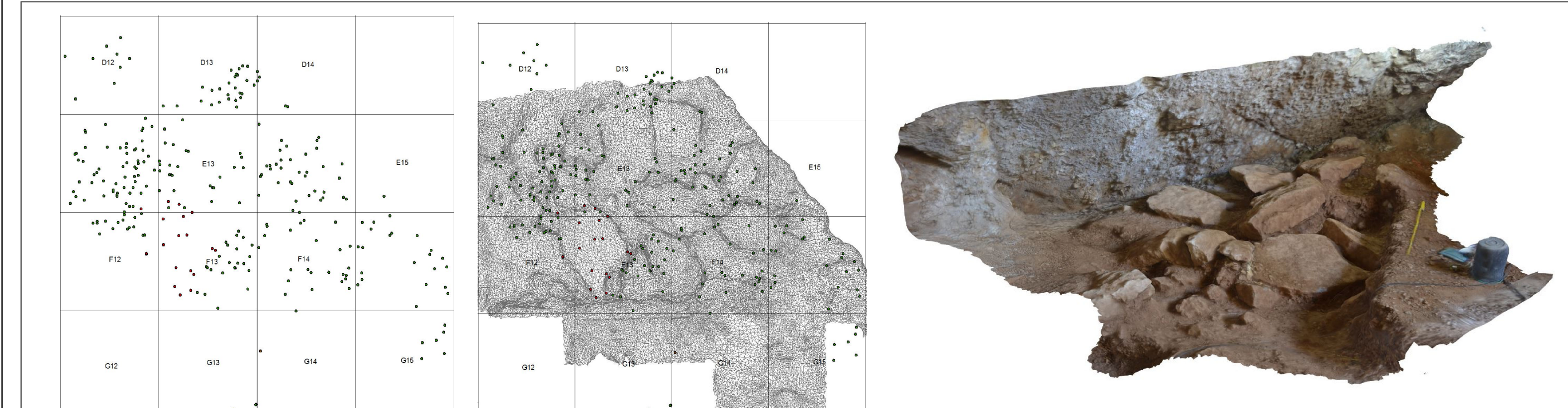

Light green dots represent corners of clasts. Red dots represent the control points chosen for the layer "T" model. From left to right; A top view of layer "T" clast points with no model for context; with a model for context; Layer "T" model facing cave east as if standing on the current excavation surface.
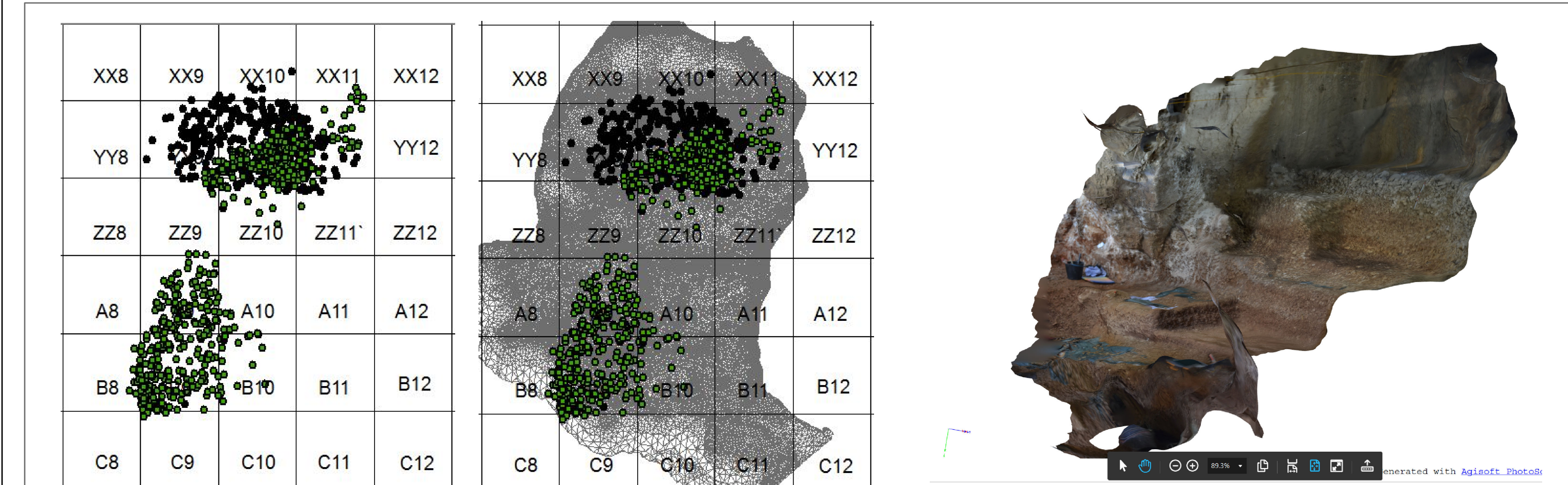

Green Dots represent material from Layer "T" hearths. Black dots represent material from Layer "O" hearths. From left to right: Top view of the back room without the model; with the model; The back room facing cave north-west as if standing on the excavation surface.
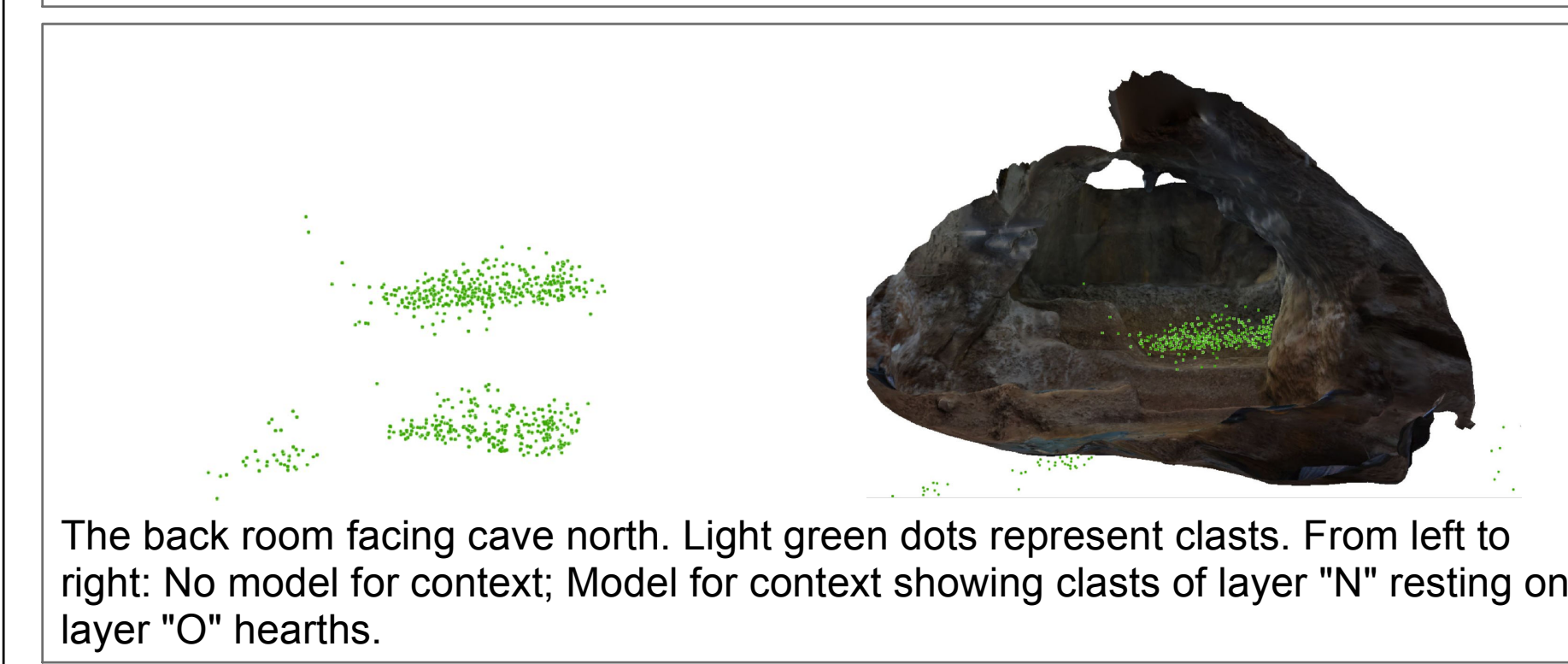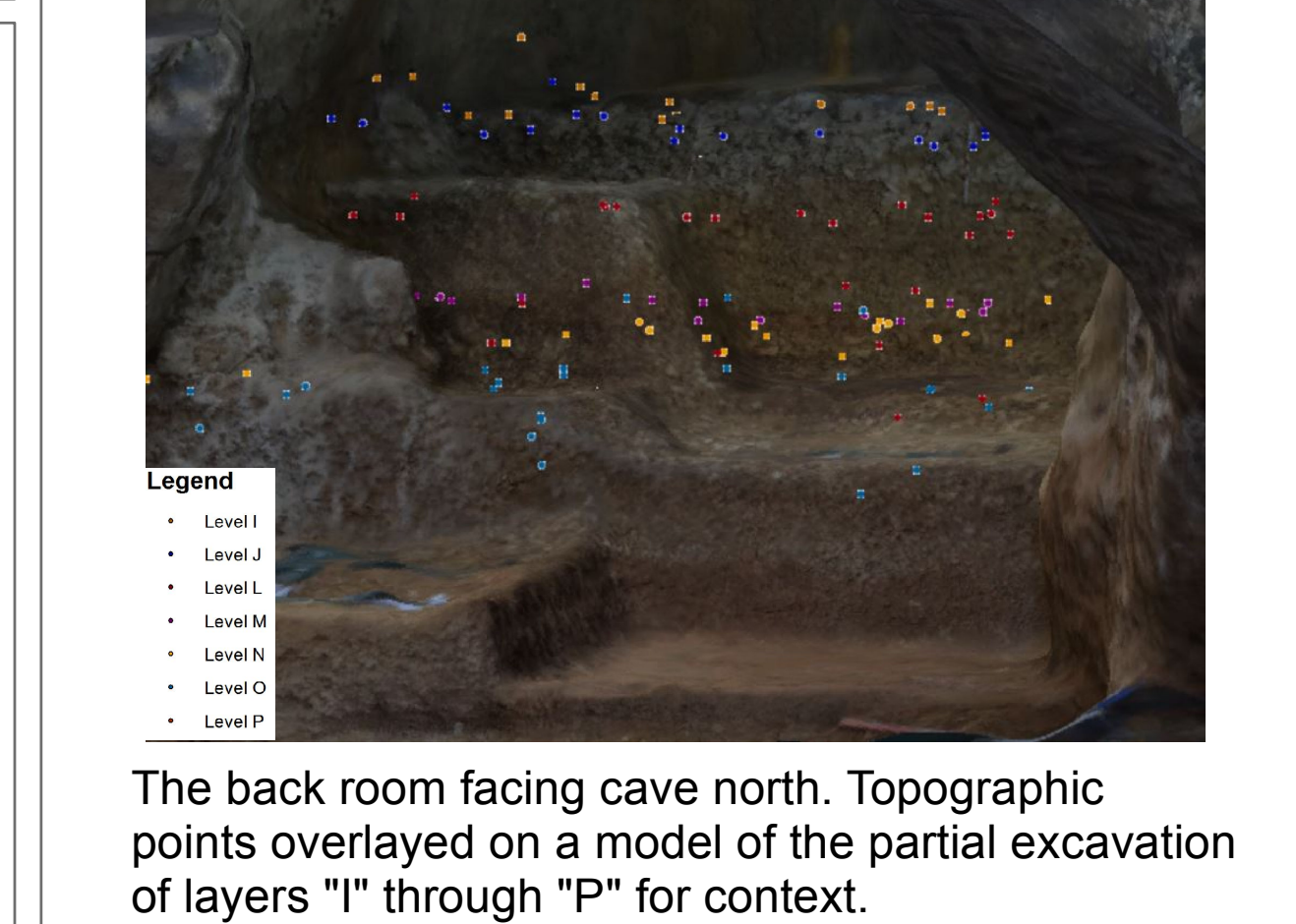

The back room facing cave north. Light green dots represent clasts. From left to right: No model for context; Model for context showing clasts of layer "N" resting on layer "O" hearths.
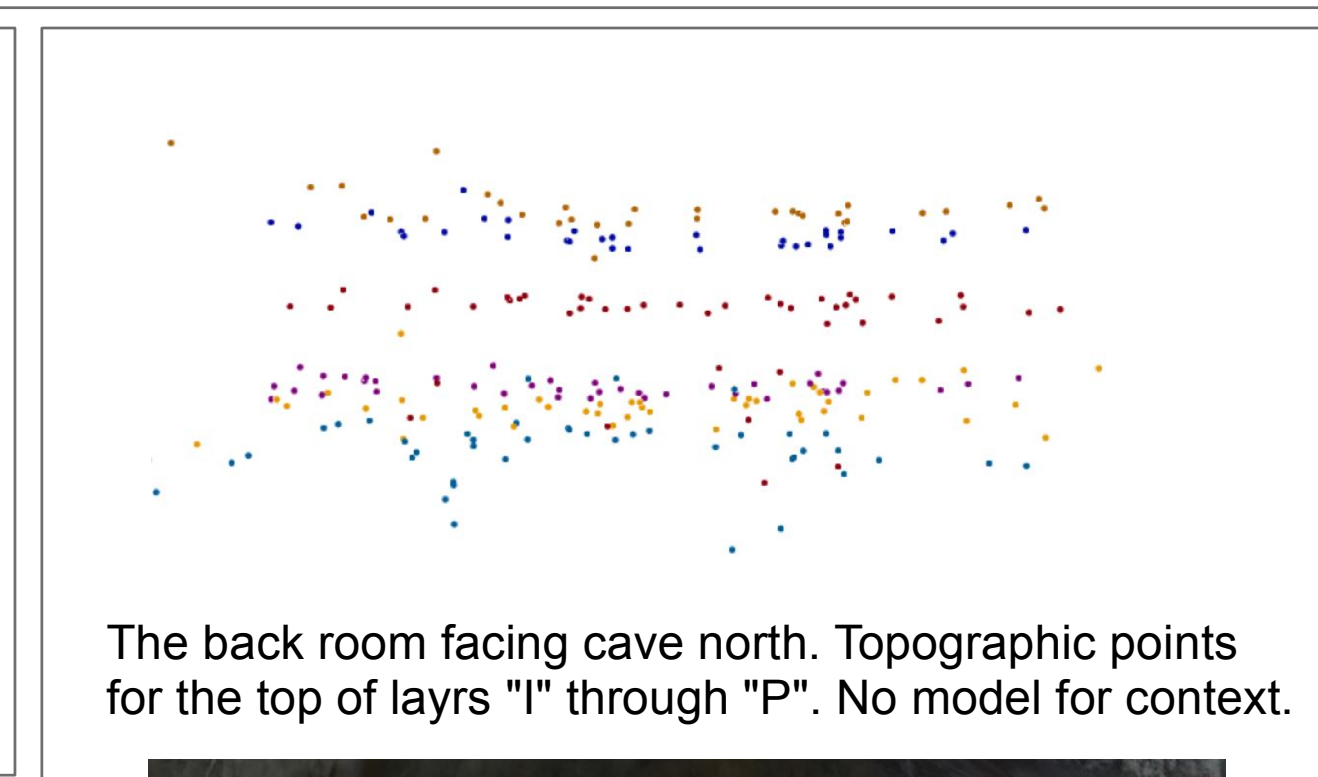
The back room facing cave north. Topographic points for the top of layrs "I" through "P". No model for context.
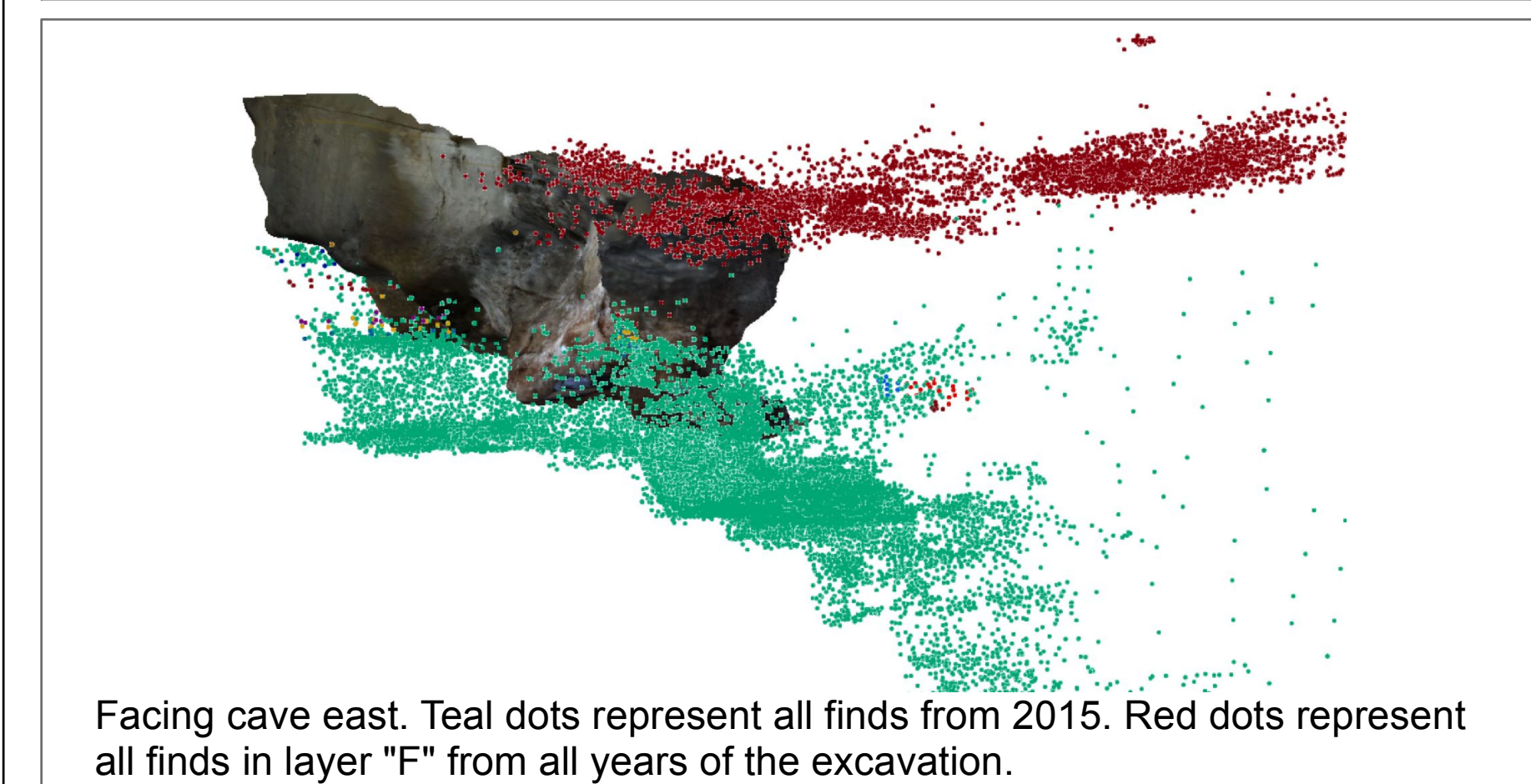
Facing cave east. Teal dots represent all finds from 2015. Red dots represent all finds in layer "F" from all years of the excavation.

The back room facing cave north. Topographic points overlayed on a model of the partial excavation of layers "I" through "P" for context.

DISCUSSION

This is the first year of a multiple year study of photogrammetry at Lapa do Picareiro. In 2016, large scale models of the entire excavation will be made during different stages in the season. In 2017, we will have collected LiDAR data and photogrammetric models for three consecutive years. Volumetric calculations and analysis can be made comparing the two methods of recording spatial information. Accuracy, resolution, time, expenses, and ease of production will be compared and discussed in the final product of this study. Artifact density calculations, spatial analysis, and digital rendering of the site will benefit from the context provided by the models and terrains made during the course of this exercise.