

# Example of Strategy for an optimized digital mapping of an excavation

*Implementation in the archaeological site of Puig Ciutat, Barcelona*

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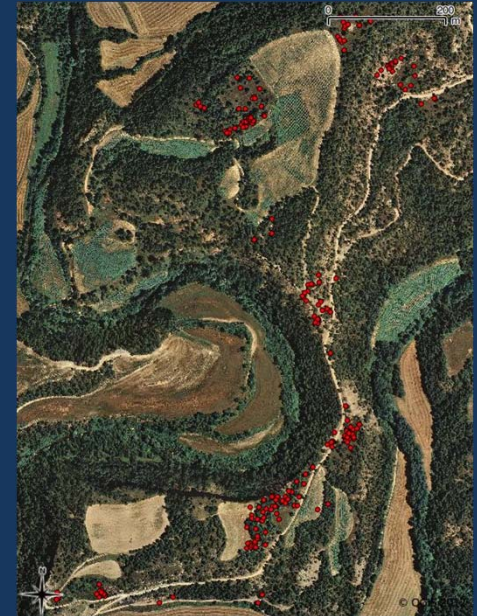
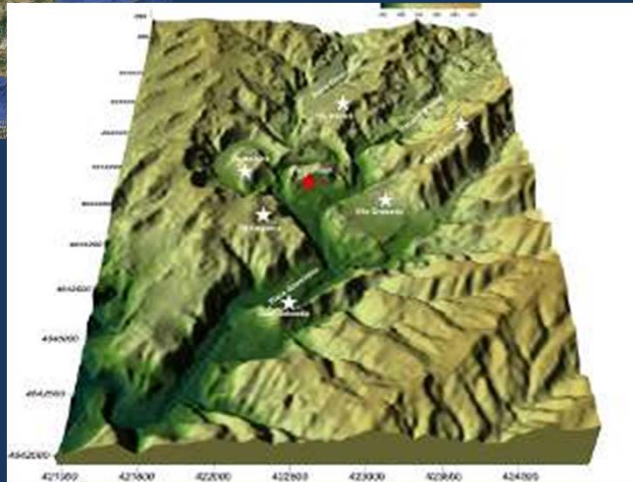
1 SOT Archaeological Prospection, 2 Universitat de Barcelona, Departament de didàctica de les ciències socials, 3 GIRA Association, 4 Euskal Herriko Unibertsitatea, Mineralogia eta Petrologia saila, 5 Institut Català d'Arqueologia Clàssica



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Context of application: The archaeological site of Puig Ciutat

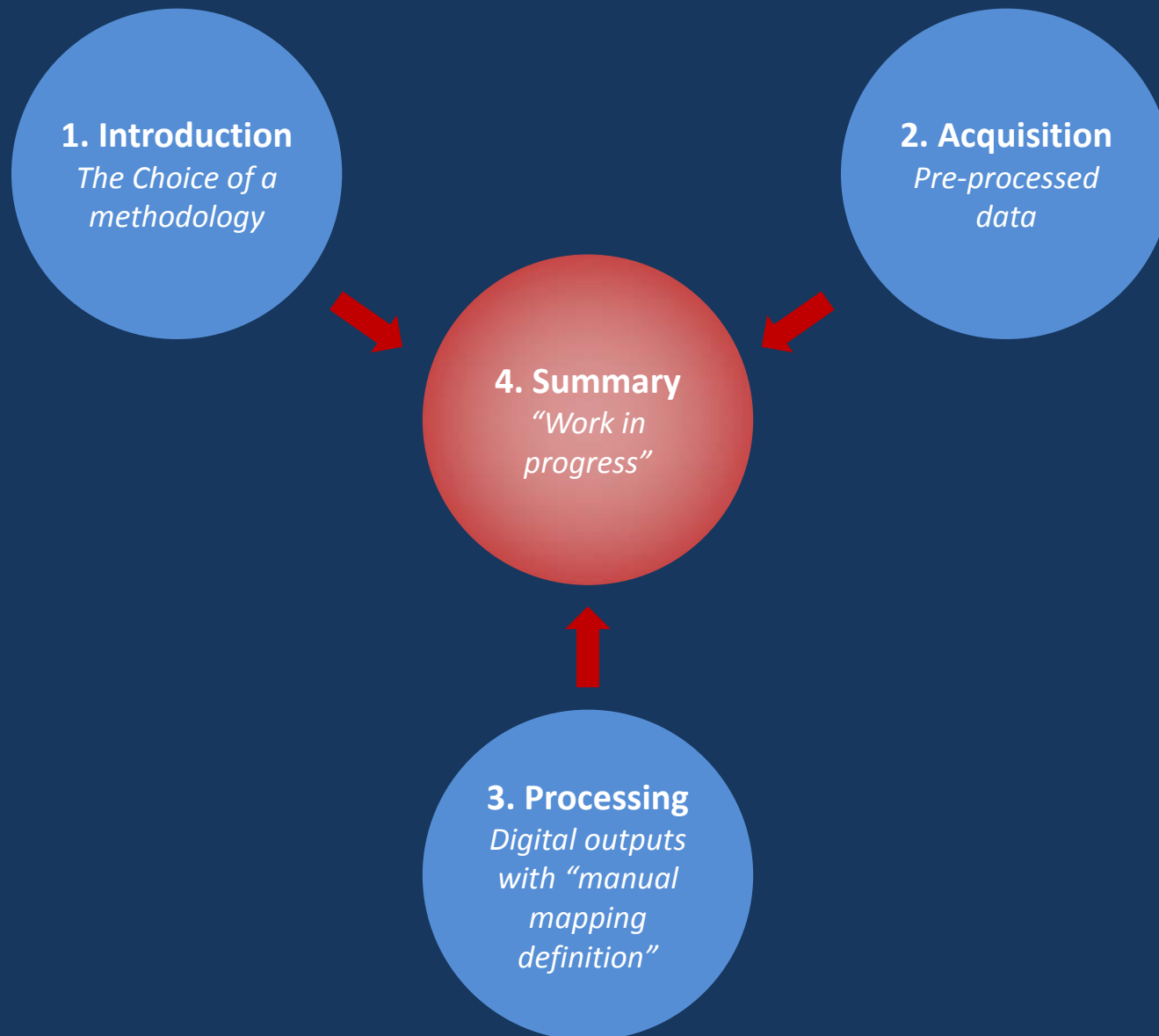
Puig Ciutat is a Roman settlement used as a test site for the implementation of new methodologies



The project needed a methodological approach and a platform for a combined interpretation of both exploration and excavation results

The main limiting factors being a limited budget, only two weeks of excavation per year, a processing depending on volunteer work and no staff fully dedicated to the projected

# Example of Strategy for an optimized digital mapping of an excavation



**PART 1**  
**Introduction**  
**The Choice of a Methodology**

**PART 2**  
**Acquisition**  
**Pre-processed data**

**PART 3**  
**Processing**  
**Digital outputs with a “manual definition”**

**PART 4**  
**Summary**  
**“Work in Progress”**

## 1.1 Mapping an excavation: From manual to digital

### First campaigns with manual mapping

Local references for each excavated sector  
Difficult comparison with exploration results

### Third campaign with a total station

Easy use for the referencing of artefacts  
Problems to define a nomenclature for the acquired points  
Problems to decide when to use it without losing the definition of the manual approach

### Fourth campaign with a robotized total station

Only one operator for the mapping  
Acquisition with a clear nomenclature limiting field documentation  
Implementation of a protocol for the digital mapping of the excavation

## 1.2 Systems and Software: A large diversity

Manual measures + Dumpy level



Separated (X, Y) and Z  
Relative references  
Continuous representation

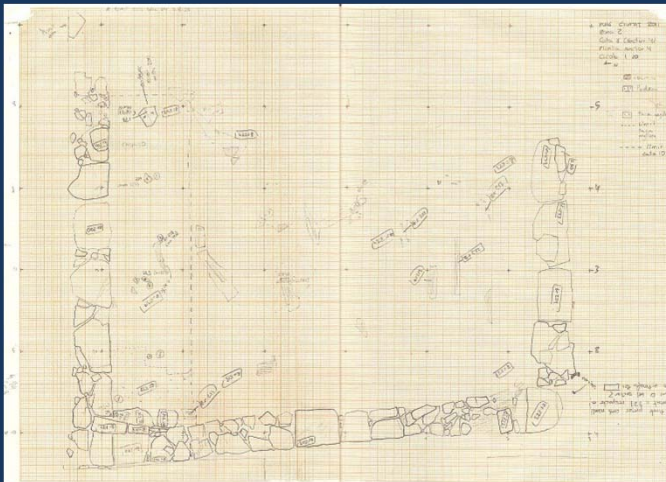
## 1.2 Systems and Software: A large diversity

## Manual measures + Dumpy level

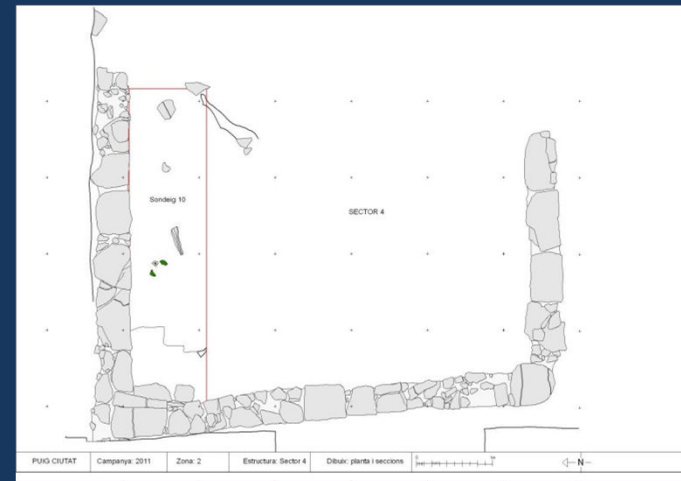


Separated (X, Y) and Z  
Relative references  
Continuous representation  
Manual transfer to digital formats

## Field measures



## Digital results



## 1.2 Systems and Software: A large diversity

Differential  
GPS



Varying precision  
Satellite coverage dependent

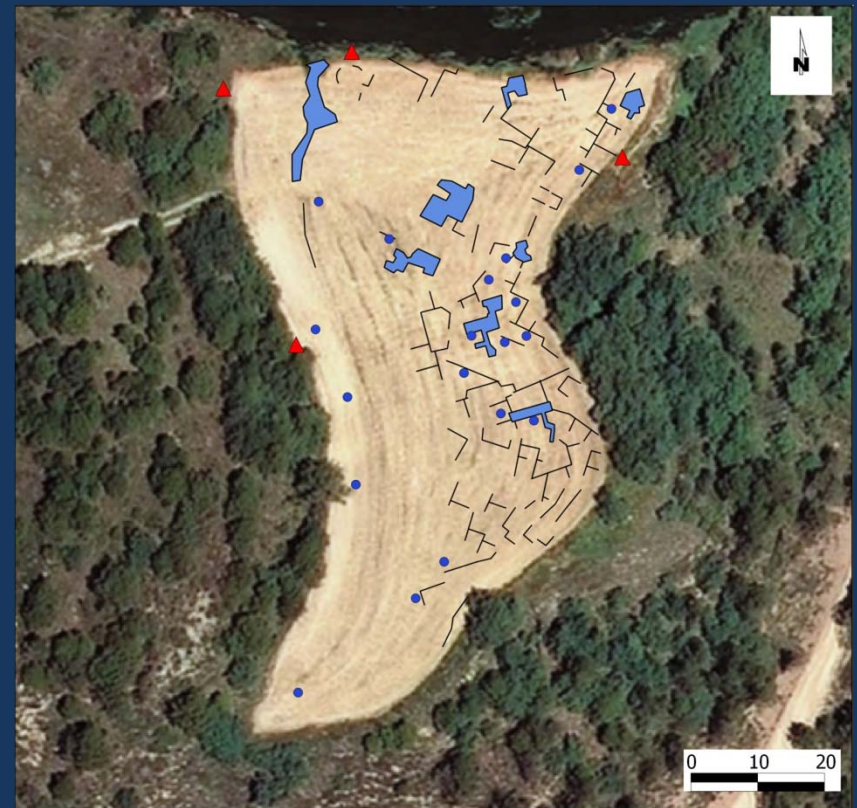


## 1.2 Systems and Software: A large diversity

Differential  
GPS



Varying precision  
Satellite coverage dependent  
Used for global referencing



Points for georeferenciation and referenced  
geophysical interpretation

## 1.2 Systems and Software: A large diversity

Total Station

Robotized  
Total Station



Georeferenced Coordinates

Digital data

Possibility of measures with only 1 operator

## 1.2 Systems and Software: A large diversity

Total Station

Robotized  
Total Station

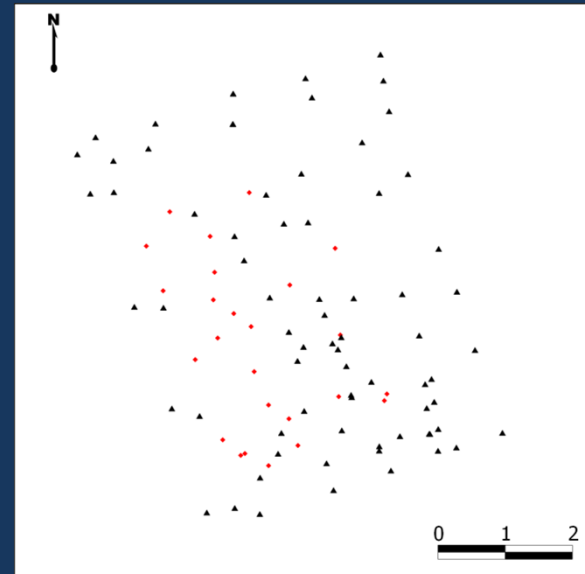


Georeferenced Coordinates

Digital data

Possibility of measures with only 1 operator

Scattered points



## 1.2 Systems and Software: A large diversity

Total Station

Robotized  
Total Station

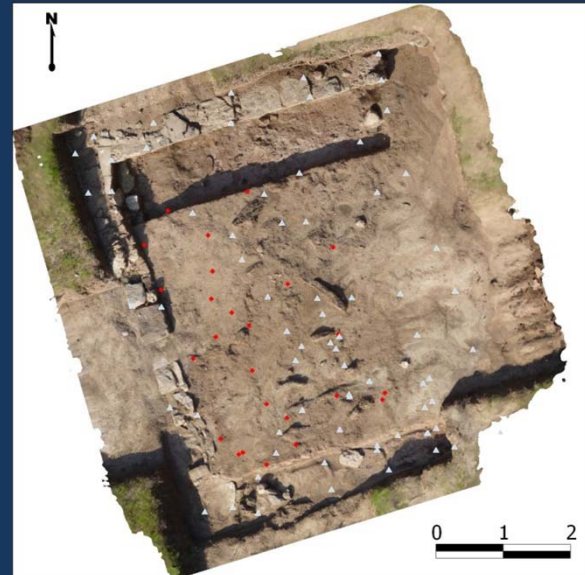


Georeferenced Coordinates

Digital data

Possibility of measures with only 1 operator

Scattered points



## 1.2 Systems and Software: A large diversity



Dumpy level



Differential  
GPS



Total Station

**The topographical systems do not offer viable geo-referenced continuous digital mapping possibilities**

## 1.2 Systems and Software: A large diversity



Dumpy level



Differential  
GPS



Total Station

+



Digital  
Camera



Laser  
Scanner



Micro Unmanned  
Aerial Vehicle

The coordinates acquisition can be combined with digital mapping systems

## 1.2 Systems and Software: A large diversity



Dumpy level



Differential  
GPS



Total  
Station

+



Digital  
Camera



Laser  
Scanner



Micro Unmanned  
Aerial Vehicle

In order to process , combine and  
present the acquired data

A large diversity of software are in use

Vector Graphics Editors

Office and Database management

CAD and GIS

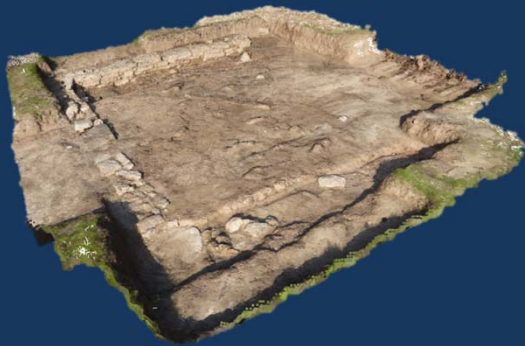
3D Software

Dedicated software

## 1.3 3D Models: 3D acquisition, when and how?

### First approach

Systematic use of photogrammetry for the documentation of each stratigraphic unit



### Problems

Interferences with the excavation process  
(light, cleaning, timing, deterioration of the exposed artefacts)

Specific time consuming and computer dependent processing

Large data volumes that require additional archiving specifications



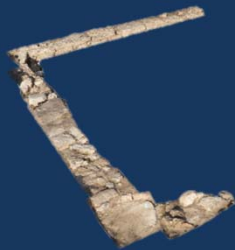


## 1.3 3D Models: 3D acquisition, when and how?

### Second approach

Use of photogrammetry for the documentation of complex 3D structures

Additional ortho-rectified photographs combined with a 3D surface for the documentation of the stratigraphic units



### Advantages

Interferences with the archaeological excavations are very limited in time

The processing is limited and can be performed with GIS tools

The large data volumes are restricted to complex structures while most of the documentation consists of single high resolution photographs



## 1.4 Summary of Choices

### Systems

**Robotized Total Station and Digital Camera**

*Requires a documentation of the measured points*

### Acquisition

**A Pre-processed acquisition**

*Implementation of an acquisition protocol that defines the nomenclature of the measured points and the objects to map*

### Software

**Open source solutions for processing, mapping and data management  
Final rendering with Vector Graphics Editor**

*Requires the design of the database and the transfer of the existing information*

### 3D Models

**A Combined approach**

*An intermediate methodology in order to enlarge documentation possibilities while limiting data, processing and breaks in the excavation process*

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## 2. Acquisition: Pre-processed data

How can the topographical acquisition be designed for an easier export and processing of the results?

1

Objects to map

2

Nomenclature

3

Special cases

4

Field work documentation

## 2.1 Categories of Objects to map

We defined the different categories that should be mapped and easy to separate during processing

Artefact



Soil samples



Stratigraphic Units



Ortho-rectified photographs associated to objects



Vertical sections



Reference Points



Photogrammetries



## 2.2 Nomenclature of the acquisition

How to assign a unique identifier to points during the topographical acquisition

Field 1		Field 2		
Category and Id Number		Point Number	Stratigraphic Unit	Unique Key Identifier
C	Artefacts with coordinates			<u>C-19</u> <u>2099</u>
PXX	Planimetry			<u>P05-34</u> <u>2101</u>
SXX	Vertical section	Relative point number	Unique Id per:	
MXX	Soil sample		Zone	
RXX	Reference point		Sector	
FXX	Photogrammetry		Campaign	(...)
CatXXF	Ortho-rectified photograph			<u>C19F-04</u> <u>2099</u>

## 2.3 Specific cases

A specific methodology was implemented for certain categories of objects in order to anticipate the processing

### Planimetrics

First, the lateral extension of the stratigraphic unit is measured

**Points must  
be ordered in  
sequence**





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A specific methodology was implemented for certain categories of objects in order to anticipate the processing

### Planimetrics

First, the lateral extension of the stratigraphic unit is measured

The last measured point is identified and documented





## 2.3 Specific cases

A specific methodology was implemented for certain categories of objects in order to anticipate the processing

### Planimetrics

First, the lateral extension of the stratigraphic unit is measured

The last measured point is identified and documented

Then inner points are measured to document the vertical variations



## 2.3 Specific cases

A specific methodology was implemented for certain categories of objects in order to anticipate the processing

### Ortho-rectified Photographs

Photographs of singular objects are taken with reference points

The lower-left reference has a colored marker

The sequence of measures goes clockwise starting from the colored marker



## 2.4 Field work documentation

Additional information is registered during field work as a help for the processing

Planimetria	UE	N total	Perimetre final	Observacions										
P001	2096	15	15											
P002	2099	46	23											
P003	2102	31	13											
P004	2104	25	13											
P005	2110	90	57											
P006	2112	26	26	Hi a una planimetria posterior de la mateixa zona amb el perimetre bo (P018) i amb foto georef associada (P018F). El punt 21 es dubtos. Sols perim										
P007	2117	16	9	Foto georeferenciada associada. Forat de pal (nomes perimetre exterior)										
P008	2118	8	7	nomes perimetre exterior i un punt al mitg										
P009	2115	51	26	part sud del sector 8, separat pel MR. Es va fer una posterior (P032) que anula aquesta										
P026	2120	34	24	part nord del sector 8										
P010	2122	17	14	Foto georeferenciada associada. Perimetre interior del reompliment del forat de pal del sud del S4										
P011	2123	90	73	carrer 3. Sota UE2110. Sobre 2114 i SOTA MurE										
P012	2127	10	9	Foto georeferenciada associada. Farciment forat de pal 2126										
P013	2128	15	9	Foto georeferenciada associada. Retall a la RM al Nord de la llinda (encaix) de S4. El perimetre no tanca (es com un encaix) i els punts son pressos										
P014	2121	20	14	perimetre del retall del forat de pal un cop buidat. LES COTES BONES SON ELS DE LA P024 i no aquestes!!										
P015	2126	13	9	perimetre del retall del forat de pal un cop buidat										
P016	2117	7	6	un cop buidat FP (forat pal?). No respecta el protocol. Base interior forat Est										
P017	2129	48	30	taca vermella (possible llar de foc)										
P018	2112	29	20	Foto georeferenciada associada. Perimetre de la tanca marro fosc amb pedres. El perimetre bo es aquest i no el P006. Punts 21-22 a terra. Desde 25										
P019	2100	43	24	Carrer 1										
P020	2135	106	77	planimetria del nivell abans d'excavar UE2112, UE2129 i UE2117. Hem fet l'encaix i se li ha de retallar el perimetre de P018, P017 i P007. el resultat e										
P020B	2135	-	-	es el resultat de treure al P020 les P018, P017 i P007. No existeix a la fulla de DADES pero si als arxius de poligons generat al GIS										
P021	2134	93	44	els primer 3 punts limiten amb la el testimoni M-05 deixat al C3 per estudi de micromorfologia per la Tània Polonio										
P022	2130	43	26	Sector est comentat a excavar. 012 i 013 punts delimitadors de porta. 018 i 019 punts delimitadors porta. No s'ha apuntat al camp quins punts corre										
P023	2125	49	38	farciment de la banda de fonamentacio, abans d'excavar										
P024	2121	7		fons del forat de pal (prendre aquestes Z com a Z final i no els anteriors)										
P025	RMS4	69	35	36 a 54 cotes superficials. 55 a 65 Z retall roca mare. 66-69 segon retall en Roca Mare										

Number of perimeter points for planimetrics



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CODI	UE	Camera	Num Foto	observacions										
C019F	2114	angels	P117-187	ganivet del C3										
C023F	2096	angels	P117-0190	serra del S4										
C030F	2115	angels	NO POSA	Conjunt d'ossos, Esta inclosa al grup de fotos C52F, C53F i C54F. De fet el coordenat C31 possiblement s'anularà perquè ha estat agafat de nou amb										
C031F	2115	angels	117-0235 a 117-0238	Conjunt d'ossos. Es referencia la 235. La foto georeferenciada C054F inclou els ossos que surten a la C031F en un estat d'excavació més avançat. Pro										
P007F	2117	angels	117-0202	forat de pal (Agafa la planimetria del 2117 i 2118). S'ha fet un altre després de buidar-ho be (P016)										
P010F	2122	angels	117-0216	forat de pal al sud del S04 abans de buidar (Agafa la planimetria del 2121 i 2122)										
P012F	2127	angels	117-0228	forat de pal										
P013F	2128	angels	117-0231	encaix RM. A la foto no surten les 4 xinxetes, sols 3 (pel sol) doncs he georeferenciat utilitzant una pedra										
P018F	2112	roger	100-55 fins 100-57	perímetre amb pedres S04. es georeferencia la PC010055										
C052F	2115	angels	117-365 fins 117-371	abasta tot el conjunt d'ossos coordinats com a C-52A fins C-052J. S'ha georeferenciat el 371										
C053F	2115	angels	117-376	abasta tot el conjunt d'ossos coordinats com a C-53A fins C-053F										
C054F	2115	angels	117-377 fins 117-379	abasta tot el conjunt d'ossos coordinats com a C-54A fins C-054G. S'ha georeferenciat el 377										
C057F	2130	angels	117-460 fins 117-464	prop de mur nord, peça gran de ferro amb un clau associat. S'ha referenciat el 460										
C059F	2130	angels	117-0479 fins 117-048	s'ha referenciat el 479. S'ha fet una foto posterior que el completa. La primera foto es un estat previ amb numeros 1-4 i la segona completa nume										
C060F	2130	angels	117-0485 a 117-0486	s'ha referenciat el 485. el 486 és altre cosa (un glante amb escala i nord)										
C075F	2130	roger	339 fins 340	placa ferro. Es referencia la 339										
C076F	2130	roger	345 fins 347	tapa C70 + placa ferro C75 +fusellola C76. Primera xinxeta groga. Es referencia la 345										
C072F	2130	roger	341 fins 344	falç C72 i projectil de fona. S'ha referenciat la 343										
P016F	2117	angels	117-489	forat de pal del S04 un cop excavat (uns dies després). Es repetit de la P07F pero uns dies després										
P029F	2139	angels	117-493	forat de furtiu o el que sigui al costat de la taca vermella del S4										
C084F	2130	angels	117-0503 fins 117-05	2 claus doblegats C-84 i C-85. es referencia la 505										
C087F	2115	angels	117-506 i 117-507	ossos coordinats. Es referencia la 507										
C088F	2130	angels	117-510 fins 117-513	punta catapulta. Es referencia la 513										
C090F	2115	roger	604-605	ref. a escapula anterior										
C094F	2130	roger	609-611	claus										
C097F	2115	roger	606 fins 608	ossos										
C098F	2130	roger	617-618	cala 3?										

Identifier of the photographs and of the used camera for single photographs and photogrammetry

## 2.4 Field work documentation

**Additional information is registered during field work as a help for the processing**

[illegible]

## Identifier of the photographs and of the used camera for single photographs and photogrammetry

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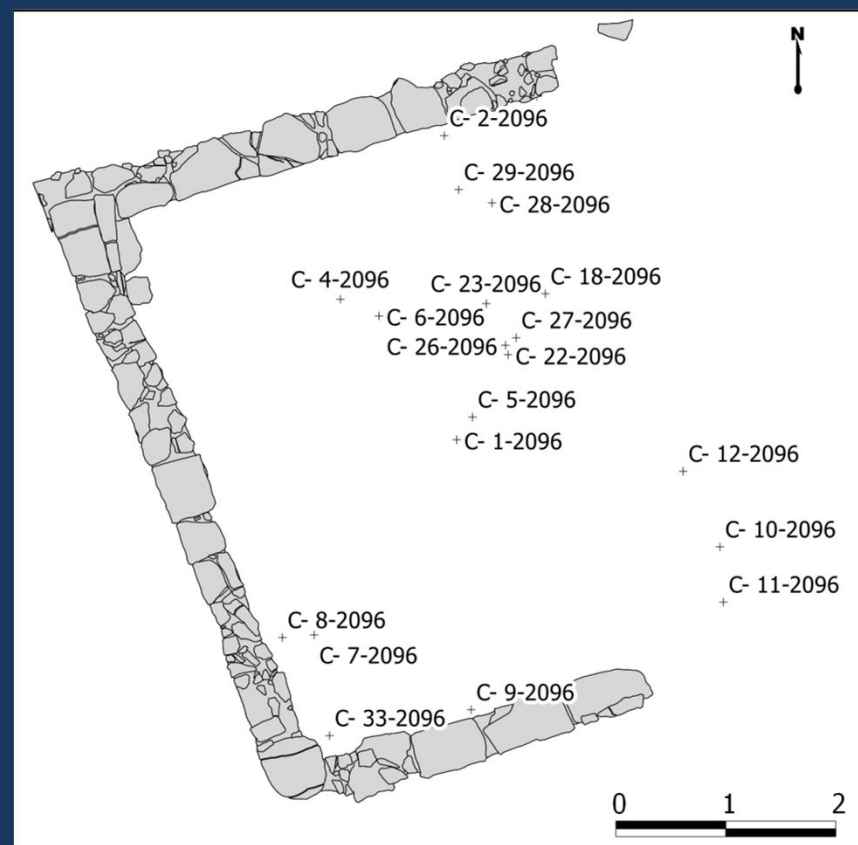
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## 3.1 Artefacts and Samples

Complete with fieldwork documentation

Map results

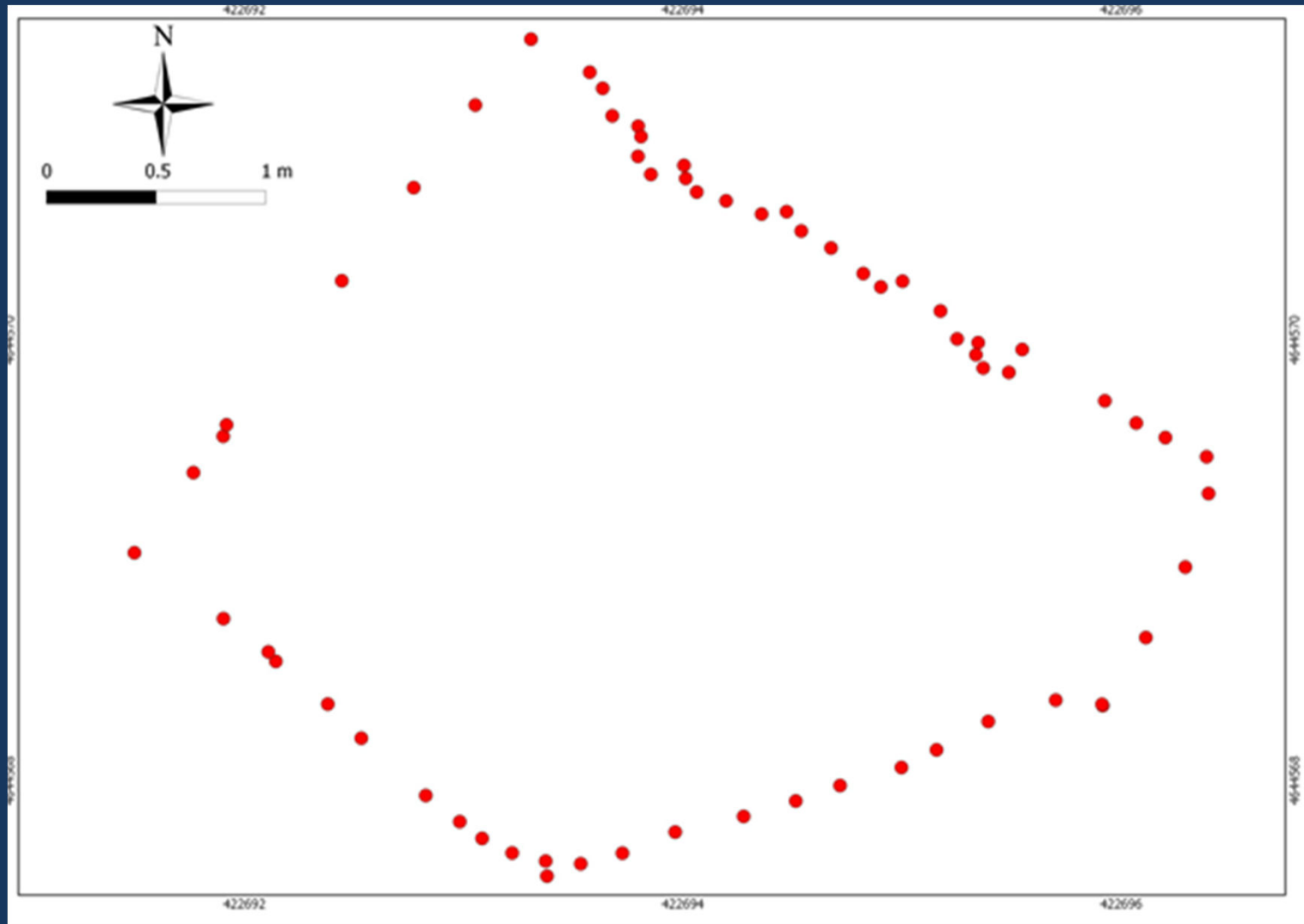
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422665.591	4644534.099	524.034	C	4	2096	1	indeterminat		metall
422666.793	4644533.028	524.019	C	5	2096	1	clau		metall
422665.942	4644533.948	524.058	C	6	2096	1	indeterminat		ceramica
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422666.779	4644530.365	524.074	C	9	2096	1	indeterminat		metall
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422669.074	4644531.345	523.906	C	11	2096	1	clau		metall
422668.708	4644532.535	523.912	C	12	2096	2	indeterminat		ceramica
422667.454	4644534.149	523.98	C	18	2096	1	indeterminat	tija	metall
422662.809	4644534.981	524.474	C	19	2114	1	ganivet	empunyadura i part de fulla	metall
422667.115	4644533.594	524.001	C	22	2096	2	indeterminat		metall
422666.917	4644534.06	524.012	C	23	2096	4	serra	fulla	metall
422662.728	4644529.223	524.27	C	24	2110	1	clau		metall
422668.557	4644530.425	523.925	C	25	2113	5	gerra	nansa	ceramica
422667.091	4644533.681	523.982	C	26	2096	6	gerra	vora	ceramica
422667.189	4644533.749	523.974	C	27	2096	9	gerra	base	ceramica
422666.969	4644534.975	523.975	C	28	2096	1	anfora	S/F	ceramica
422666.667	4644535.096	523.98	C	29	2096	1	anfora	S/F	ceramica
422665.492	4644530.13	524.055	C	33	2096	2	indeterminat	S/F	metall
422662.211	4644529.308	524.178	C	41	2134	1	clau	sencer	metall
422662.528	4644529.023	524.126	C	42	2134	1	clau	sencer	metall
422662.584	4644530.555	524.06	C	44	2134	1	clau	sencer	metall
422662.493	4644531.581	524.072	C	55	2142	1	""""tascó""""	sencer	metall
422662.981	4644529.578	523.95	C	64	2141	1	indeterminat	sencer	metall
422662.875	4644530.402	523.94	C	69	2142	1	clau	sencer	metall



Complete with other fields according to  
database  
Geo-Tagging

## 3.2 Stratigraphic Unit

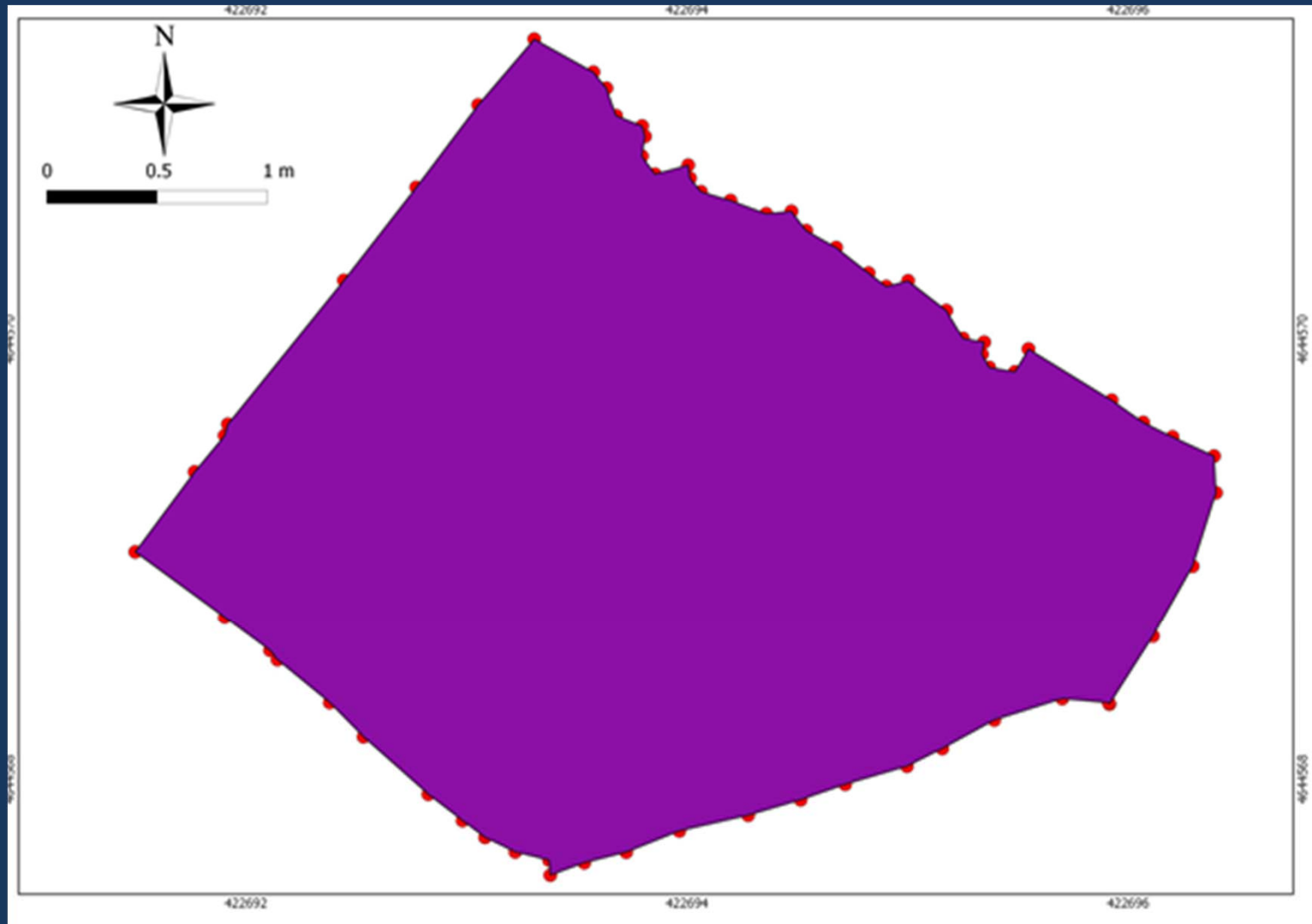
First separate perimeter points from inner ones





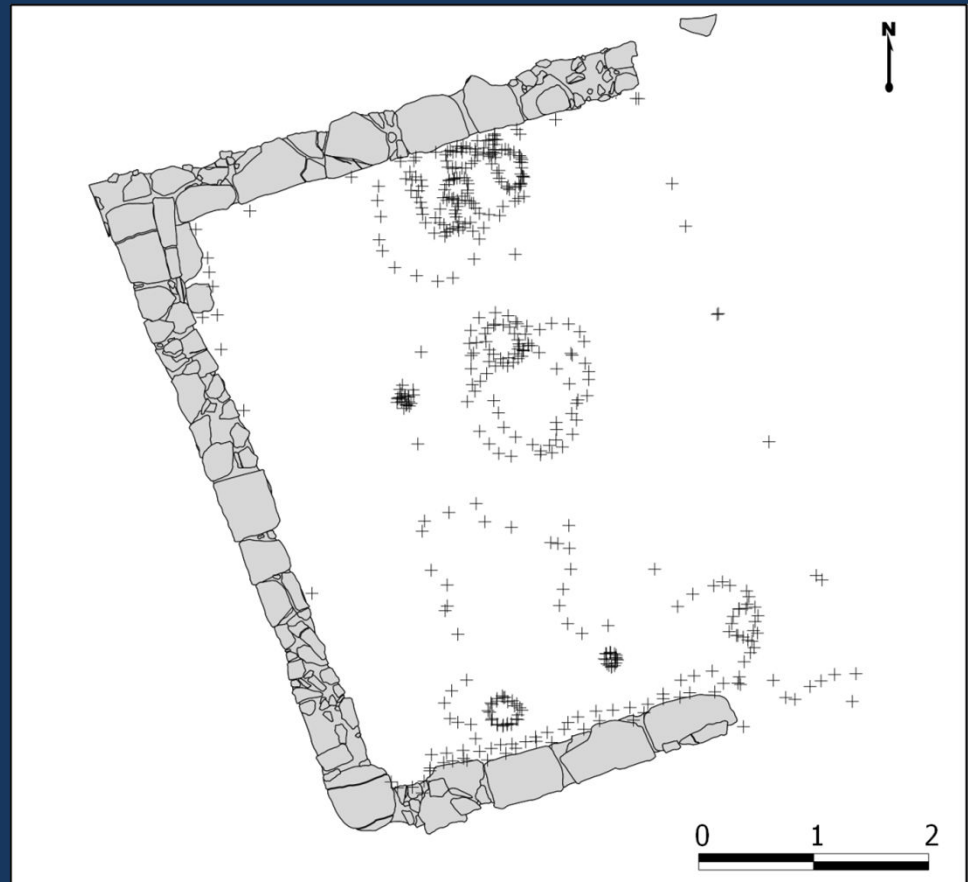
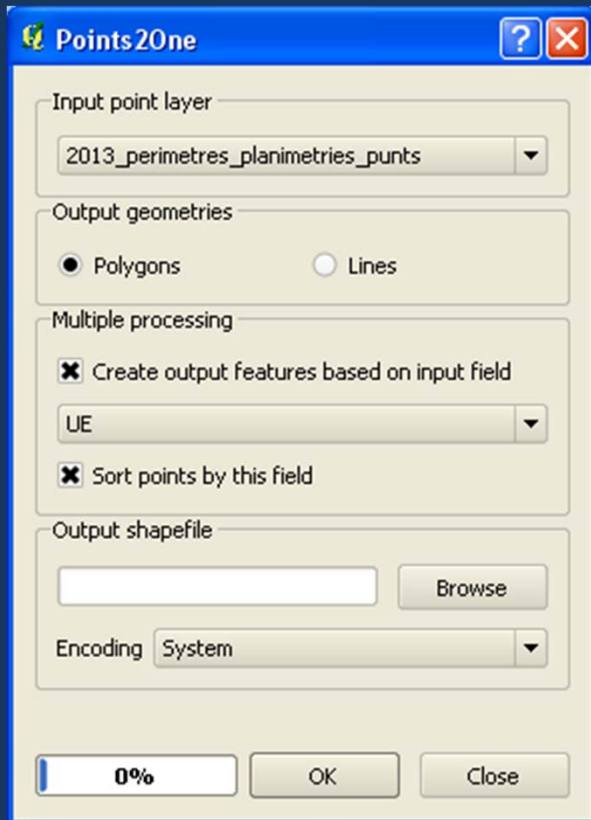
## 3.2 Stratigraphic Unit

Then convert them to a polygon, which is done correctly if points were measured in sequence



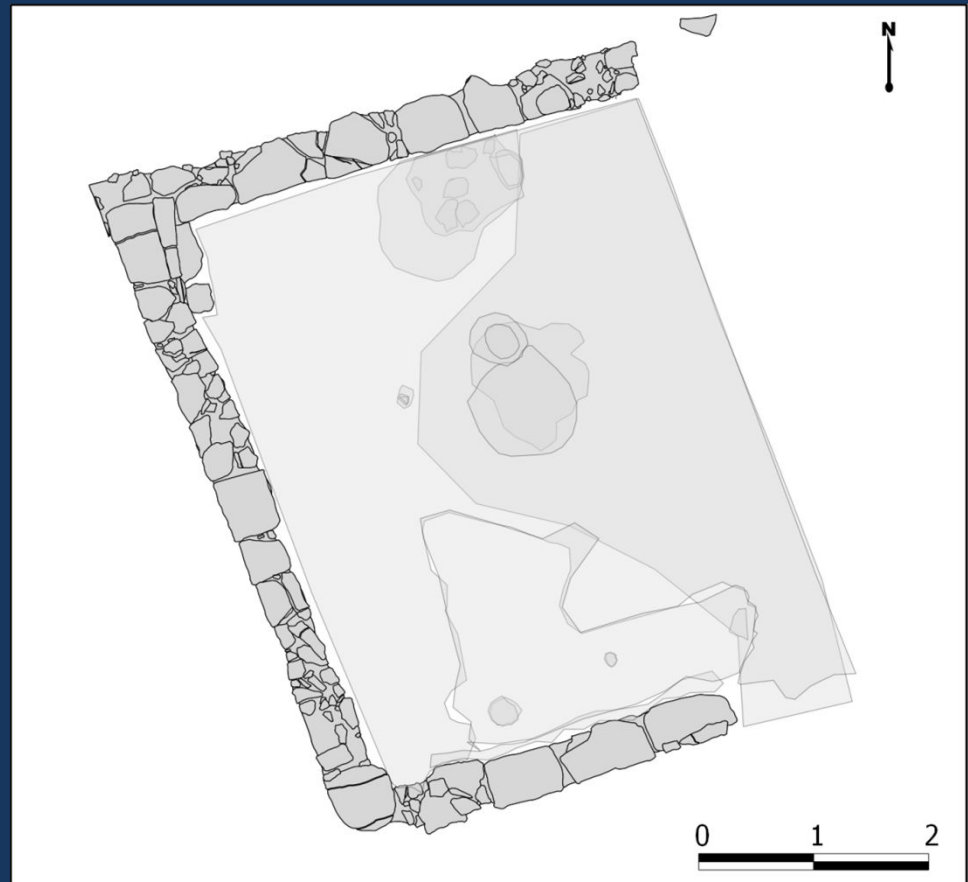
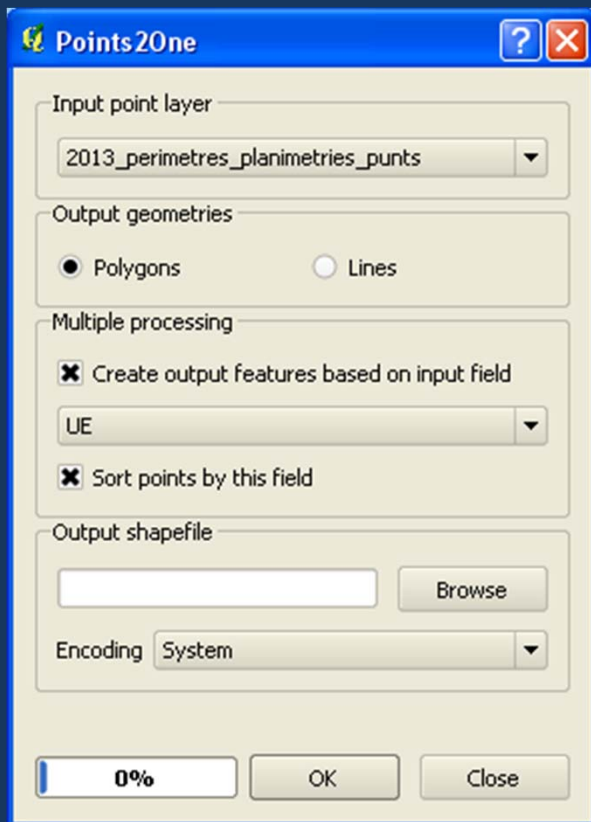
## 3.2 Stratigraphic Unit

As the Stratigraphic Unit information is associated to the points, the operation of converting all the planimetrics of the excavation can be done in one single operation



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## 3.2 Stratigraphic Unit

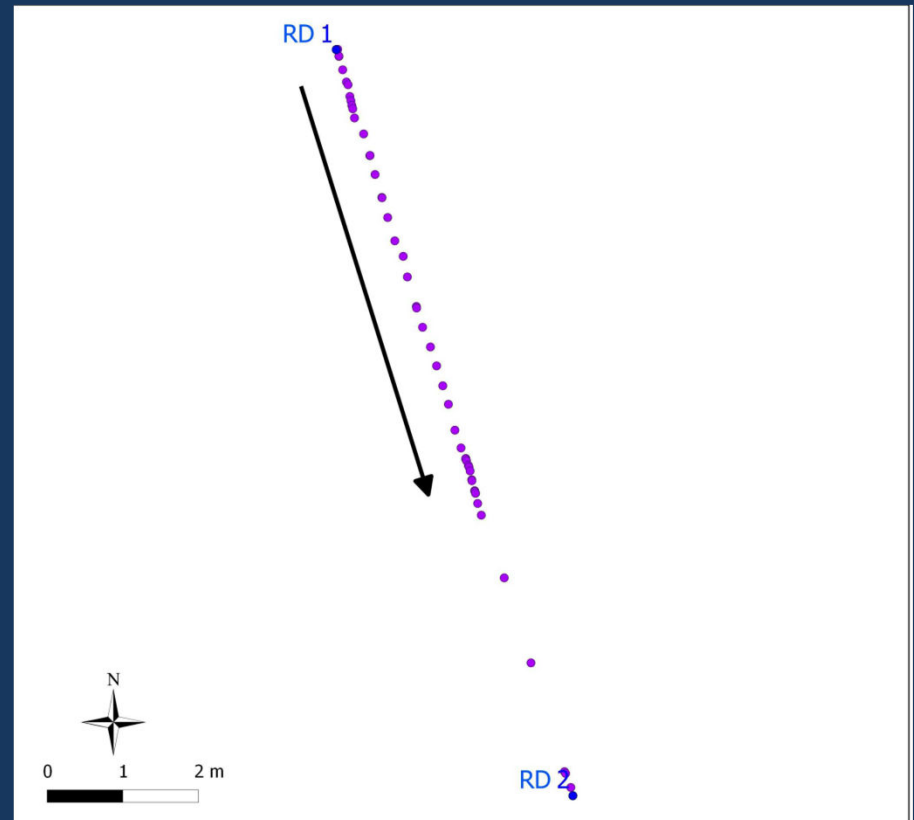
Last we add the 3D gridded information of the planimetrics to the 3D model



## 3.3 Vertical Sections

For each section several levels were acquired during the excavation. Points are compiled by section, starting from the associated reference point.

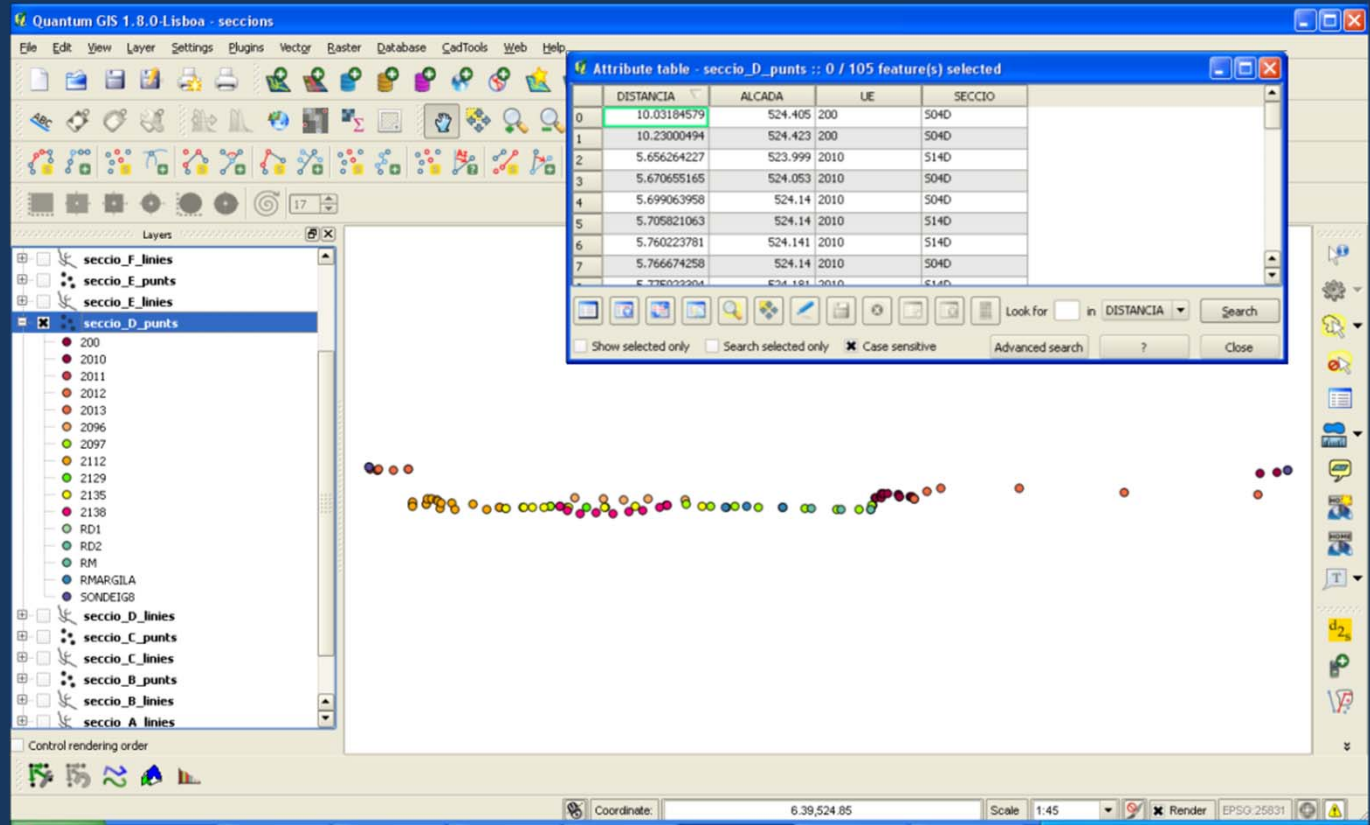
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422665.474	4644535.87	524.459	S04D	2	2011
422665.491	4644535.78	524.447	S04D	3	2011
422665.49	4644535.78	524.446	S04D	4	2012
422665.54	4644535.6	524.45	S04D	5	2012
422665.59	4644535.44	524.451	S04D	6	2012
422665.611	4644535.4	524.085	S04D	7	2112
422665.635	4644535.25	524.063	S04D	8	2112
422665.649	4644535.19	524.123	S04D	9	2112
422665.661	4644535.13	524.113	S04D	10	2112
422665.673	4644535.08	524.08	S04D	11	2112
422665.696	4644534.96	524.072	S04D	12	2112
422665.817	4644534.75	524.059	S04D	13	2112
422665.899	4644534.46	524.03	S04D	14	2112
422665.902	4644534.47	524.03	S04D	15	2097
422665.968	4644534.22	524.03	S04D	16	2097
422666.058	4644533.91	524.037	S04D	17	2097
422666.06	4644533.91	524.037	S04D	18	2096
422666.135	4644533.65	524.129	S04D	19	2096
422666.229	4644533.34	524.125	S04D	20	2096
422666.34	4644533.13	524.109	S04D	21	2096
422666.395	4644532.86	524.123	S04D	22	2096
422666.514	4644532.47	524.115	S04D	23	2096
422666.517	4644532.45	524.065	S04D	24	2097
422666.596	4644532.2	524.035	S04D	25	2097
422666.7	4644531.94	524.039	S04D	26	2097
422666.781	4644531.69	524.032	S04D	27	2097
422666.863	4644531.42	524.027	S04D	28	2097



## 3.3 Vertical Sections

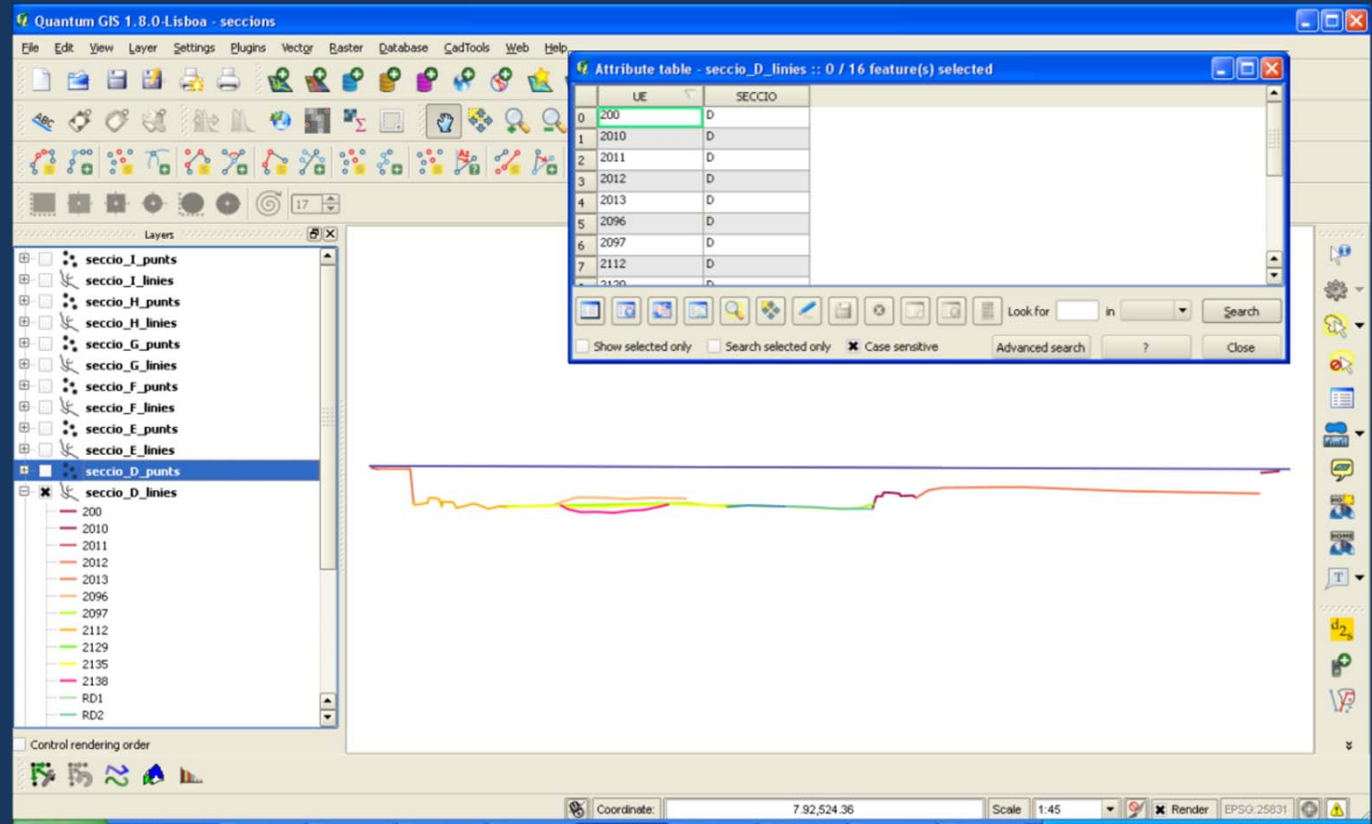
The distance relative to the first reference point is computed and the points are loaded for editing

DISTANCIA	ALCADA	UE	SECCIO
10.0318458	524.405	200	S04D
10.2300049	524.423	200	S04D
5.65626423	523.999	2010	S14D
5.67065516	524.053	2010	S04D
5.69906396	524.14	2010	S04D
5.70582106	524.14	2010	S14D
5.76022378	524.141	2010	S14D
5.76667426	524.14	2010	S04D
5.7759233	524.181	2010	S14D
5.78941396	524.183	2010	S04D
5.84225855	524.182	2010	S04D
5.95738978	524.172	2010	S14D
5.95949134	524.169	2010	S04D
5.96899807	524.143	2010	S14D
5.97249177	524.143	2010	S04D
6.09821253	524.15	2010	S14D
6.10921288	524.149	2010	S04D



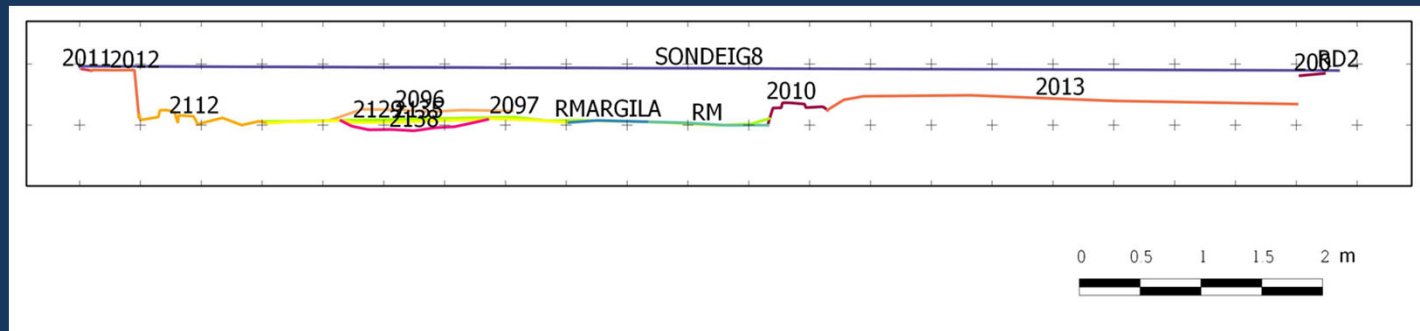
## 3.3 Vertical Sections

Points are converted to lines using the stratigraphic unit as sorting property



### 3.3 Vertical Sections

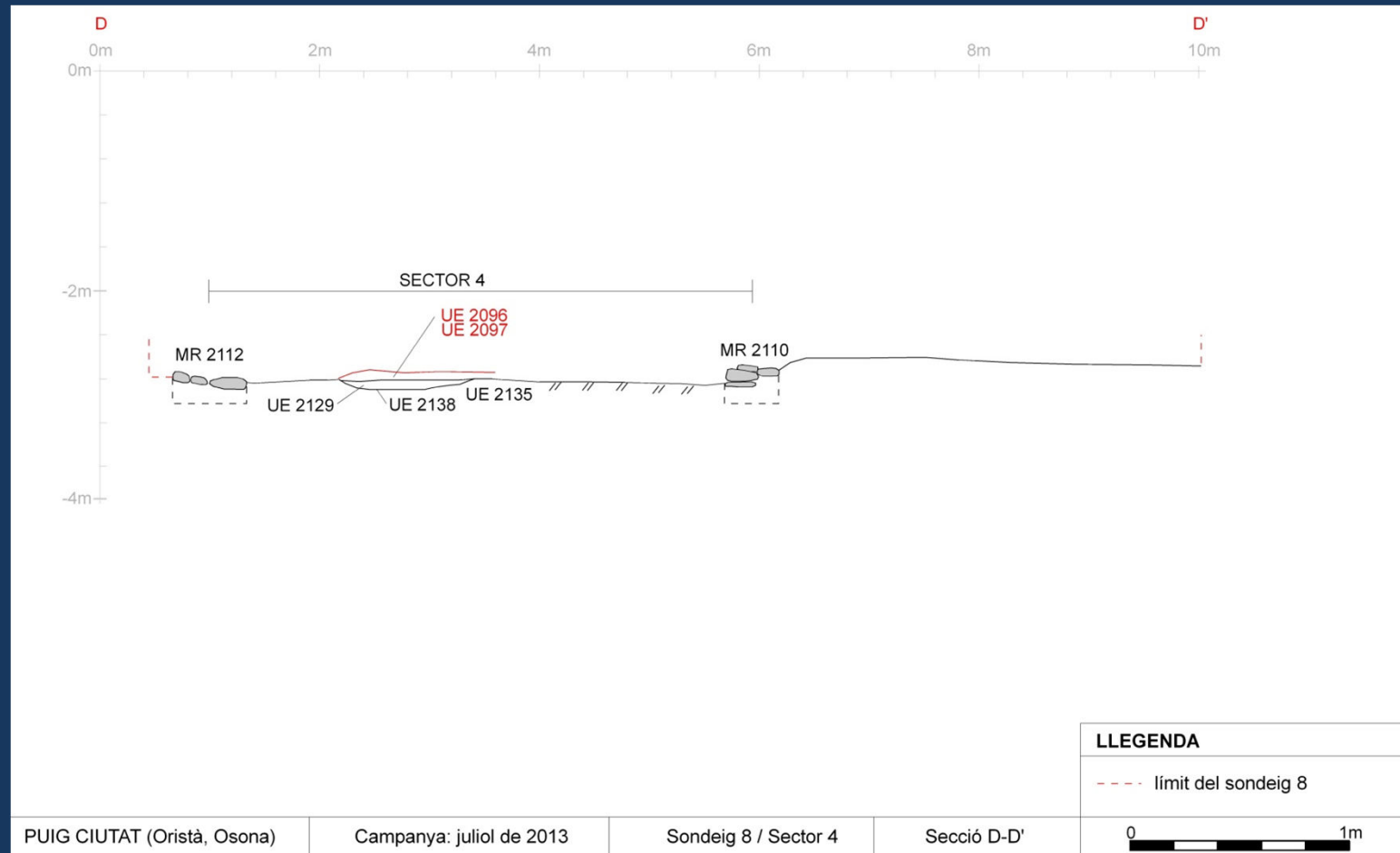
The processed output is exported in a vectorial format for additional editing





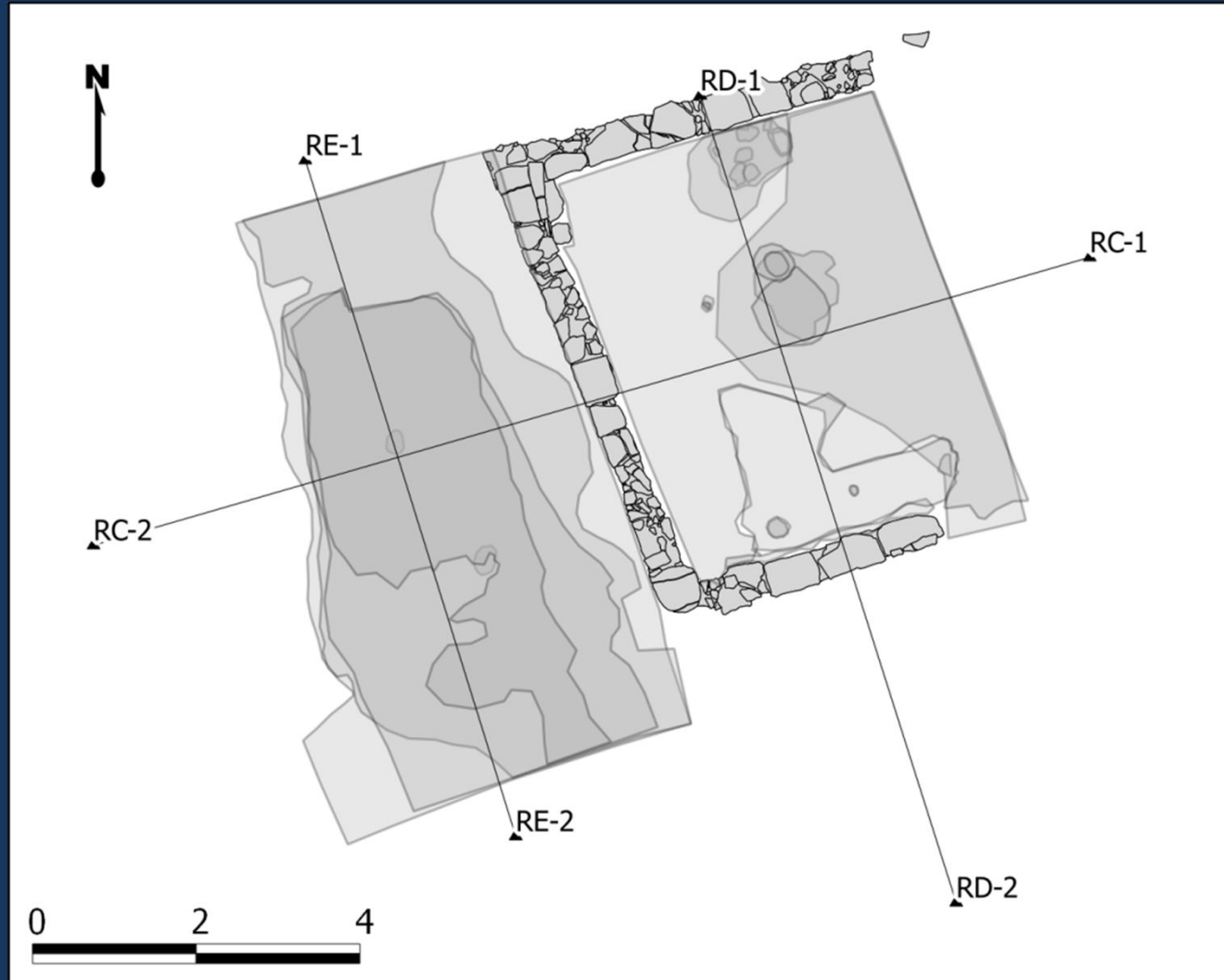
## 3.3 Vertical Sections

The vertical variations of the section that could not be measured with the total station are added to the section as well as complementary information



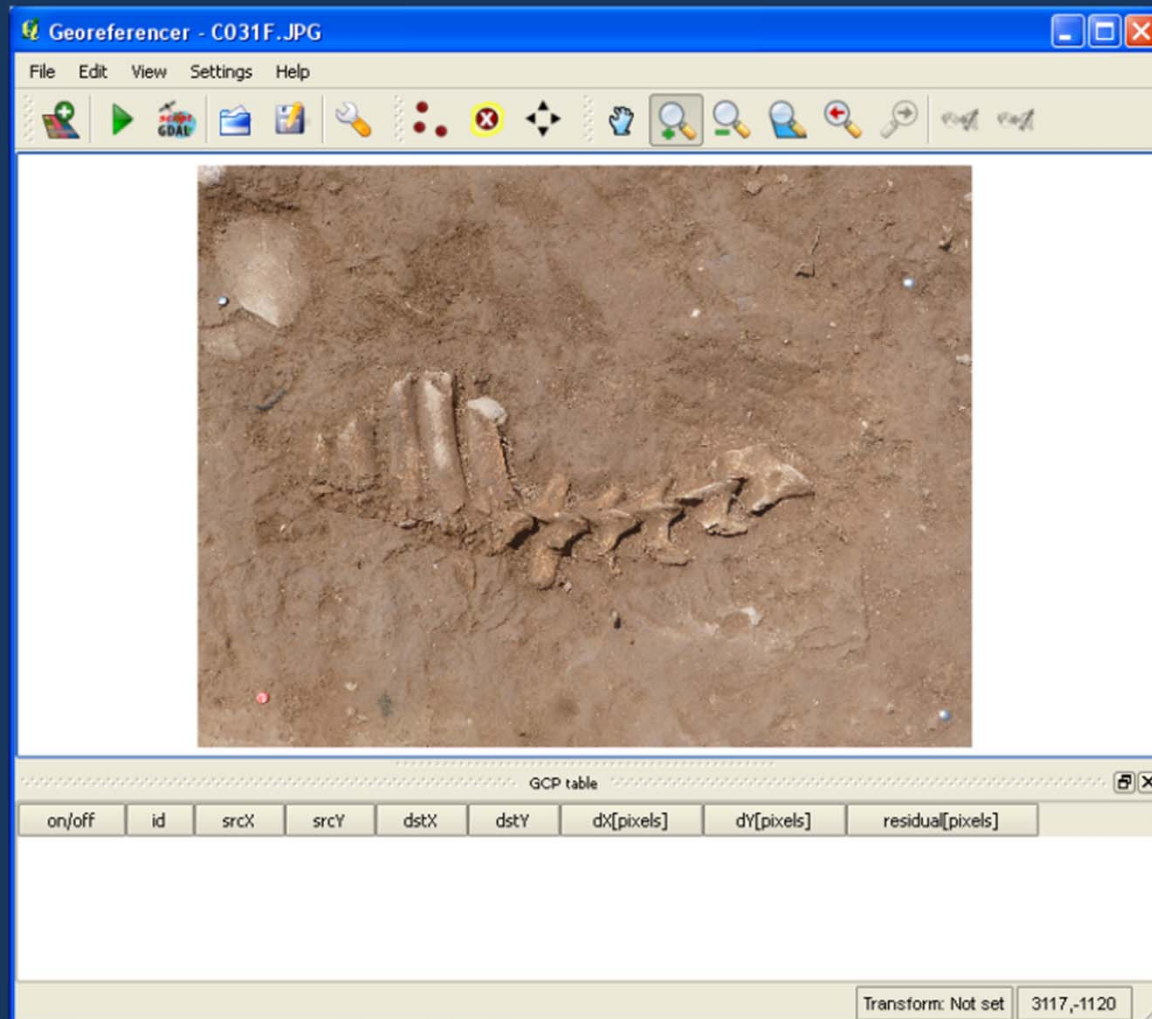
### 3.3 Vertical Sections

The position of all sections are processed and transformed into lines with specific properties including the relative path of the final image of each section



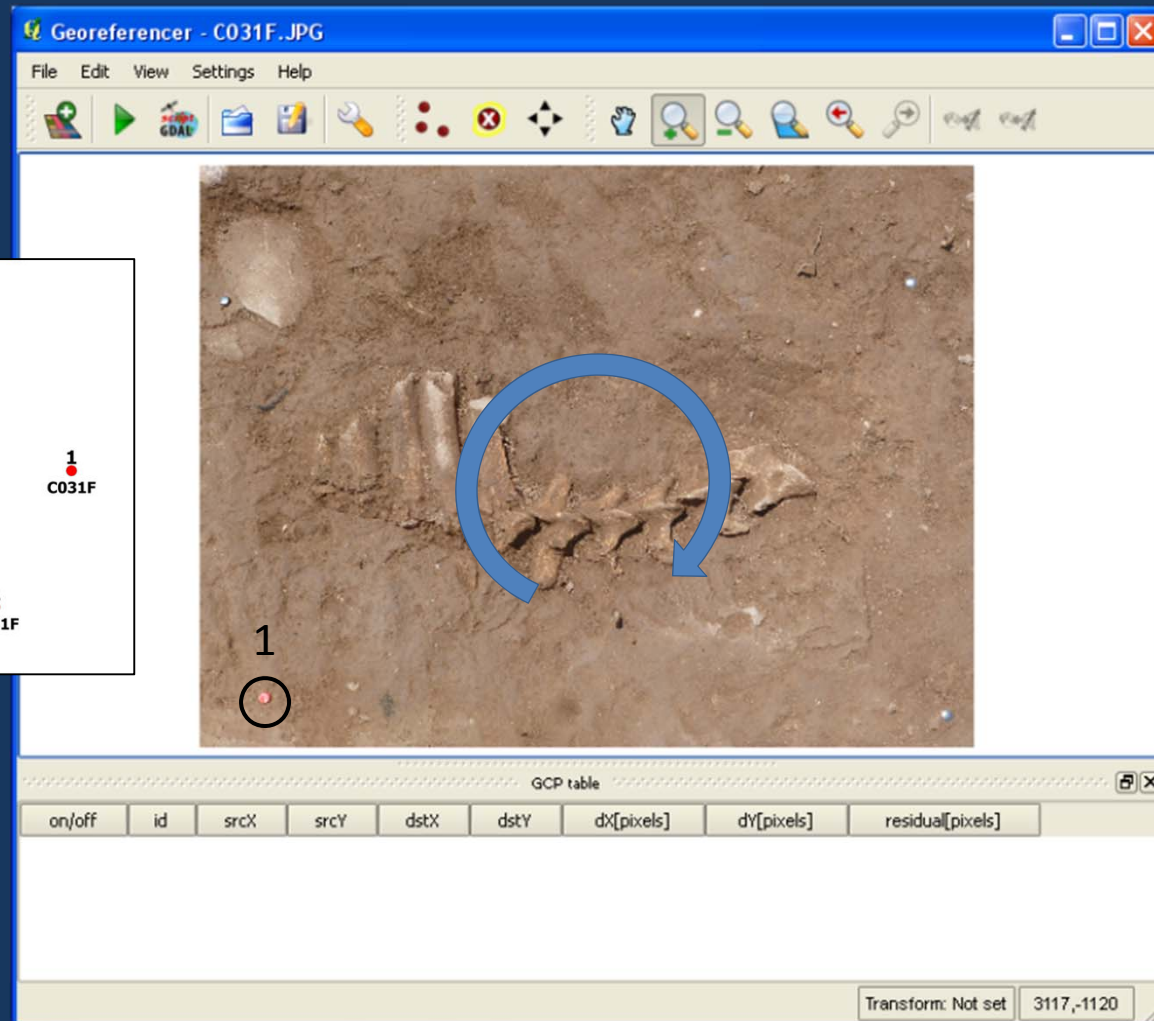
## 3.4 Ortho-rectified Photographs

Photographs are loaded for georeferenciacion



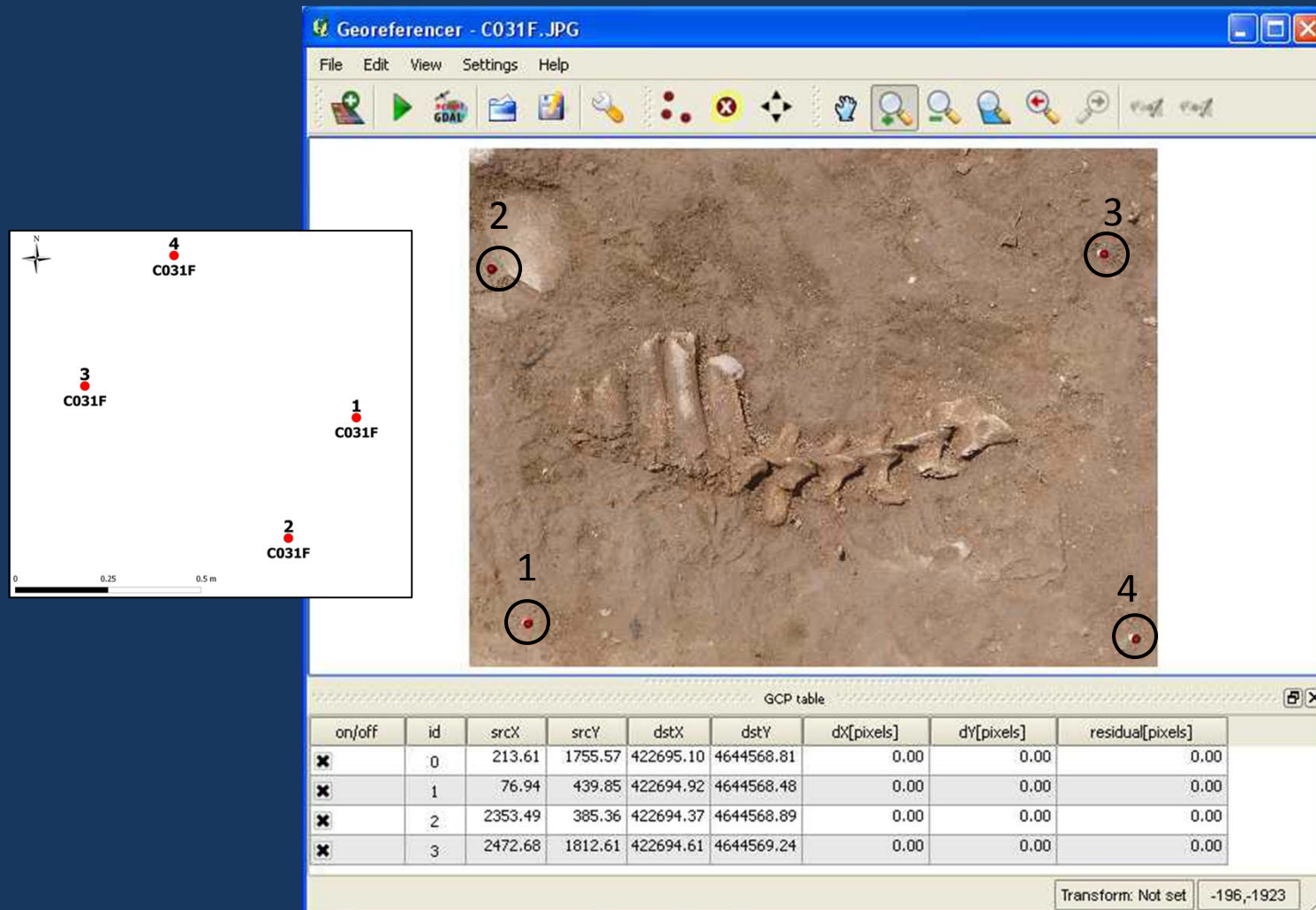
## 3.4 Ortho-rectified Photographs

Points are easily located thanks to acquisition



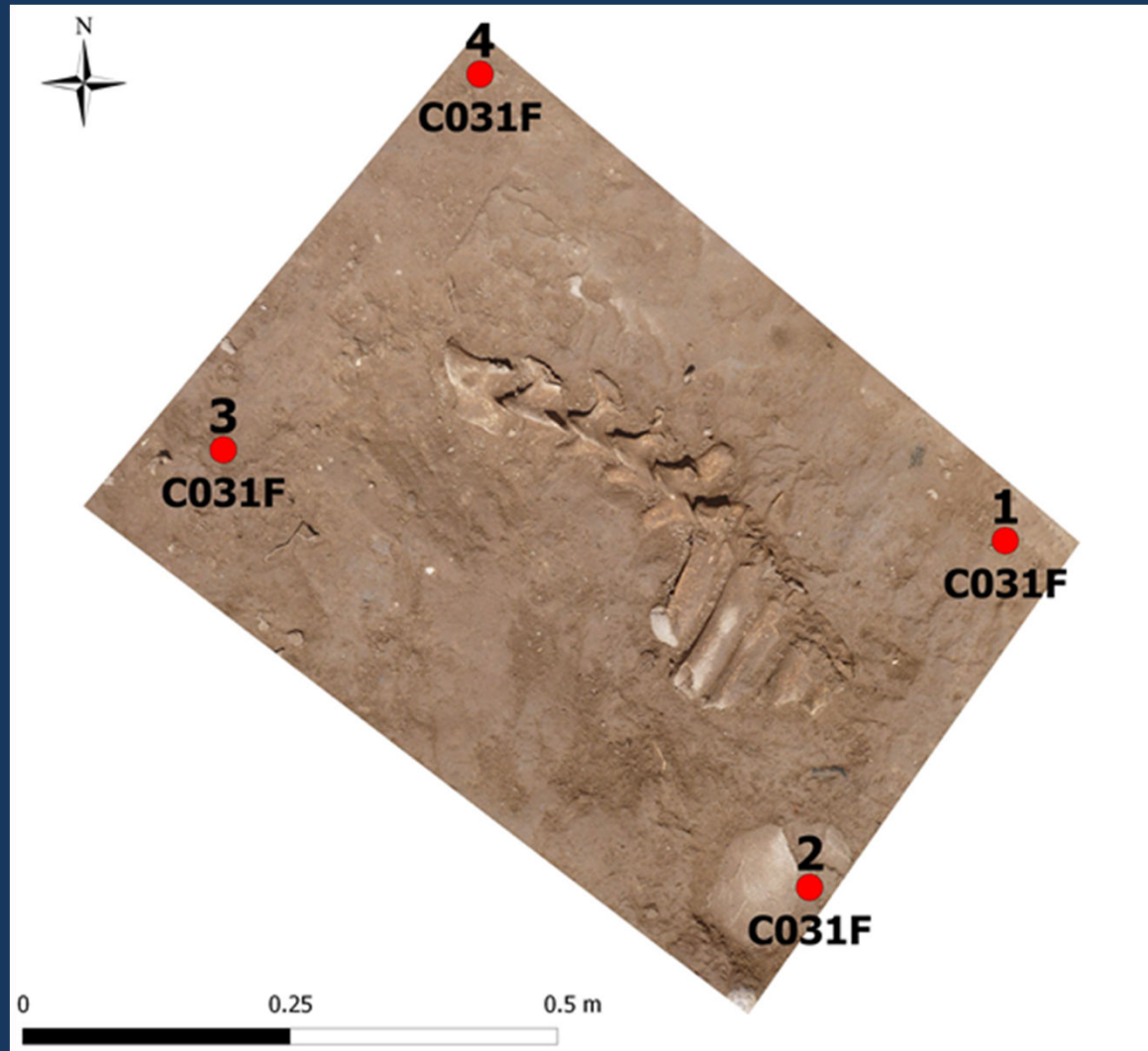
## 3.4 Ortho-rectified Photographs

Points are easily located thanks to acquisition



### 3.4 Ortho-rectified Photographs

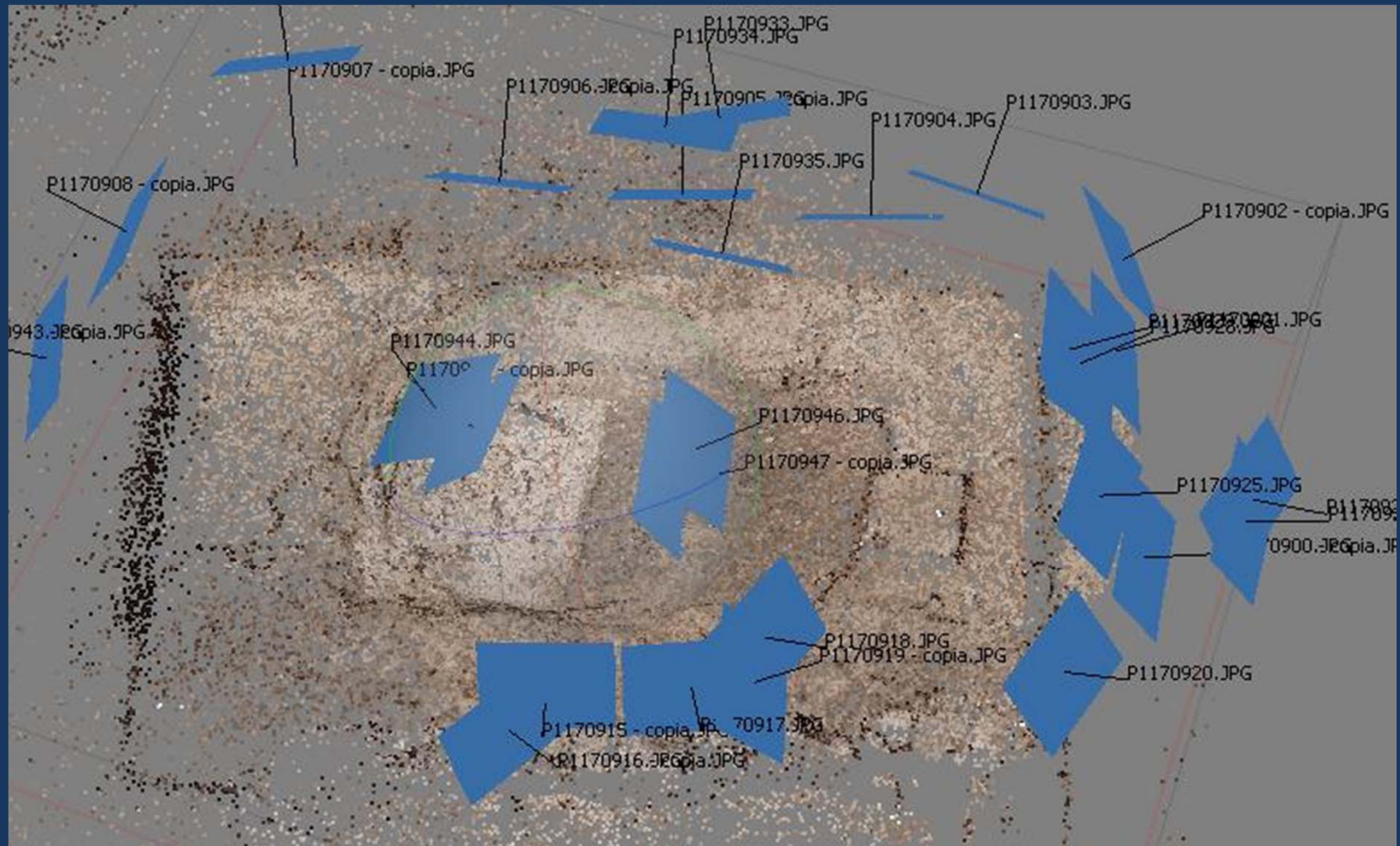
The georeferenced photograph can be used for interpretation and drawing





## 3.5 Photogrammetry

First, a selection on the photographs is processed to obtain a 3D scatter pointset





## 3.5 Photogrammetry

The scatter is then transformed into a mesh and the texture transferred



## 3.5 Photogrammetry

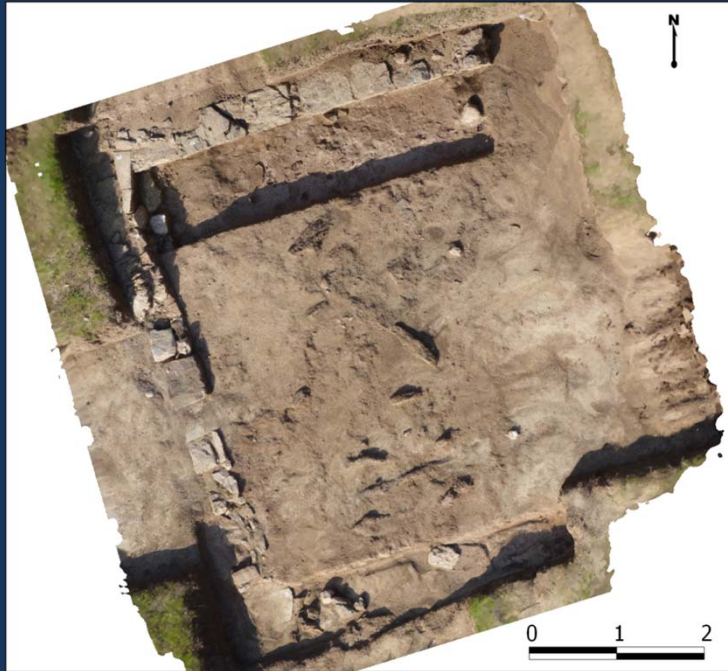
The topographic points associated to the photogrammetry are used to georeferenciate the model





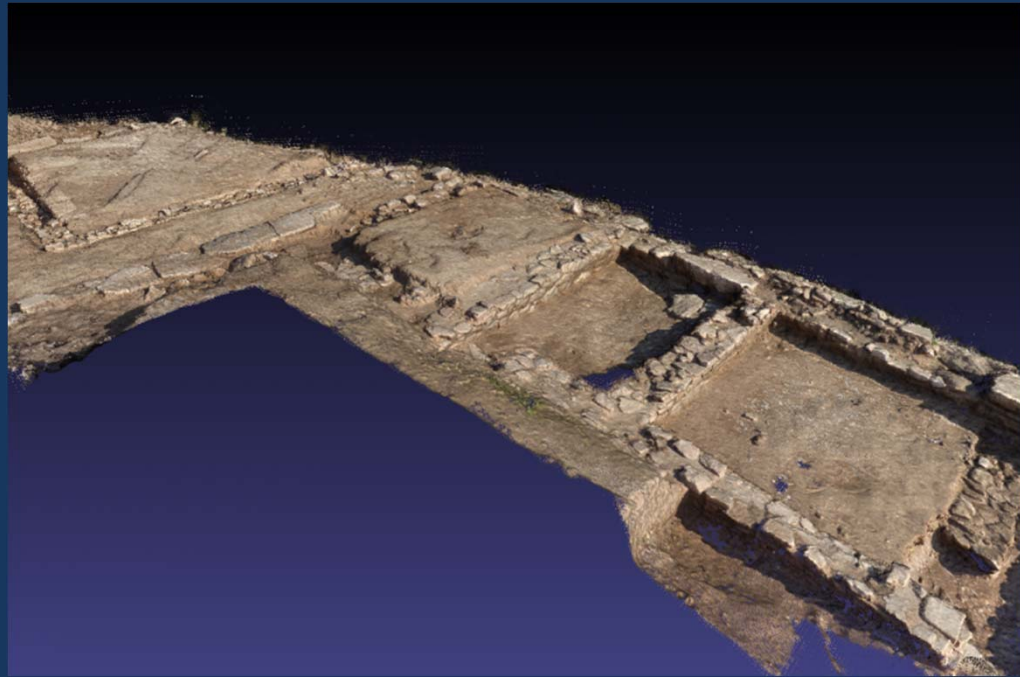
## 3.5 Photogrammetry

Final models can be used in 2D for drawing



## 3.5 Photogrammetry

Or in 3D for element extraction and virtual applications



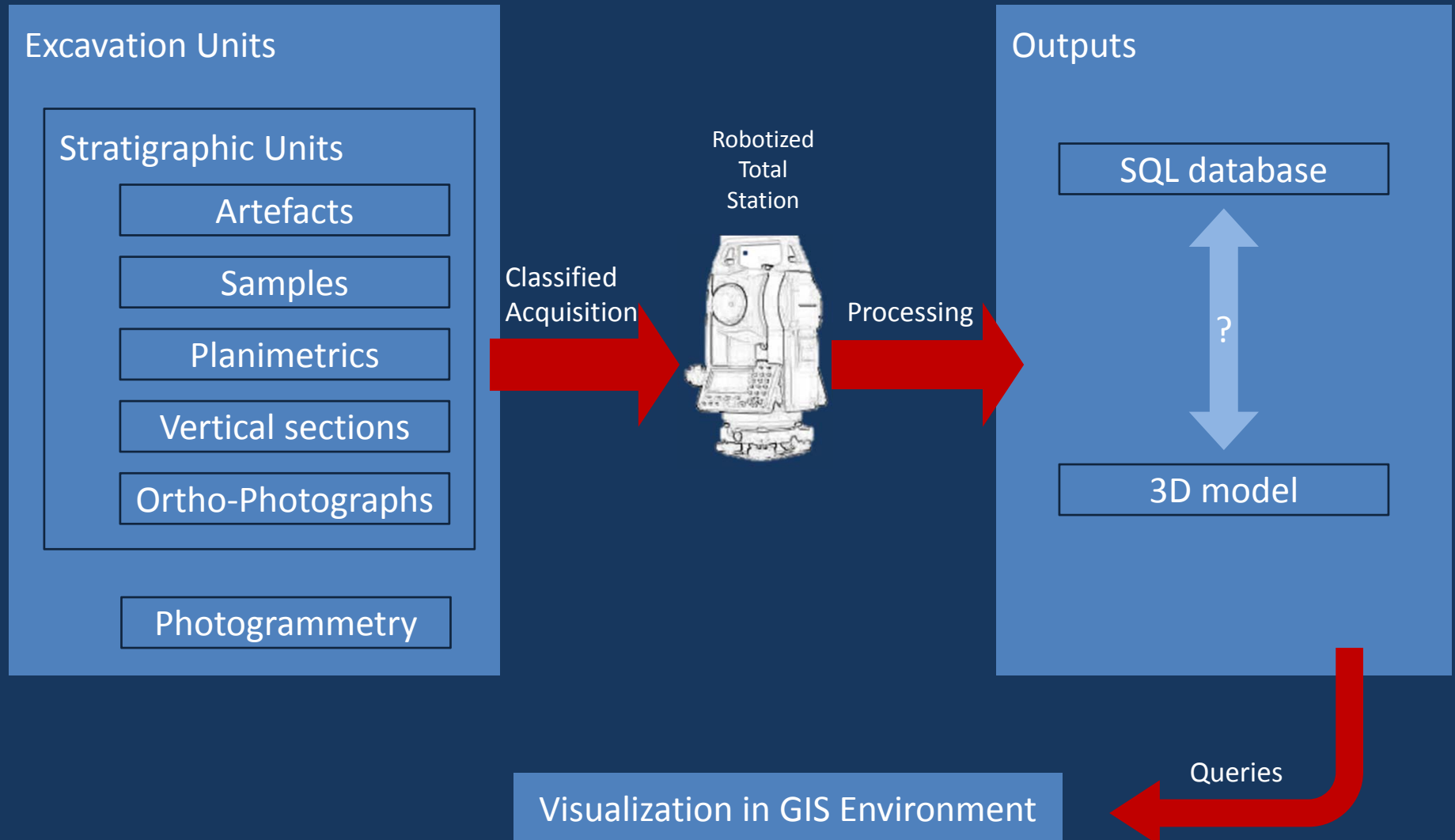
**PART 1**  
**Introduction**  
**The Choice of a Methodology**

**PART 2**  
**Acquisition**  
**Pre-processed data**

**PART 3**  
**Processing**  
**Digital outputs with a “manual definition”**

**PART 4**  
**Summary**  
**“Work in Progress”**

## 4.1 Diagram of the Chosen Workflow



## 4.2 Main Methodological Choices

The main concerns are the continuous mapping of the excavated elements and the optimization of the available resources in terms of time of processing

### Pre-processed acquisition

A Protocol  
differentiating  
categories of objects  
to map

An Association of  
objects to map with  
single ortho-  
photographs

Field Metadata

### Processing

Drawings based on  
ortho-photographs

A mixed 2D/3D  
methodology

A combined 3D  
approach

### Outputs

A Spatial database

A 3D model



## 4.3 Problems and Open Questions

### First year of implementation

*The processing is still in progress and will require modifications of the protocol*

### Training

*The work team should be trained to the use of the main tools and the processing steps*

### Homogenization

*The data acquired before the implementation of the protocol should be integrated and updated*

### An intermediate position

*Steps of the manual approach as vertical sections are maintained and present difficulties during processing*

### A real 3D approach?

*The interpretation is still based on 2D maps, the links between the interpretation platform and the 3D model need to be implemented*

# Thank you for your attention

