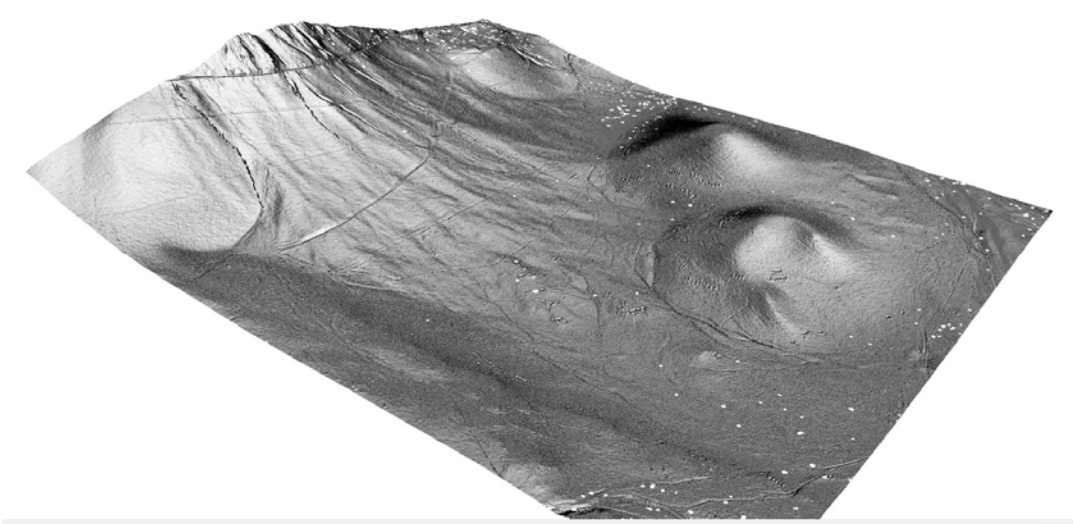
Training and Research on the Archaeological Interpretation of LiDAR 2016

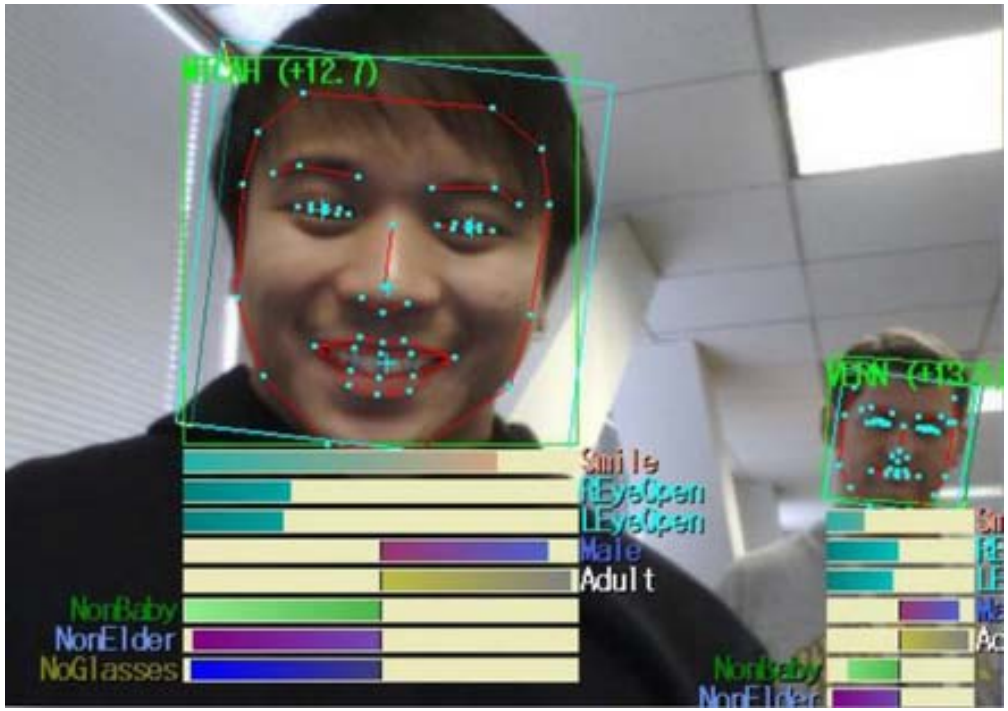
# Automatic detection of archaeological structures in LiDAR data : a first approach

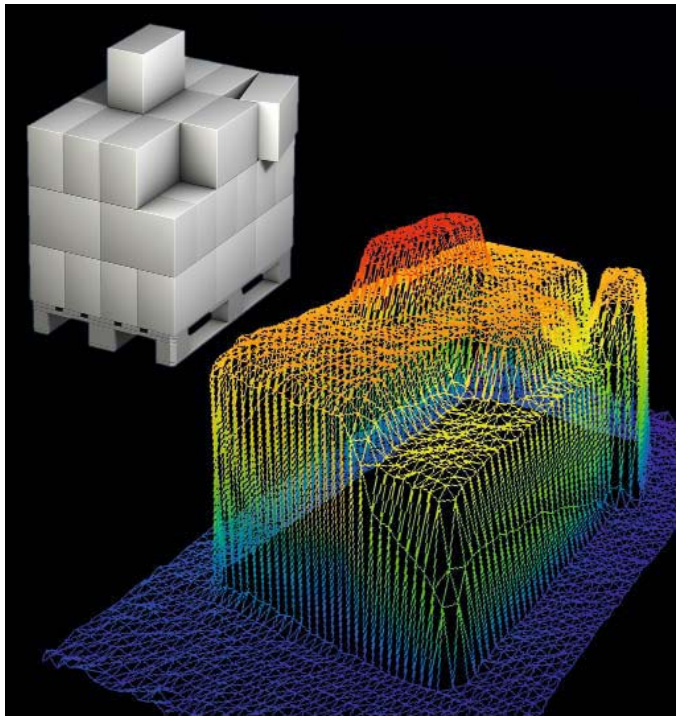


***J-P. Toumazet,*** *F. Vautier, E. Roussel, G. Rassat & B. Dousteyssier*

# Introduction

Automatic feature extraction has been initially developed for industrial applications.



In this case, the investigated element are characterized by :

« Easily » recognizable characteristics

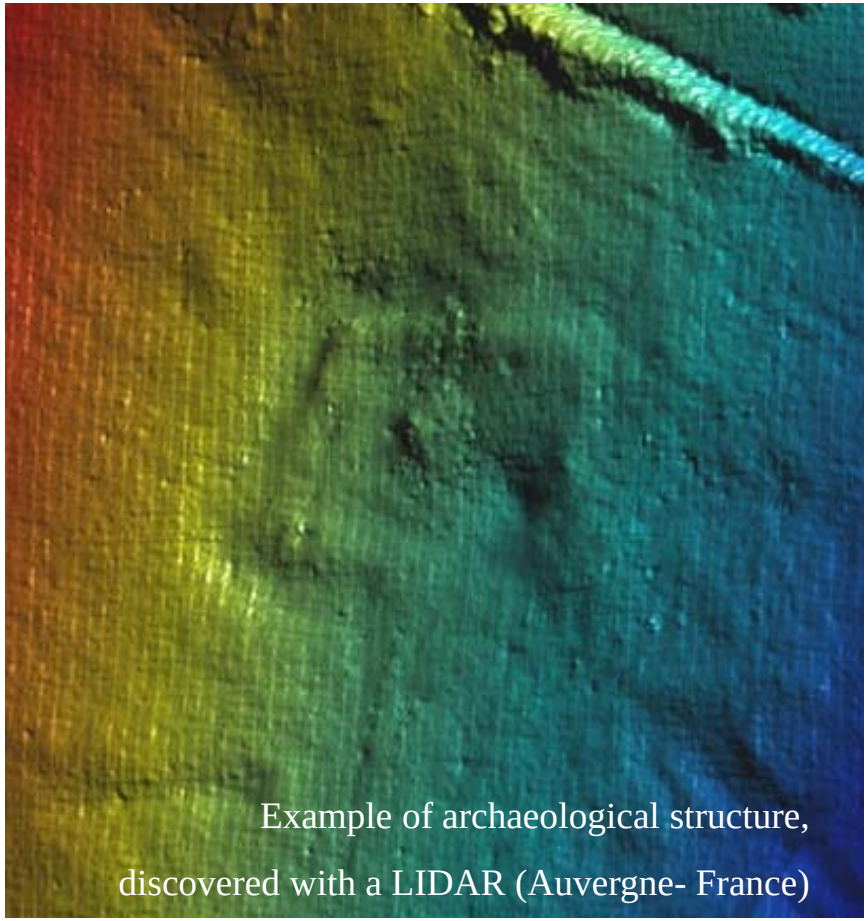
Relatively high resolution data (3D pointcloud or image)

# Introduction

A new domain for this application : the use of Airborne Laser Scanning (ALS) of archaeological regions of interest allowing accurate topographic and micro topographic description.

The obtained point clouds produce a huge quantity of data. They are still generally analyzed by a human operator. This process is time-consuming, subjective and may be non-exhaustive.

It’s why a method of automatic detection and characterization of archaeological structures, based on signal processing algorithm has been developed.



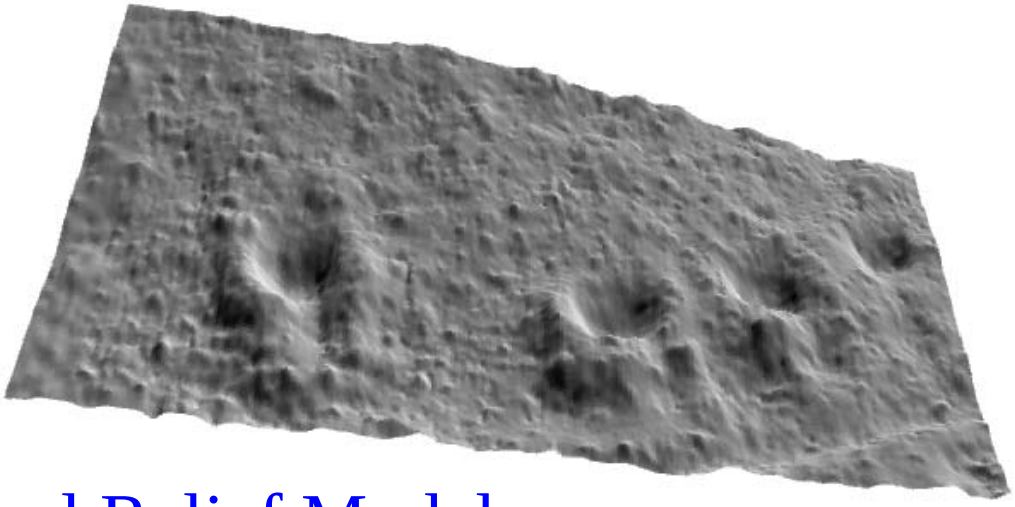
Example of archaeological structure, discovered with a LIDAR (Auvergne- France)

The automatic detection process is applied to former agricultural constructions, built from the medieval to the modern period, and cold “Tras”

They can be found in very high densities in some places in Auvergne. These structures have been chosen to test the process of automatic detection because they are particularly delicate to treat : they are indeed very variable in forms, appearing sometimes isolated, sometimes in group.

Introduction

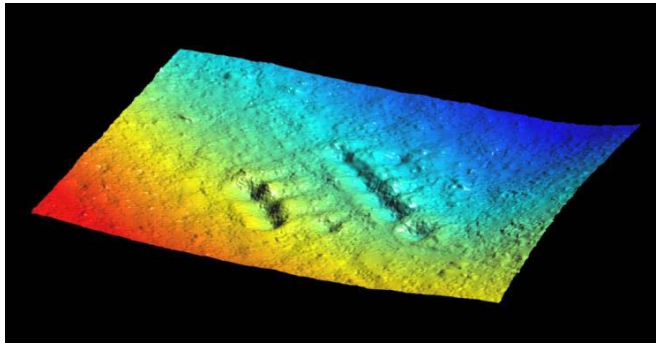
LIDAR for our application



From 3D point cloud to Local Relief Model

Automatic detection applied to archaeological structures

Conclusion

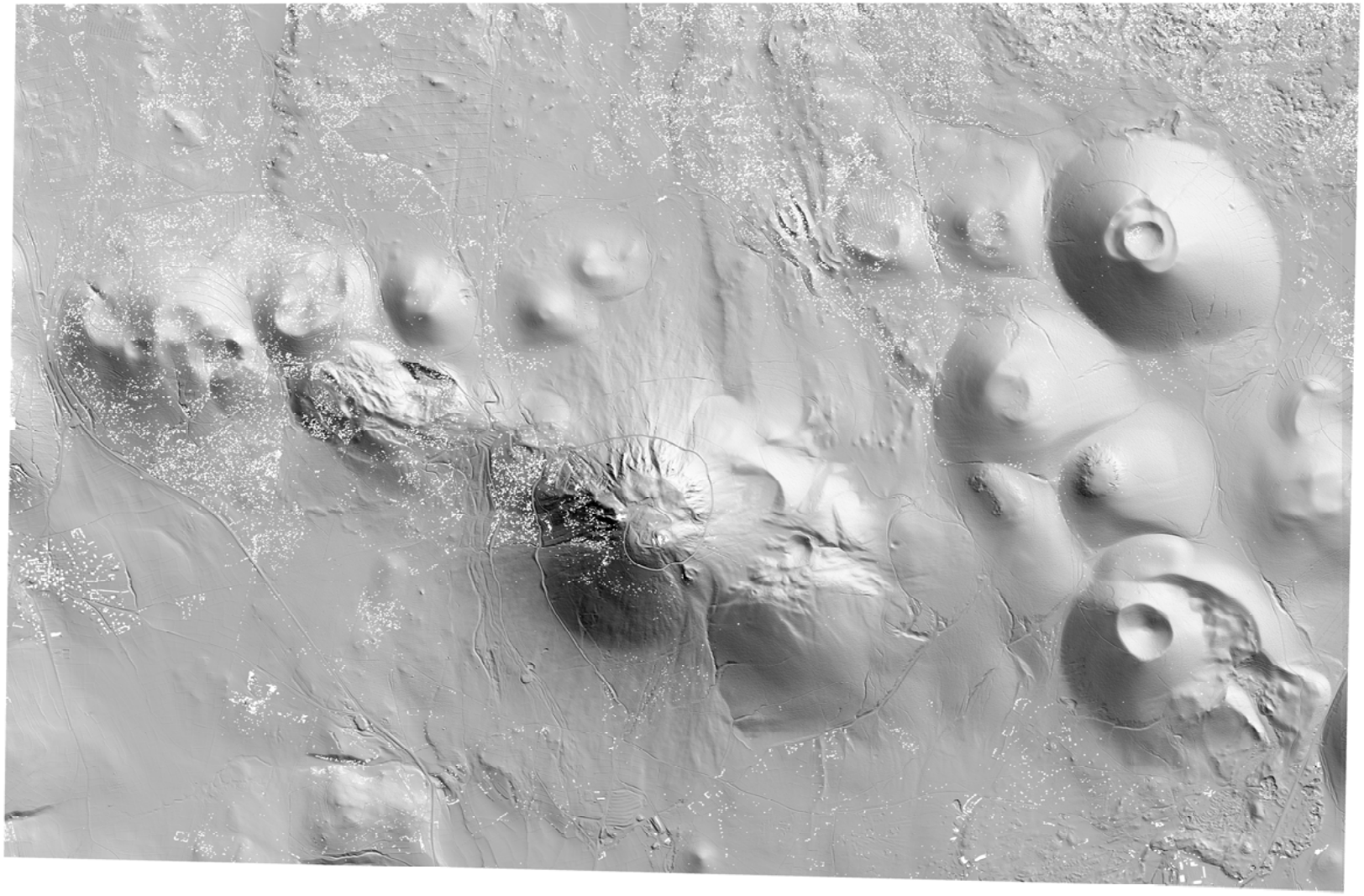


# LIDAR for our application

View of the investigated zone located near the Puy de Dôme volcano.
It is covered by a dense forest of deciduous trees.

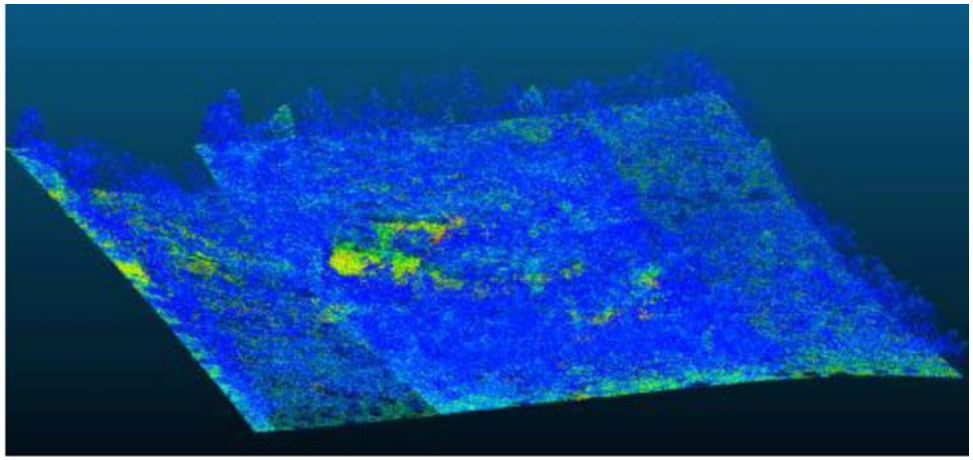
# LIDAR for our application

Digital Terrain Model (DTM) obtained from the LIDAR results.



# Process used to calculate the DEM

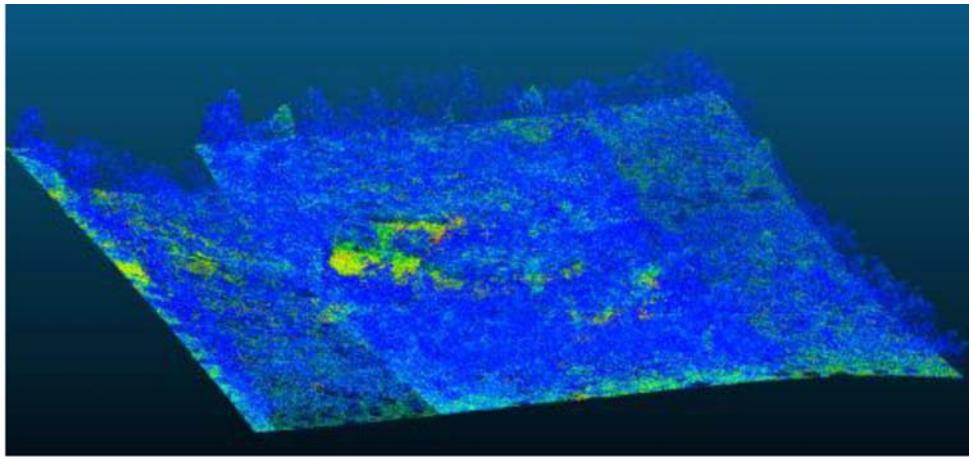
Point cloud generated by LIDAR



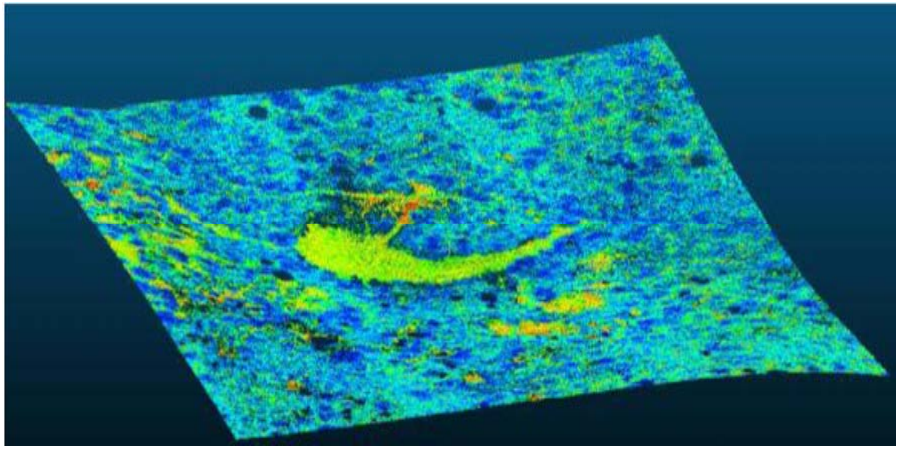
# Process used to calculate the DTM

Point cloud generated by LIDAR

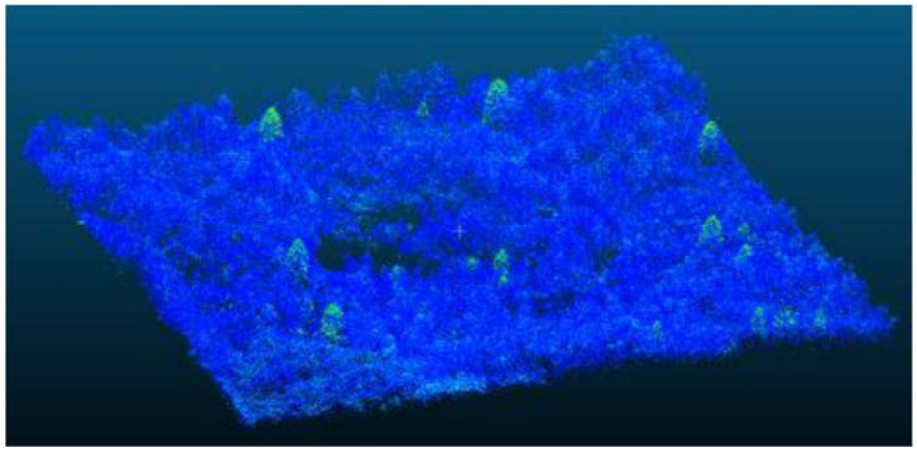
Classification of ground points



General point cloud

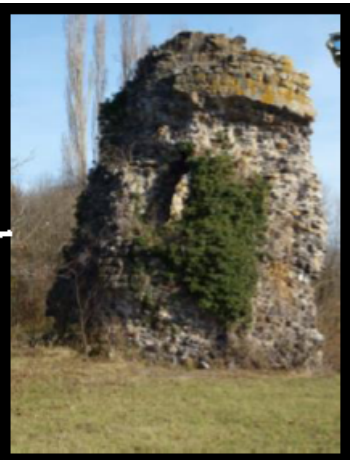


Ground points



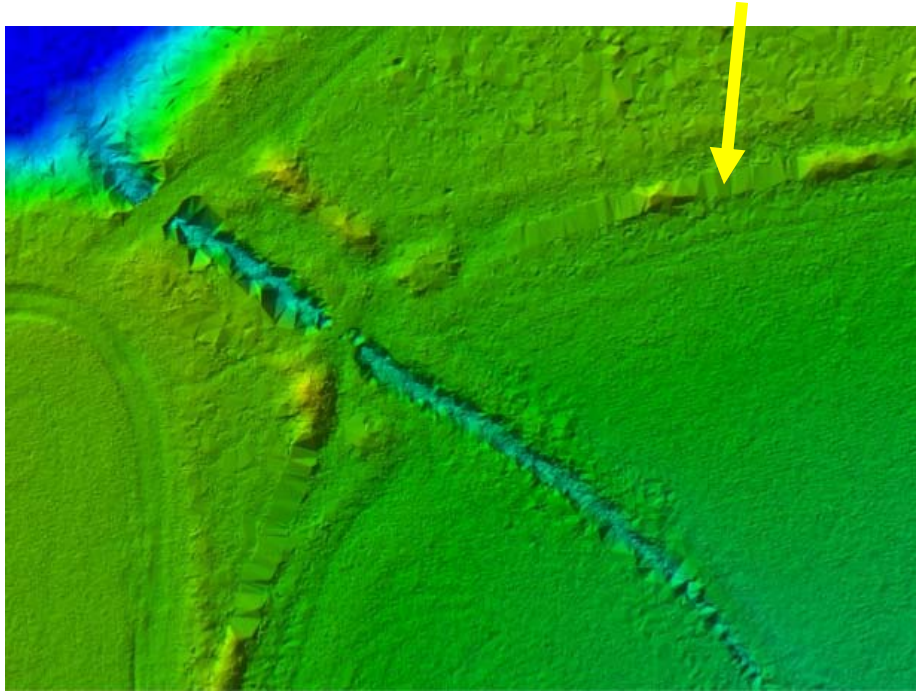
Vegetation points

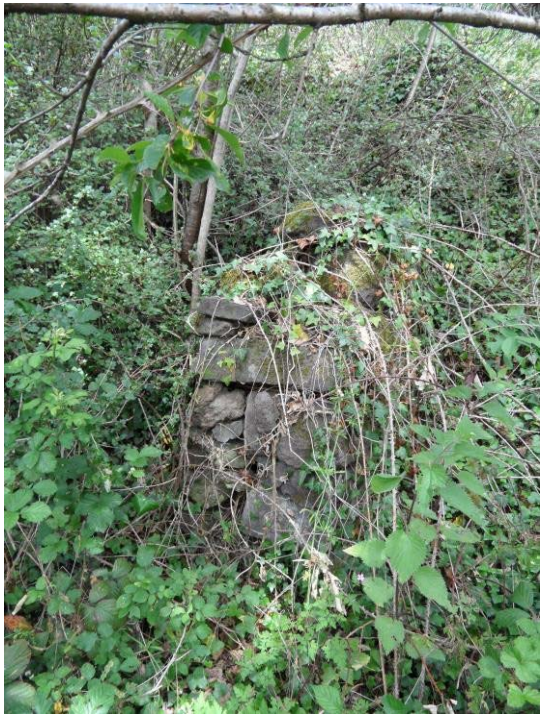
# Example of classification problems

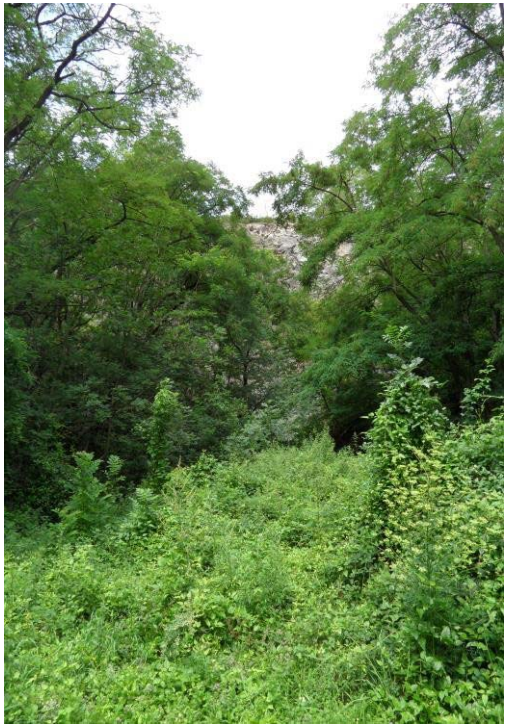


Ground points

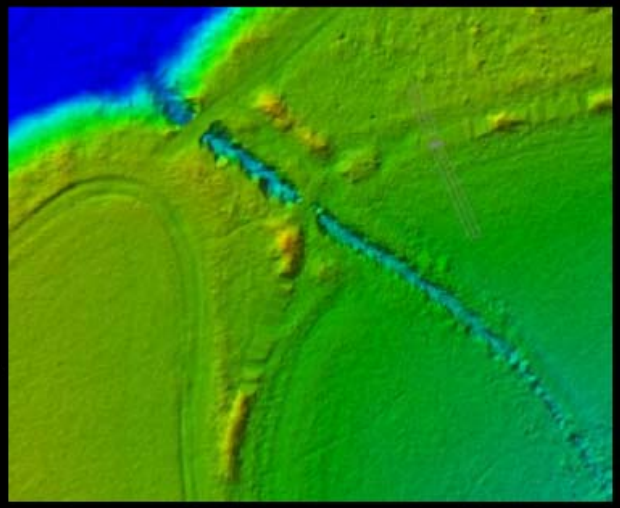
Elevation points

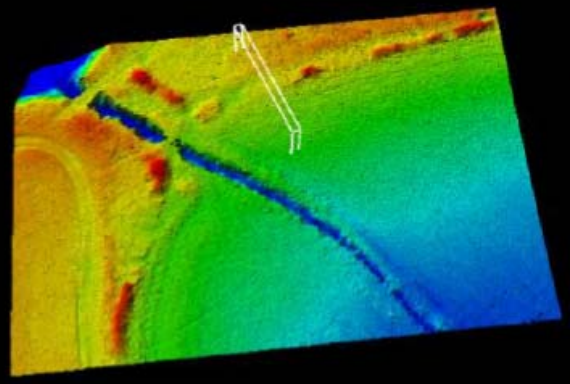




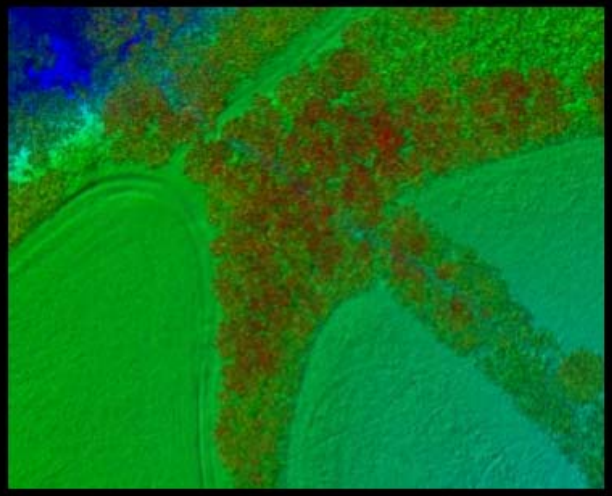


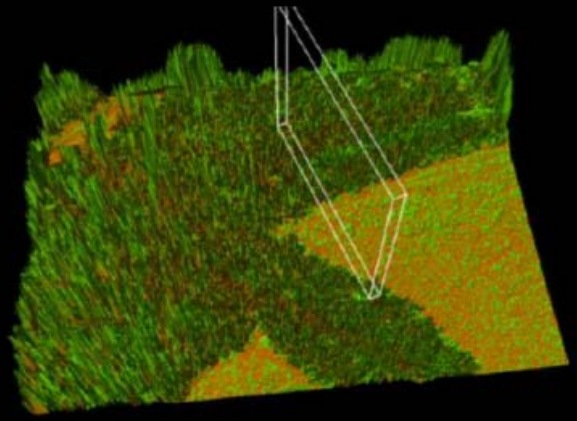
sol

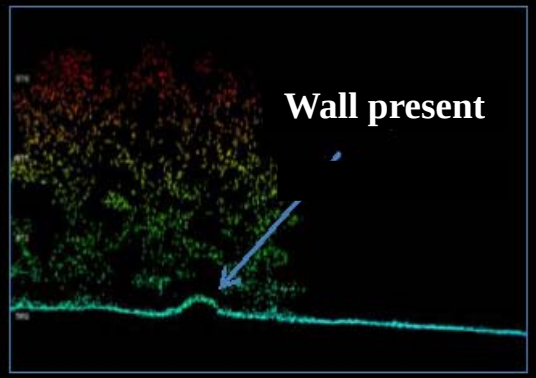





sol + élévation







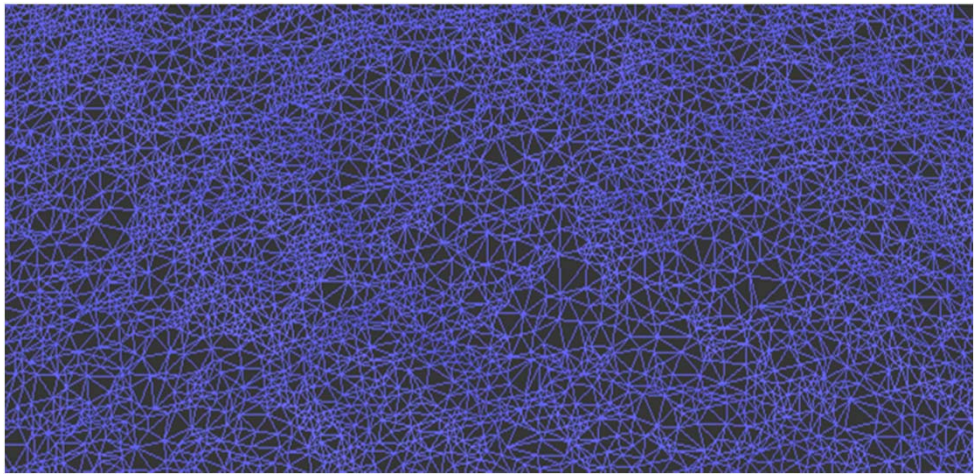

« Refinements of ALS point cloud through the assessment of bare earth classification algorithms », Simon F-X et al

# Process used to calculate the DEM

Point cloud generated by LIDAR

Classification of ground points

Generation of a mesh based on classified ground point



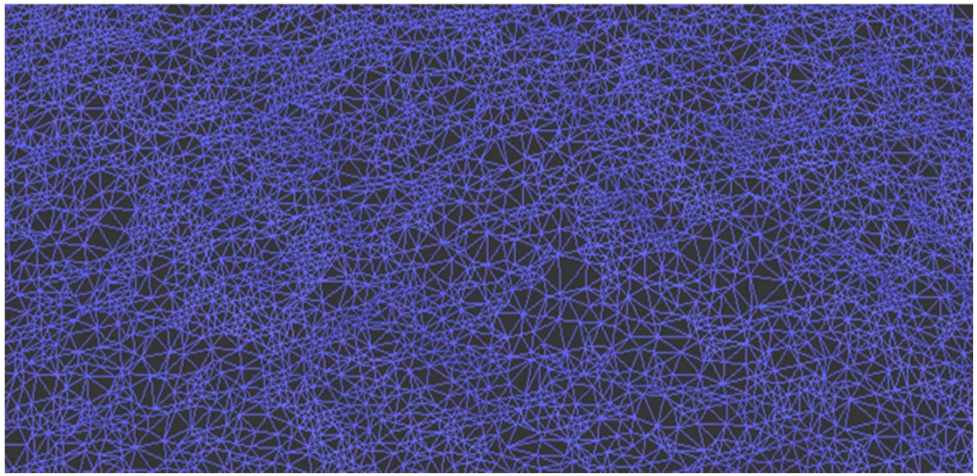
# Process used to calculate the DEM

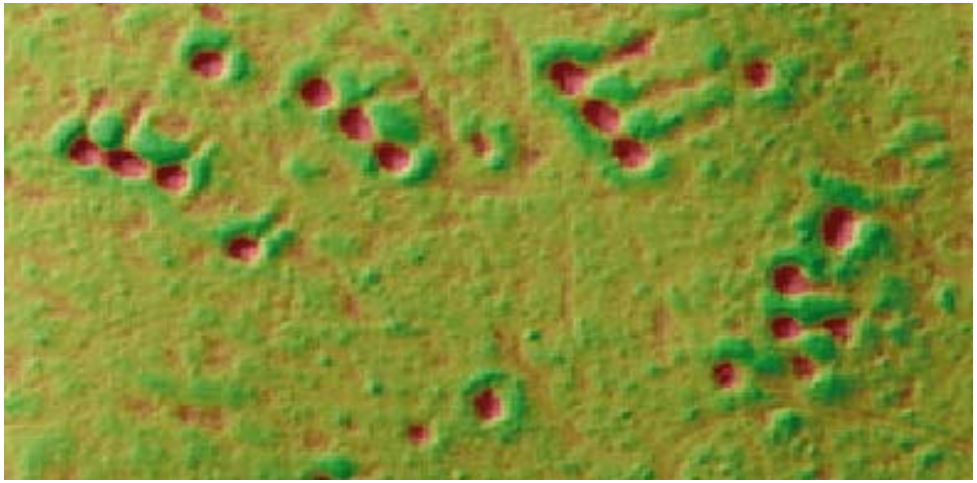
Point cloud generated by LIDAR

Classification of ground points

Generation of a mesh based on classified ground point

Interpolation of the mesh to obtain a matrix of elevation values

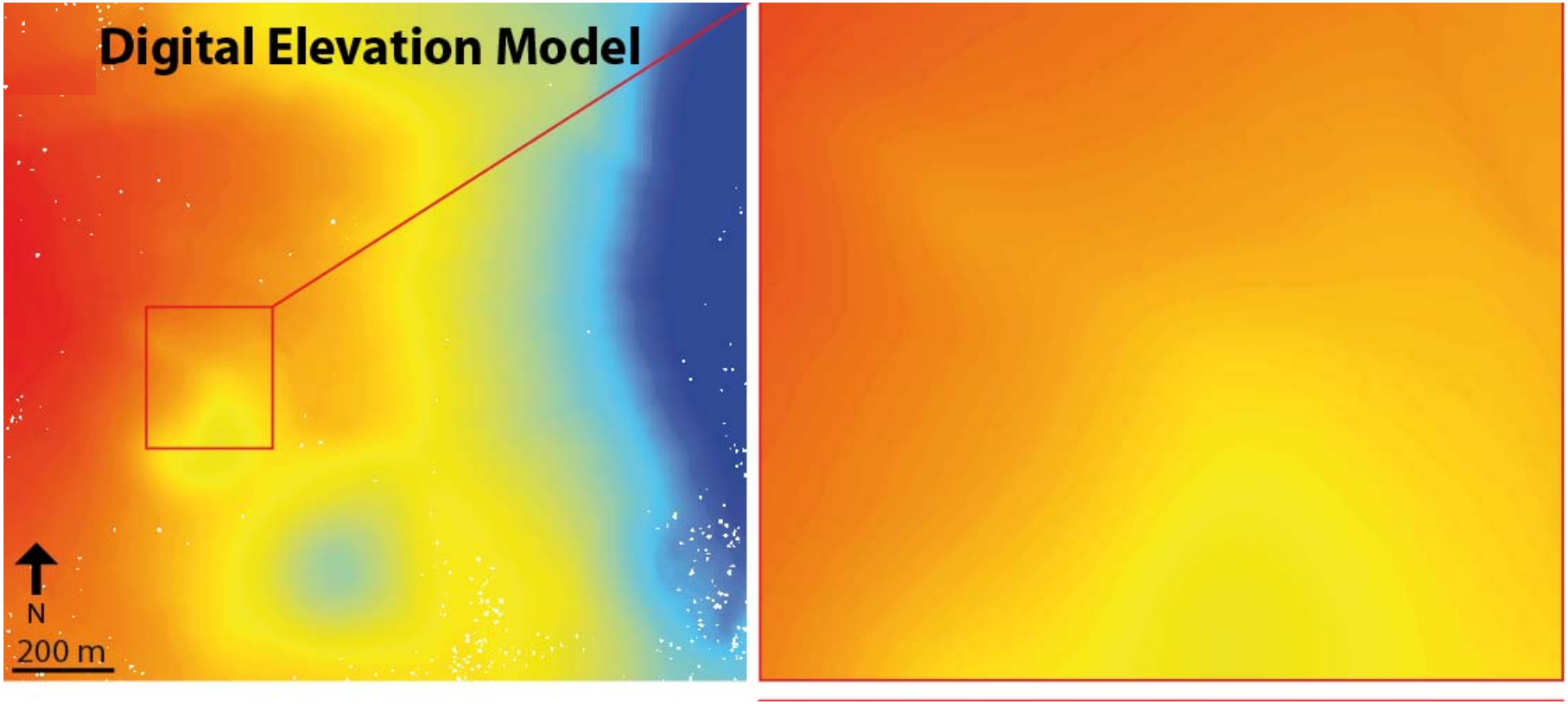




# Presentation of the investigated zone

In our case, we will focus on a smaller zone, in order to test the automatic detection process.

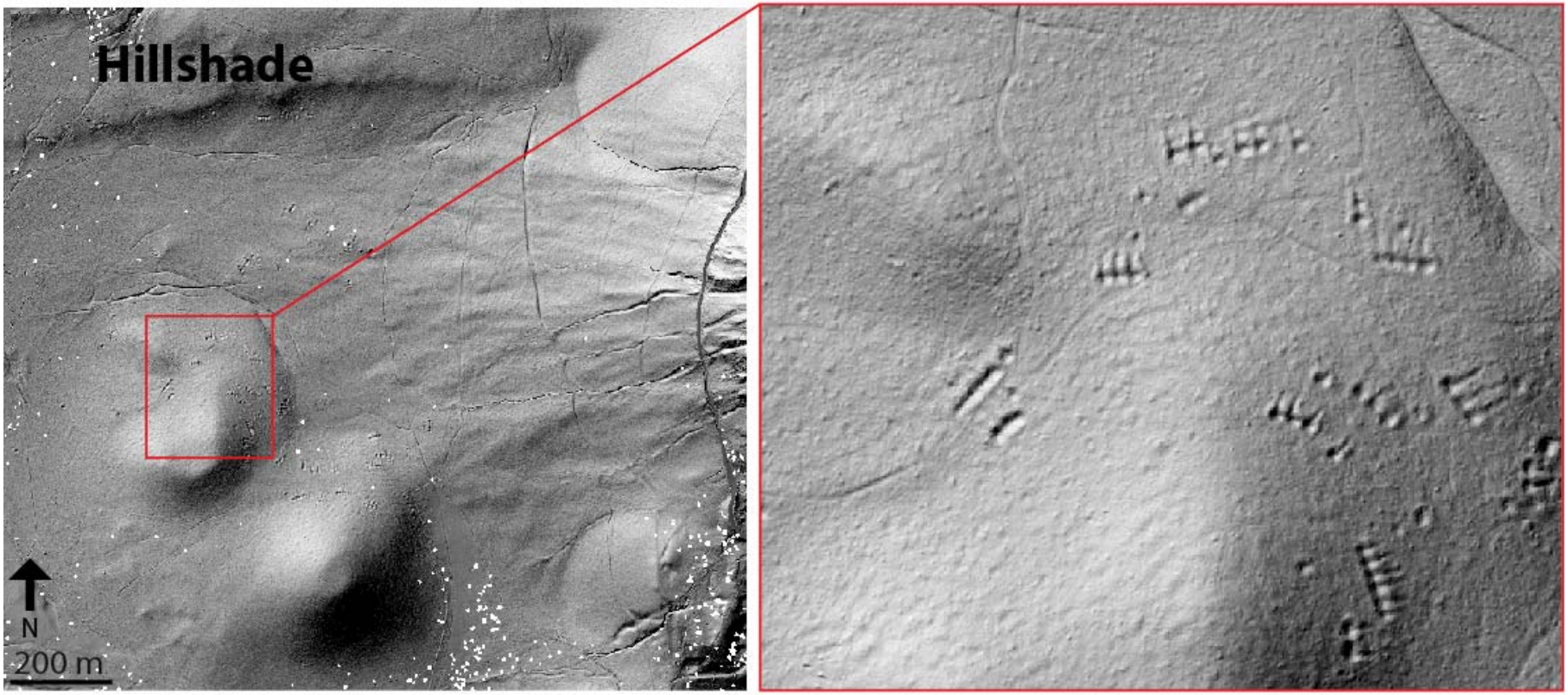
# Presentation of the investigated zone




- Not efficient for structure detection, because the elevation variation due to the archaeological structures are very small compared to natural altitude variations in the studied area.

- Necessity to find another representation of the data.

# A classical vizualization technique

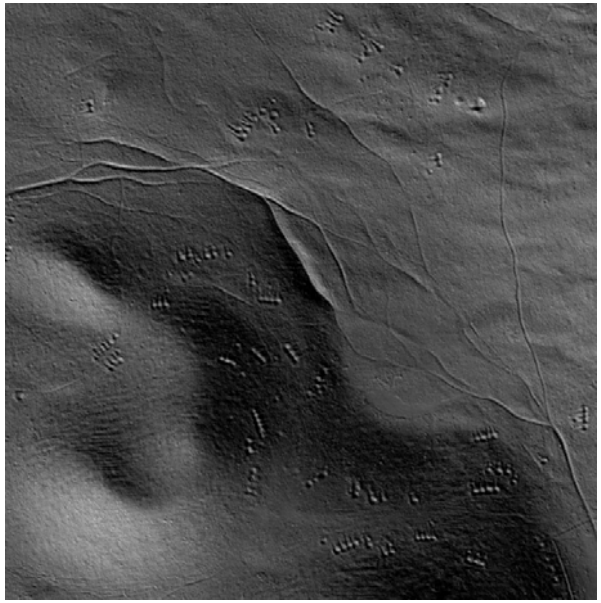


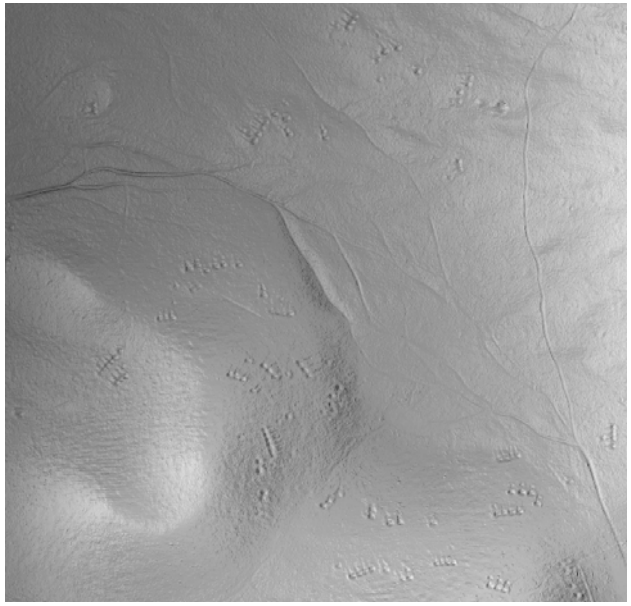

- The hillshade function is the most commonly used in GIS software. The position of an artificial illumination source is arbitrary chosen by the operator, and the illumination values are calculated for each cell or the DEM.

- Archaeological structured shadows become then visible, but it introduces an error of position and the shape of each structures is distorted.

# The most appropriated vizualisation technique

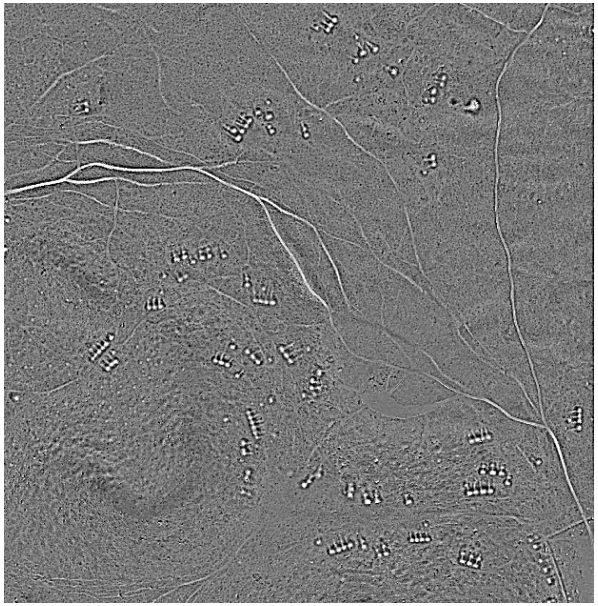
Hillshade





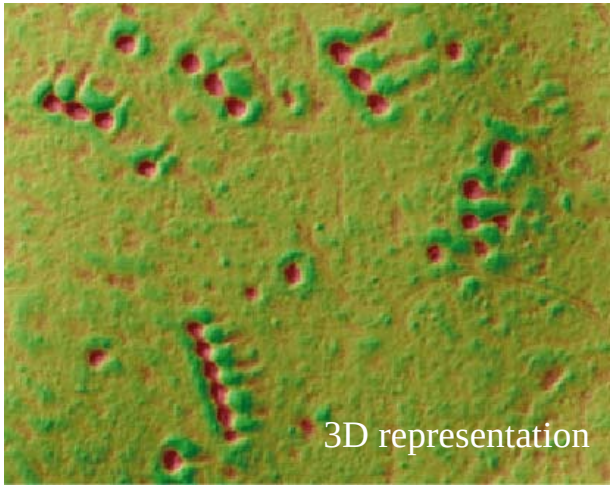
MDOW

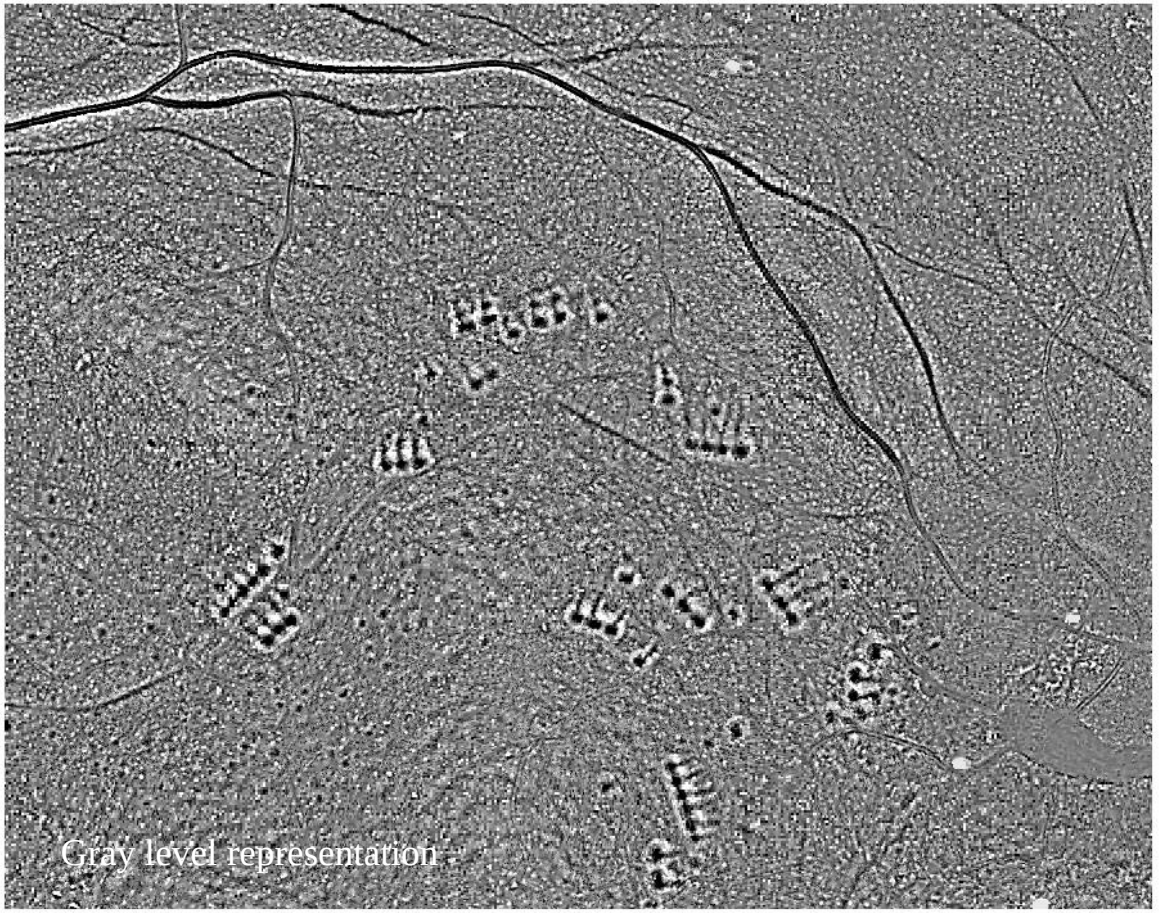
LRM



SVF

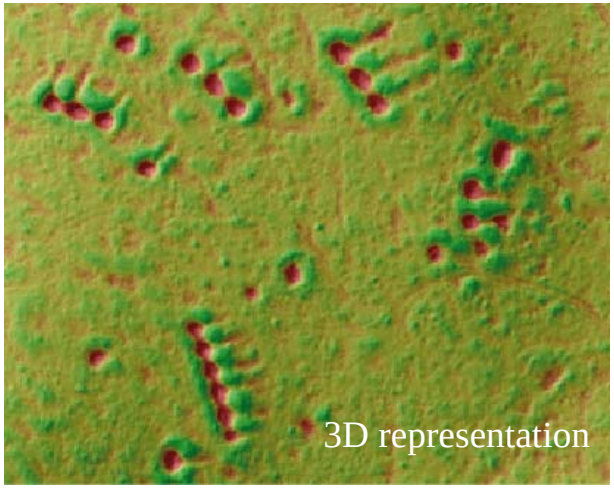
# Automatic detection and characteristic extraction

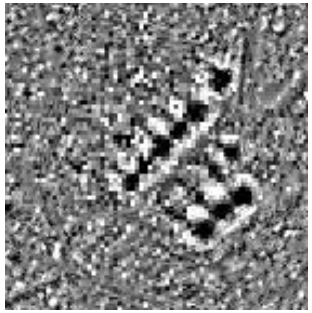


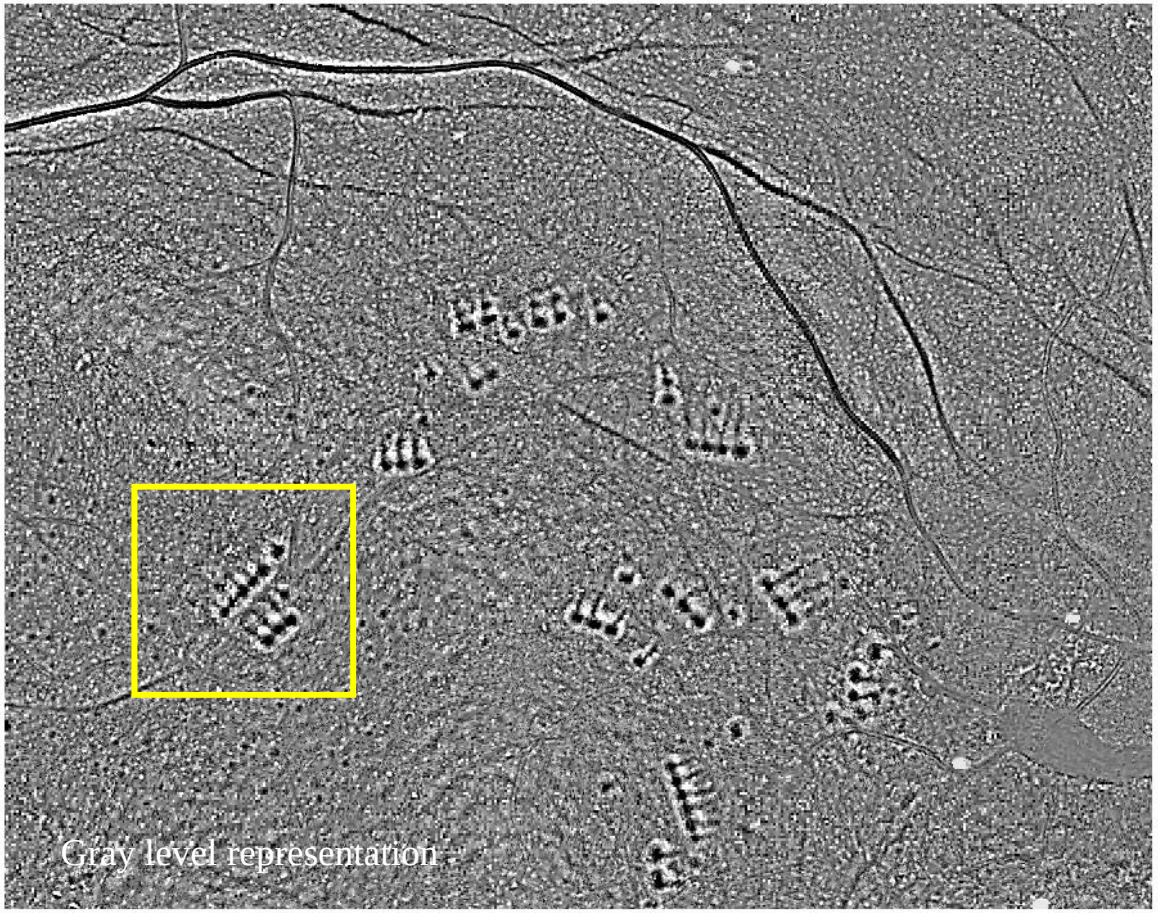




The difficulty is to indentify structures with different typologies (composed of a variable number of elements) and being more or less eroded.

# Automatic detection and characteristic extraction

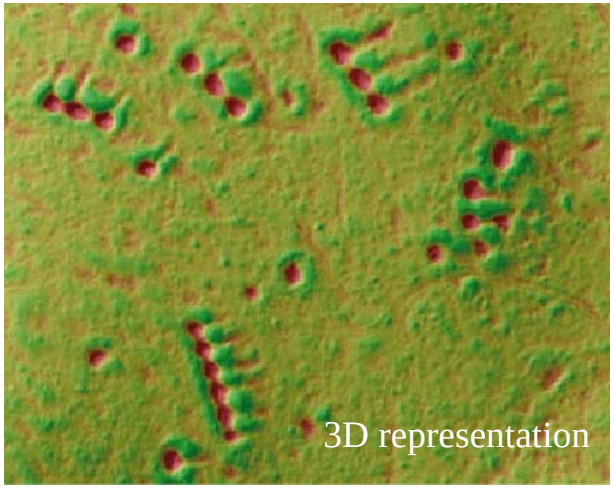


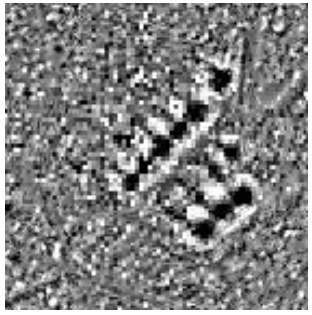



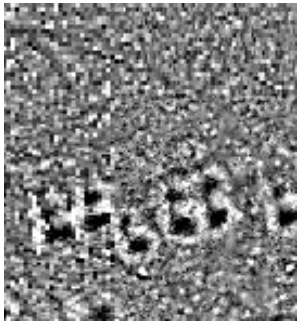


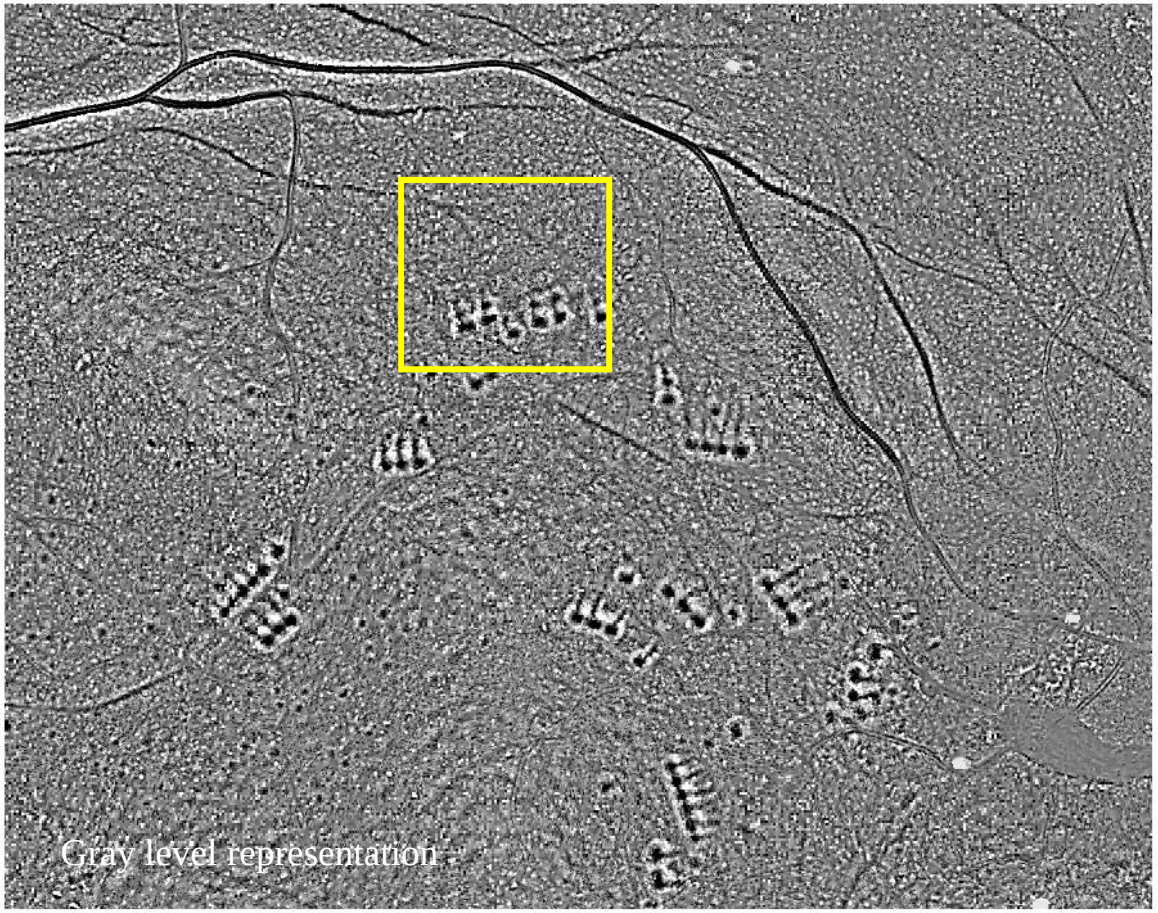

The difficulty is to indentify structures with different typologies (composed of a variable number of elements) and being more or less eroded.

# Automatic detection and characteristic extraction



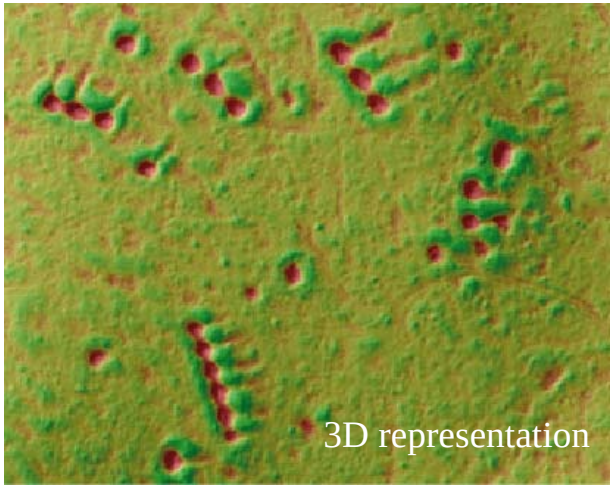



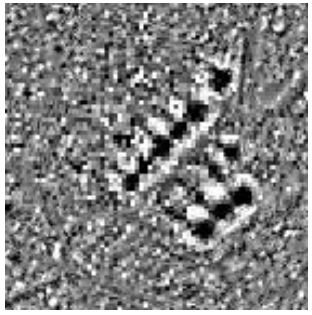


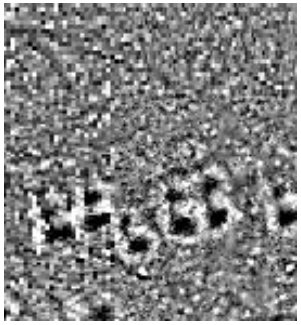


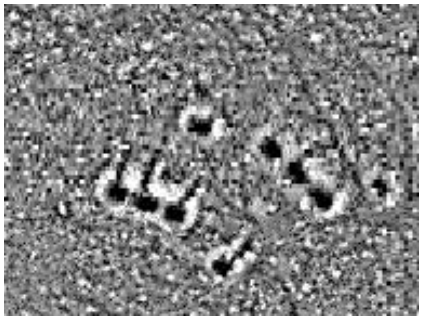

The difficulty is to indentify structures with different typologies (composed of a variable number of elements) and being more or less eroded.

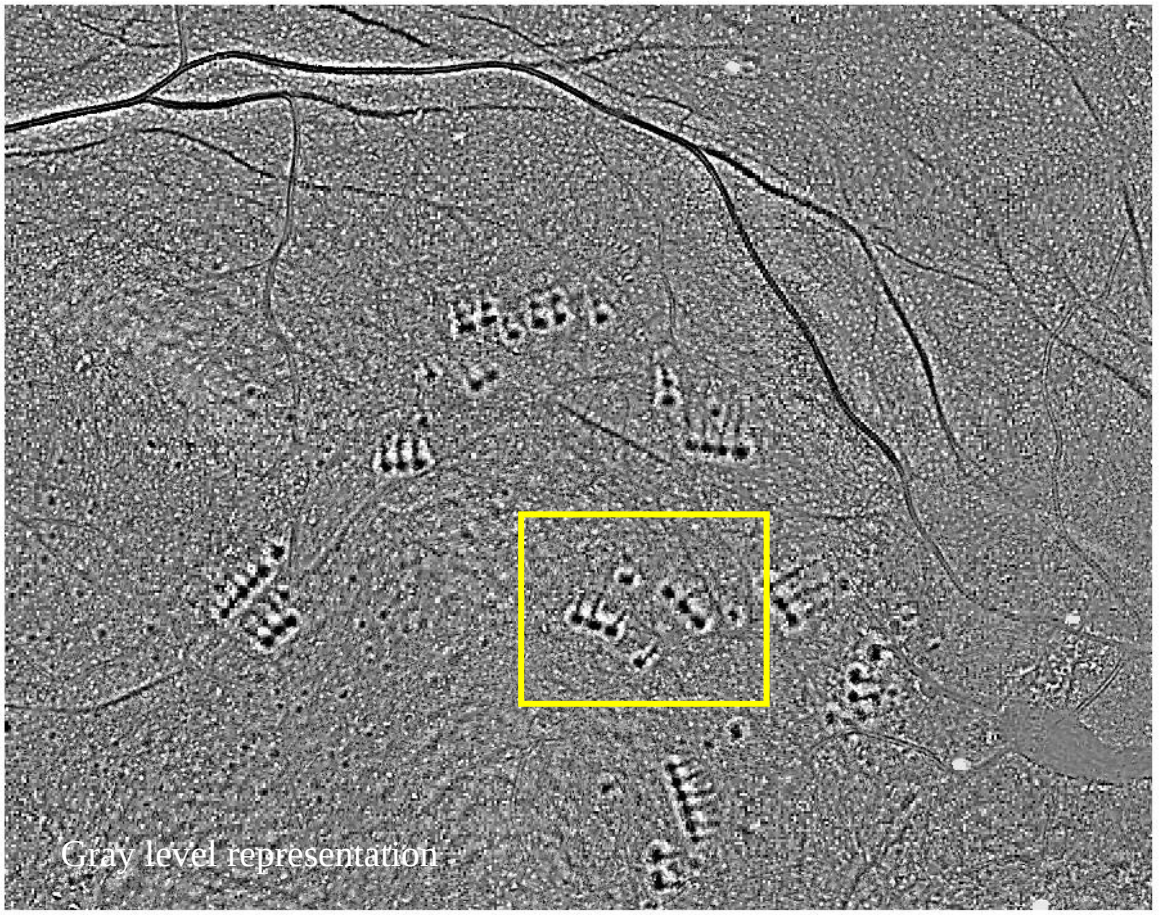
# Difficulties for automatic detection










The difficulty is to indentify structures with different typologies (composed of a variable number of elements) and being more or less eroded.

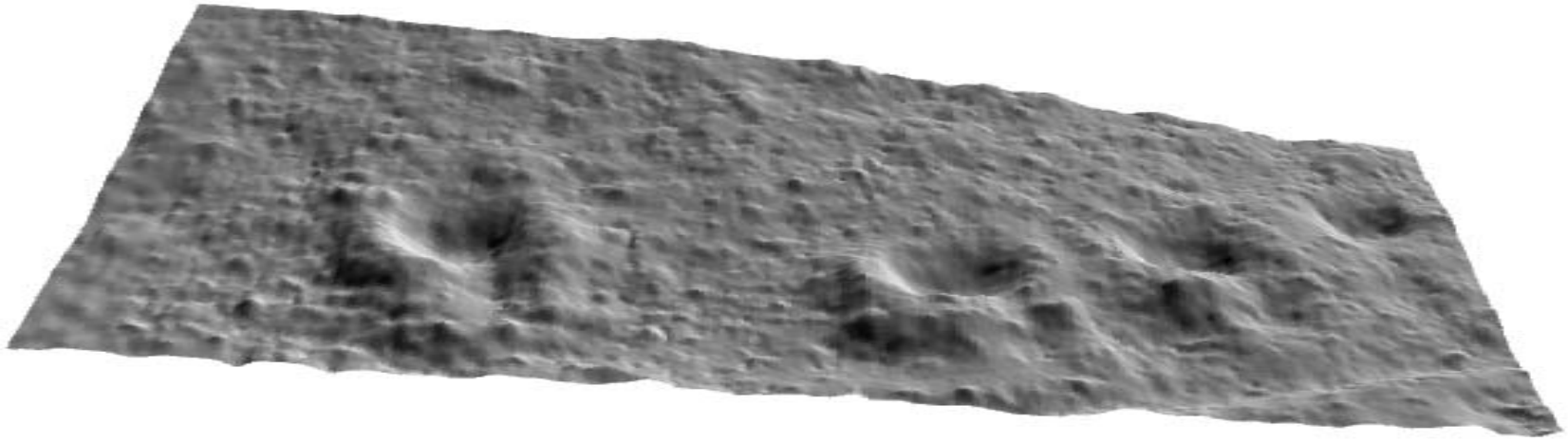
# Difficulties for automatic detection

2 questions, before starting automatic detection :

What are the features of the item of interest ?

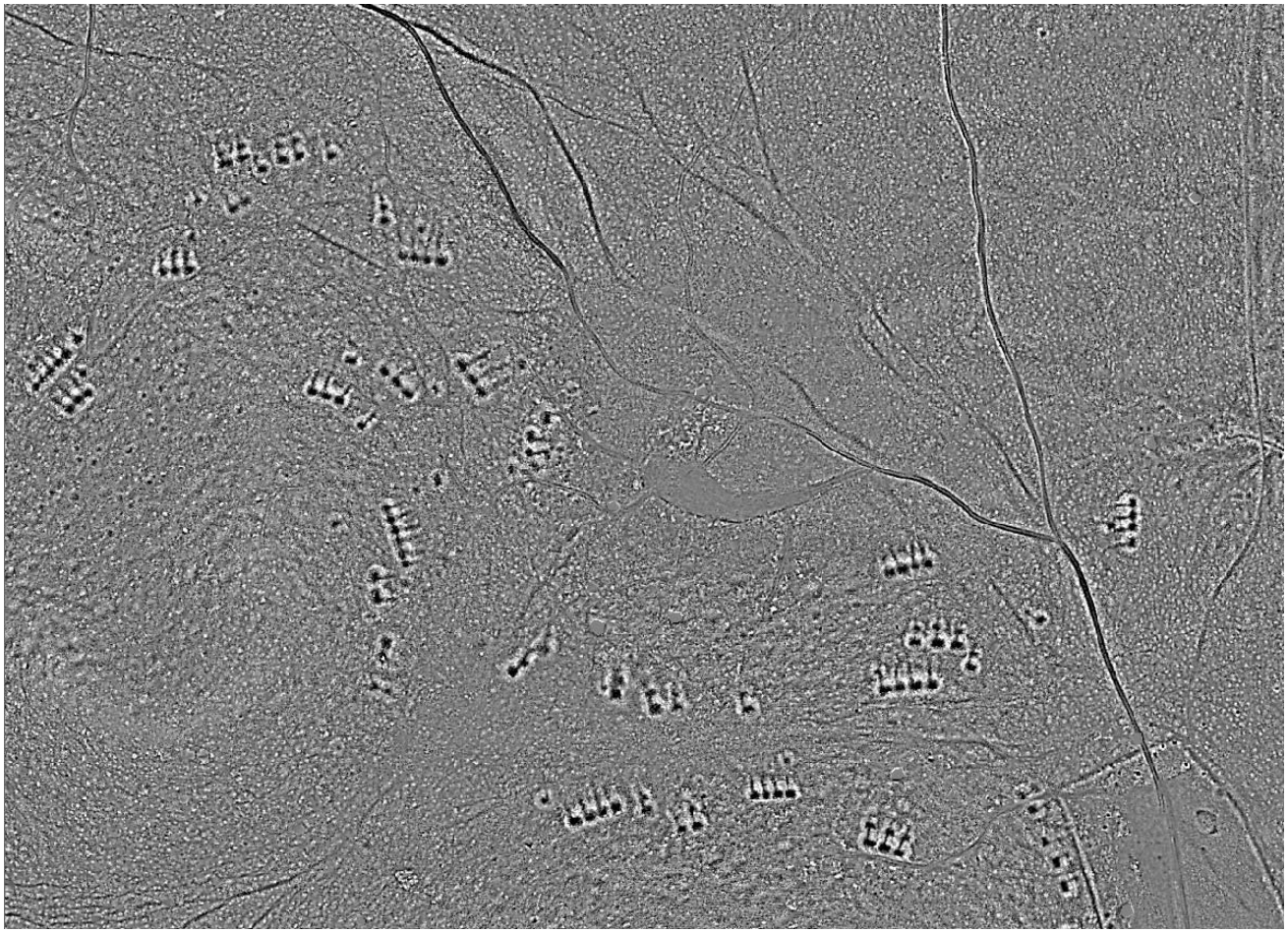
&

What is our strategy for automatic detection ?



# What are the features of the item of interest

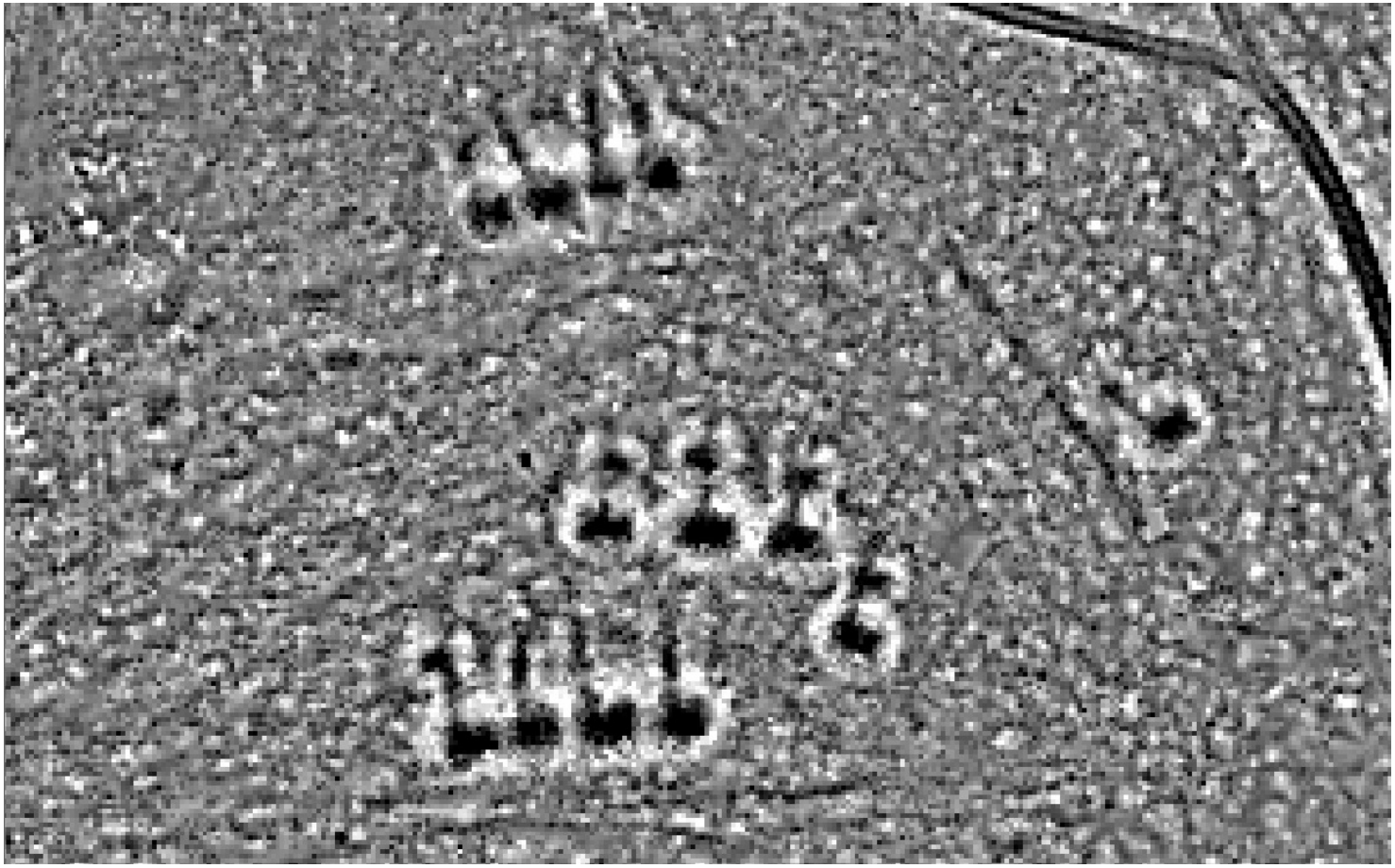
It is so easy to identify ! A black circle, surrounded by a white circle !



But is it so simple…

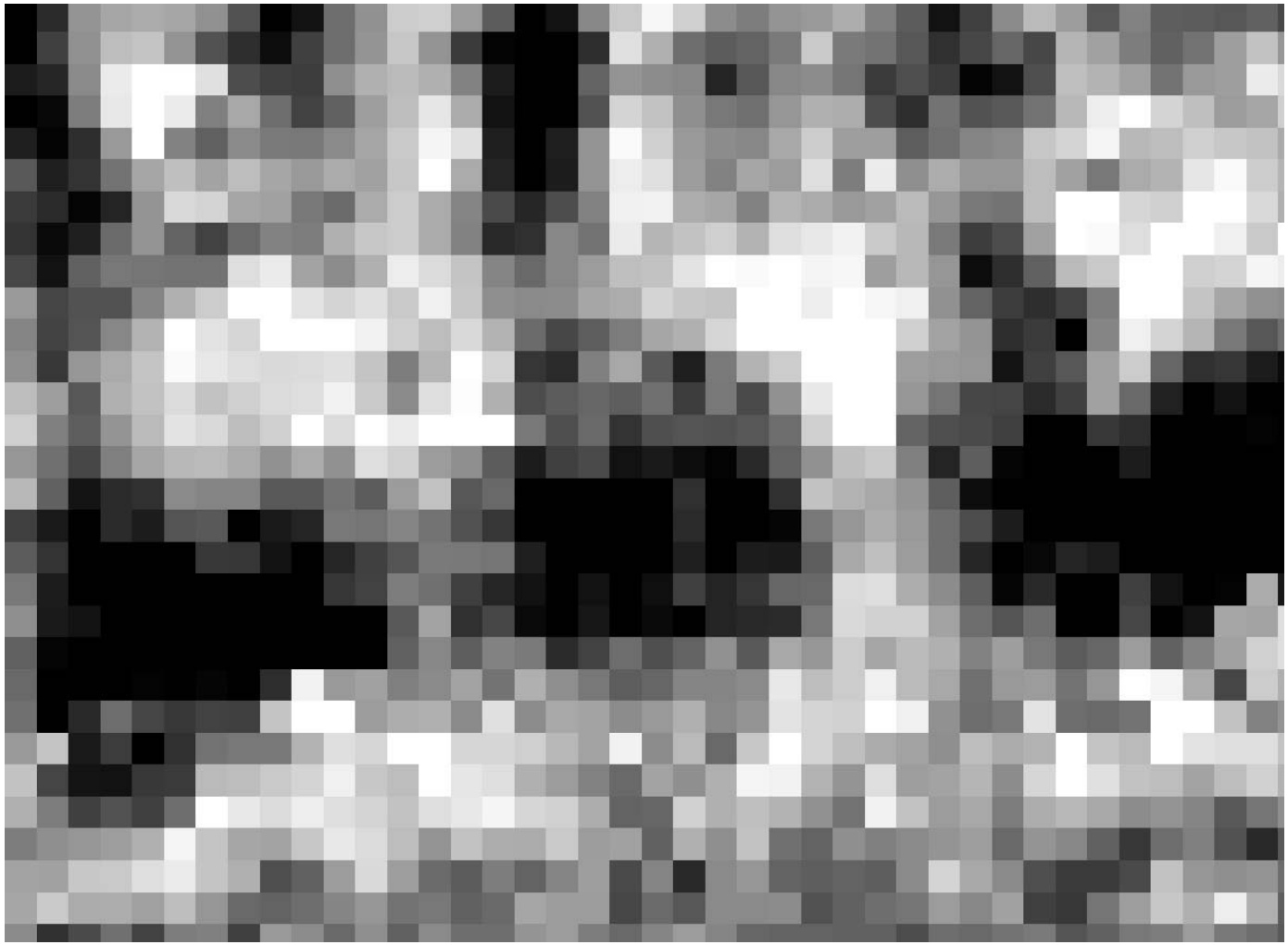
# What are the features of the item of interest

Let’s look closer : Are the structure really circular, or square, or oval… ?
Are they always surrounded by a white part ?



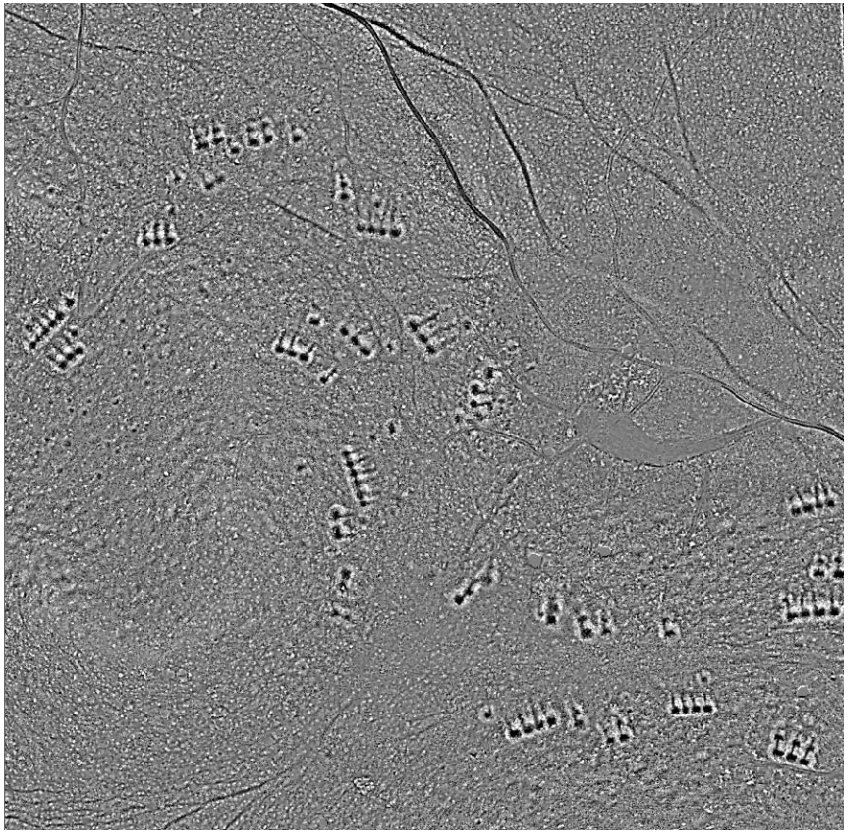
# What are the features of the item of interest

If we look much closer :
It becomes more and more difficult to define the structures boundary.
Worse yet, 2 « similar » structures seems now to be different

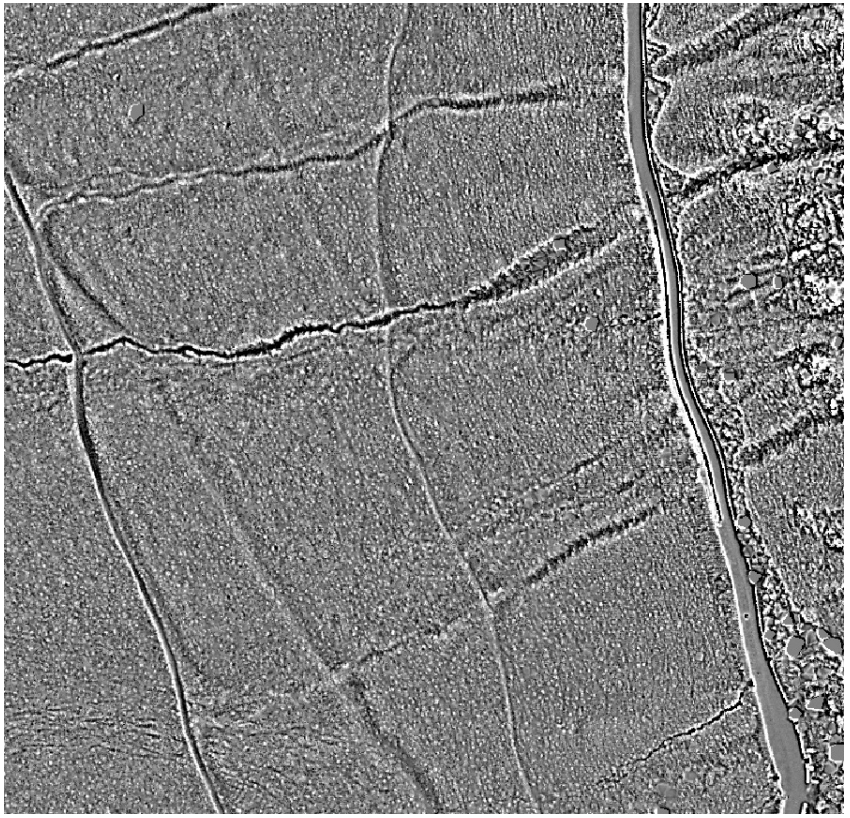


# What about artifacts ?

**An archaeological structure may be easy to differentiate from natural relief**

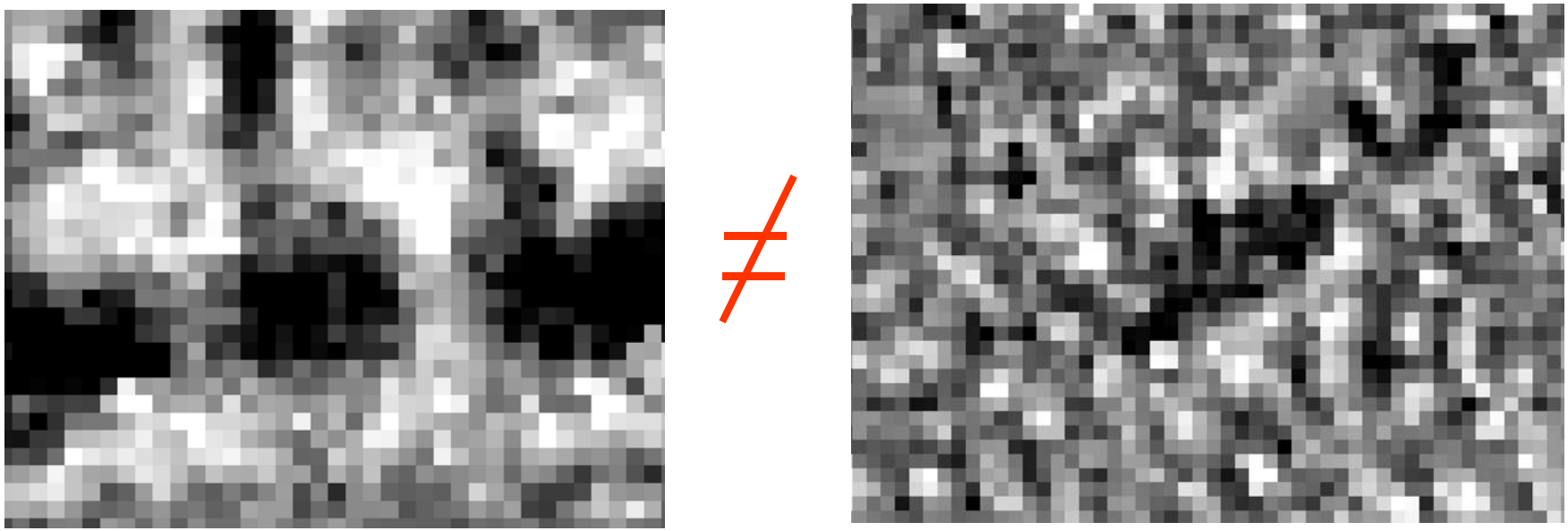


≠



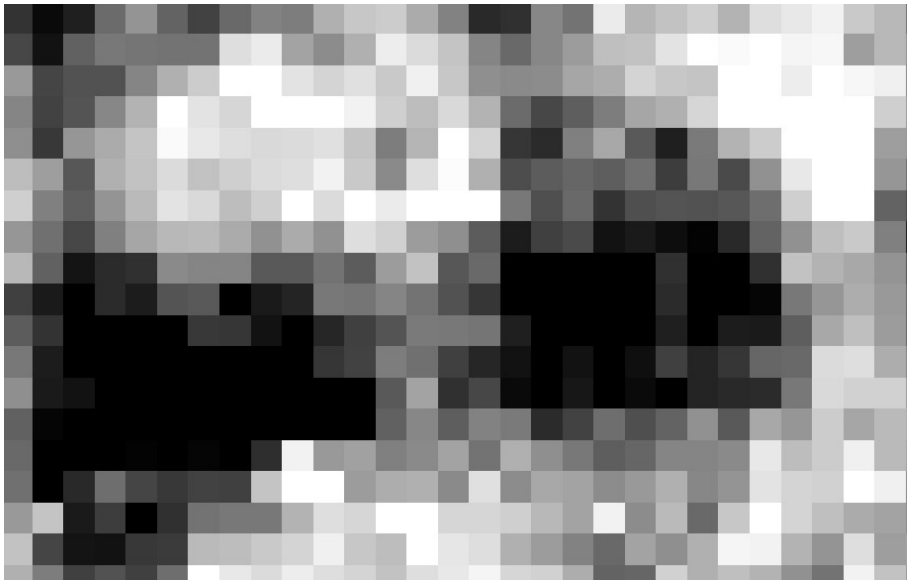
But is it so simple…

# What about artifacts ?

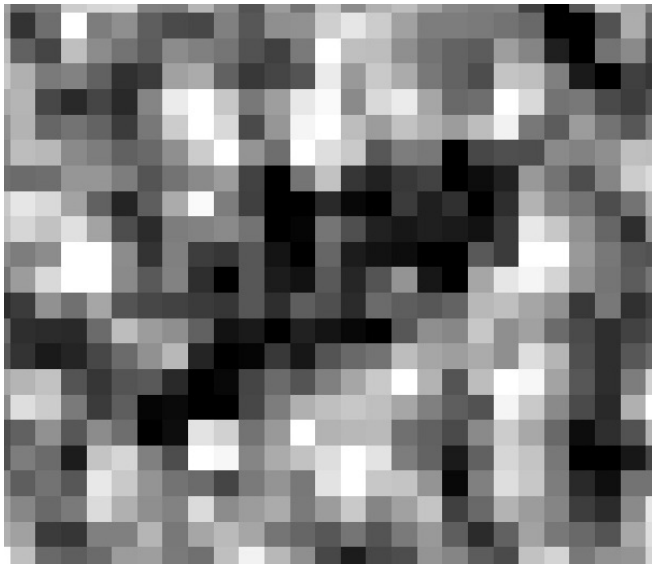


# What about artefacts ?

**At this scale, the difference between two archaeological structures is nearly of the same order as the one between an archaeological structure and an artefact**



≠

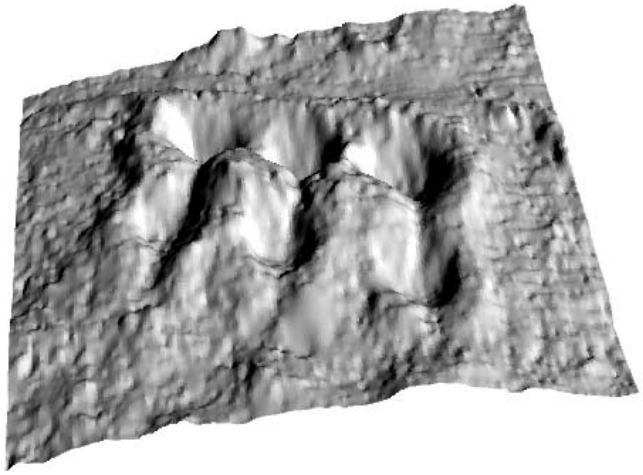


**It is at this scale that the automatic detection will process.**
**The human eye + brain have a filtering effect, that has to be replaced by objective criteria for the automatic detection**

# So, what about the detection strategy ?

**The detection must be a multi-criteria detection**

- ☞ **general aspect considerations**
- ☞ **morphometric considerations**



**Necessity to build a model of the structure**

**The strategy of detection must be chosen**

**1) A high similarity with the model is preferred :**

benefit : there will be few artifacts

drawback : the eroded or unusual structures won’t be detected

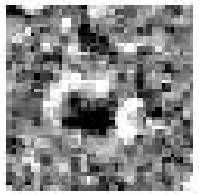
**2) A lower similarity with the model is preferred :**

benefit : the eroded or unusual structures will be detected

drawback : there will be more artifacts

# Automatic detection and characteristic extraction algorithm

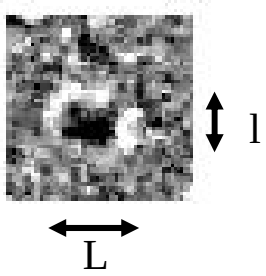
Definition, by the archaeologists, of the searched item



# Automatic detection and characteristic extraction algorithm

Definition, by the archaeologists, of the searched item

Automatic extraction of the item main properties



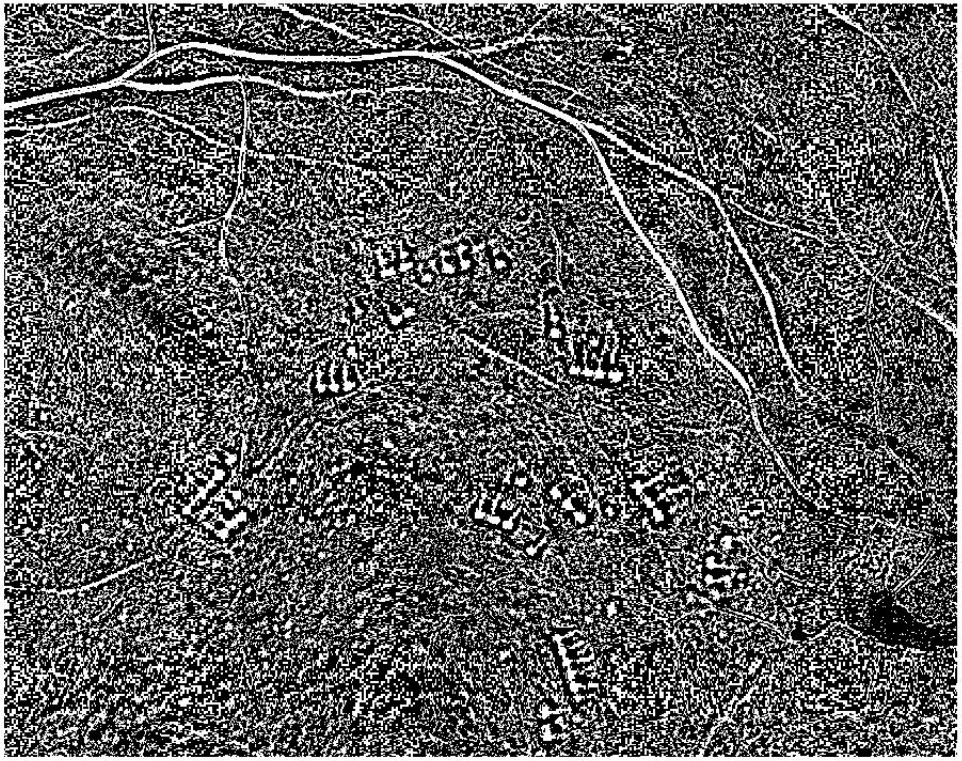

Dimension, ratio L/l, morphology

# Automatic detection and characteristic extraction algorithm

Definition, by the archaeologists, of the searched item

Automatic extraction of the item main properties

LRM binarization



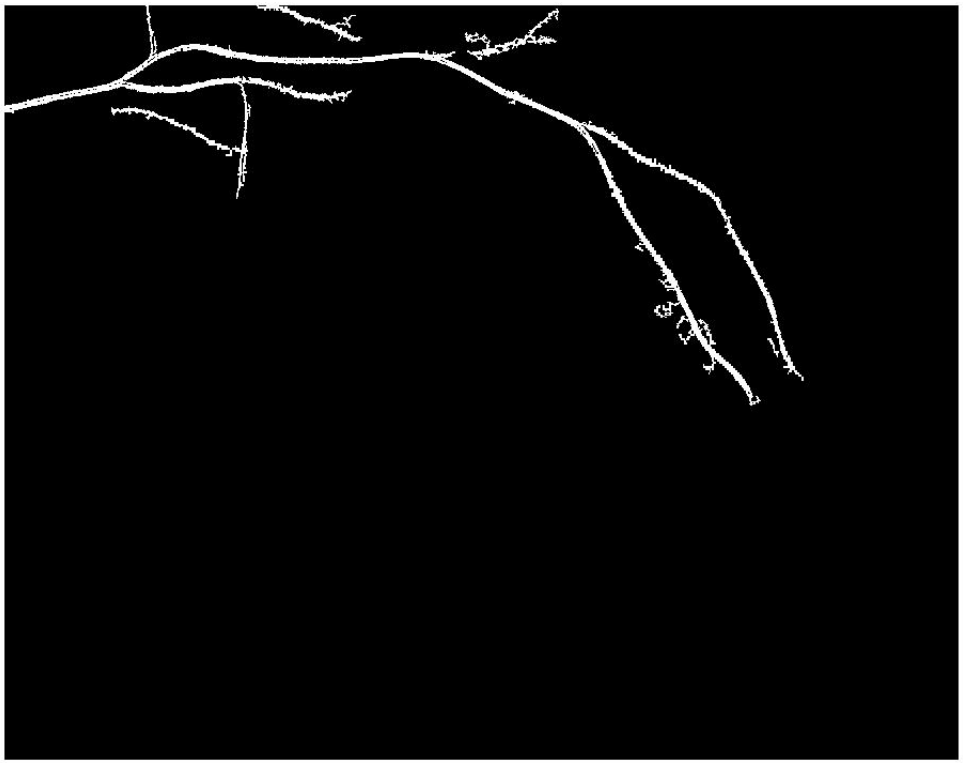
# Automatic detection and characteristic extraction algorithm

Definition, by the archaeologists, of the searched item

Automatic extraction of the item main properties

LRM binarization

Detection and suppression of linear elements (roads, paths)



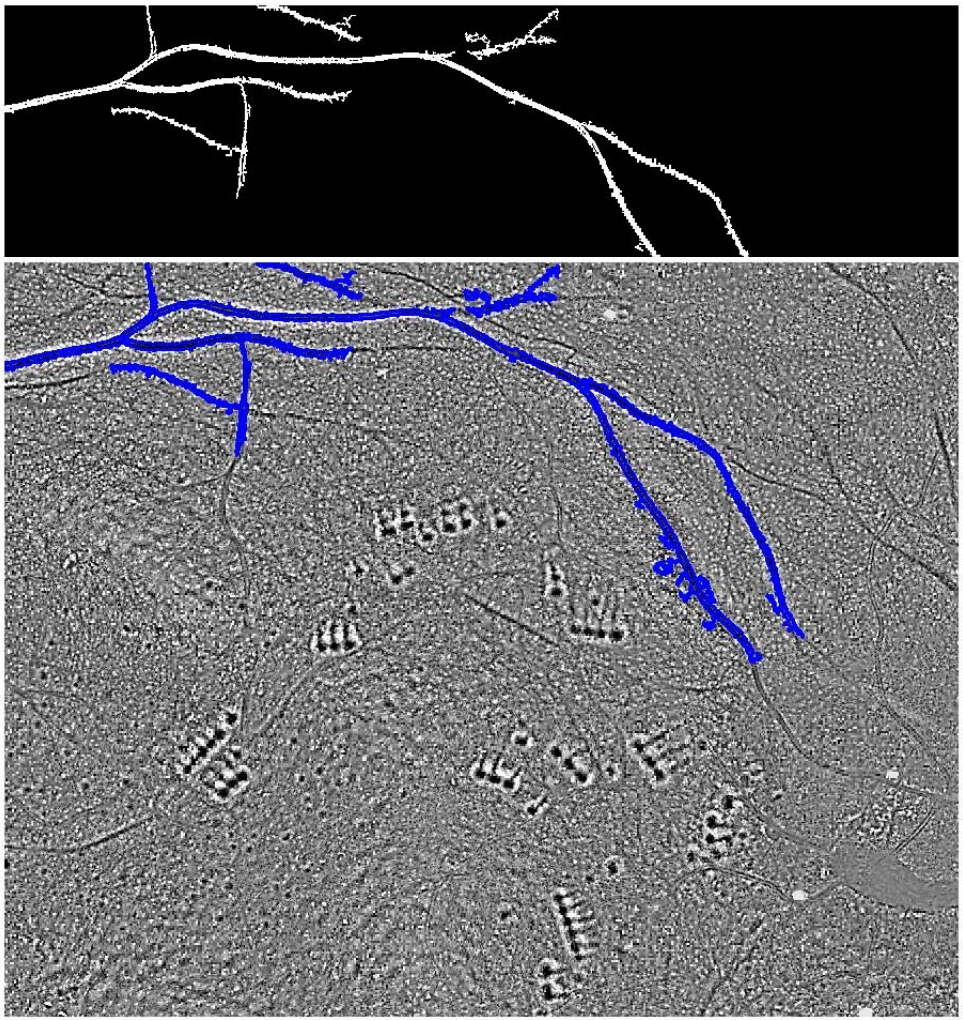
# Automatic detection and characteristic extraction algorithm

Definition, by the archaeologists, of the searched item

Automatic extraction of the item main properties

LRM binarization

Detection and suppression of linear elements (roads, paths)



# Automatic detection and characteristic extraction algorithm

Detection of hollow parts of archaeological structures

Coupled detection using both :

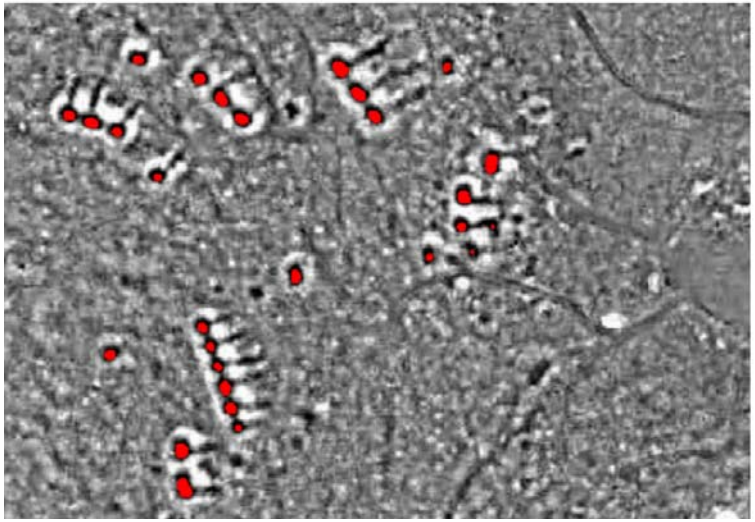
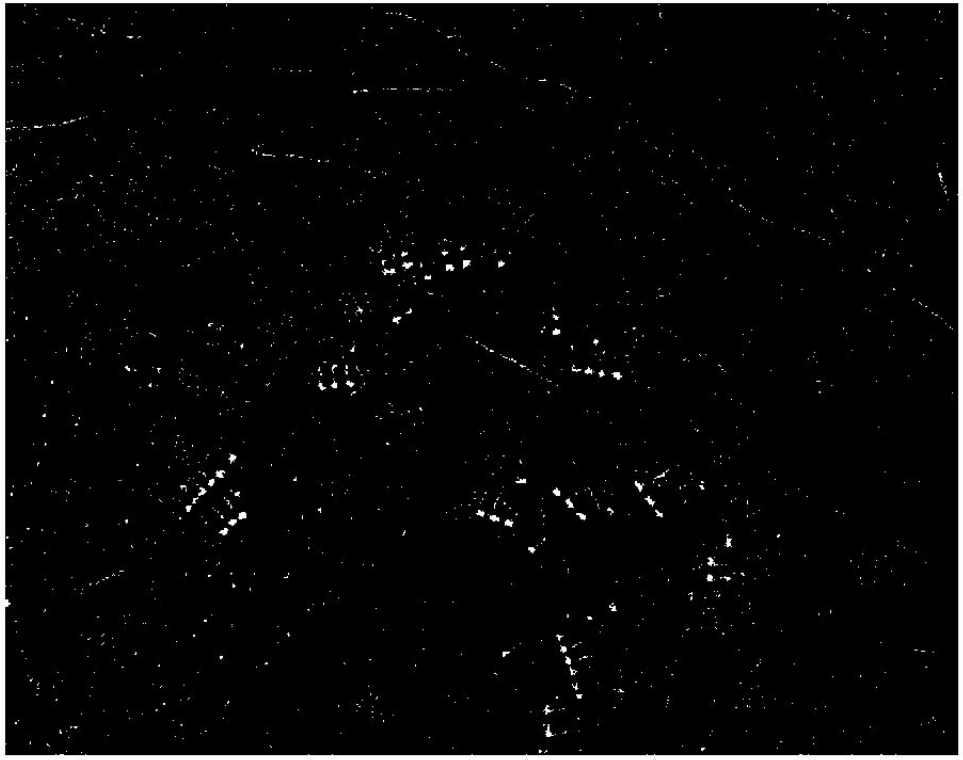


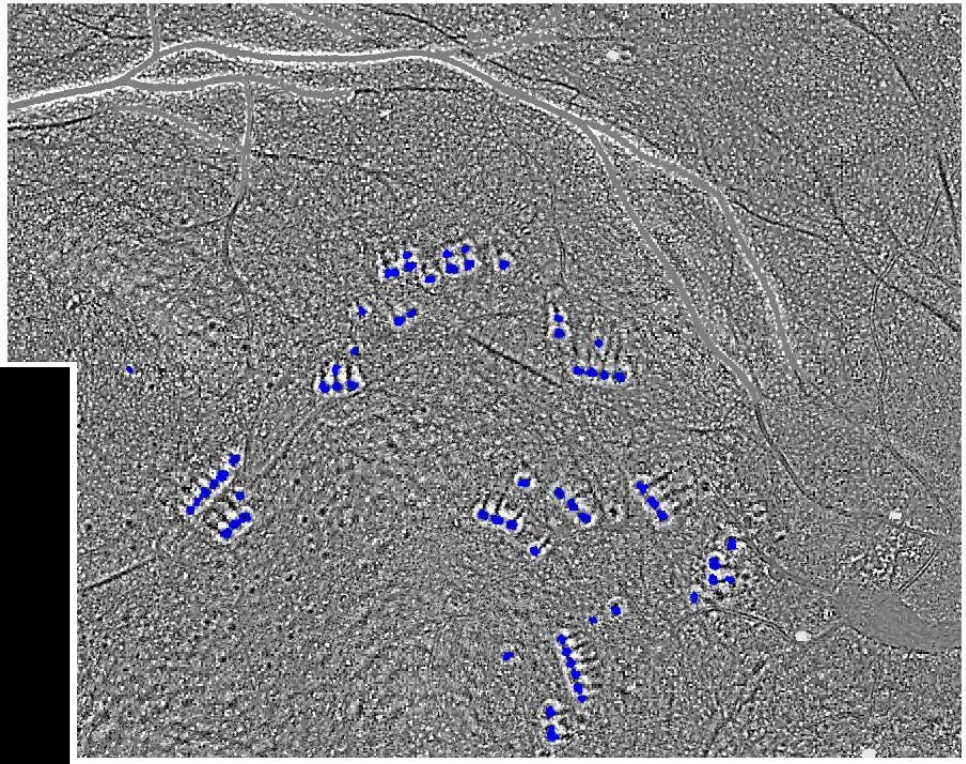
Image correlation

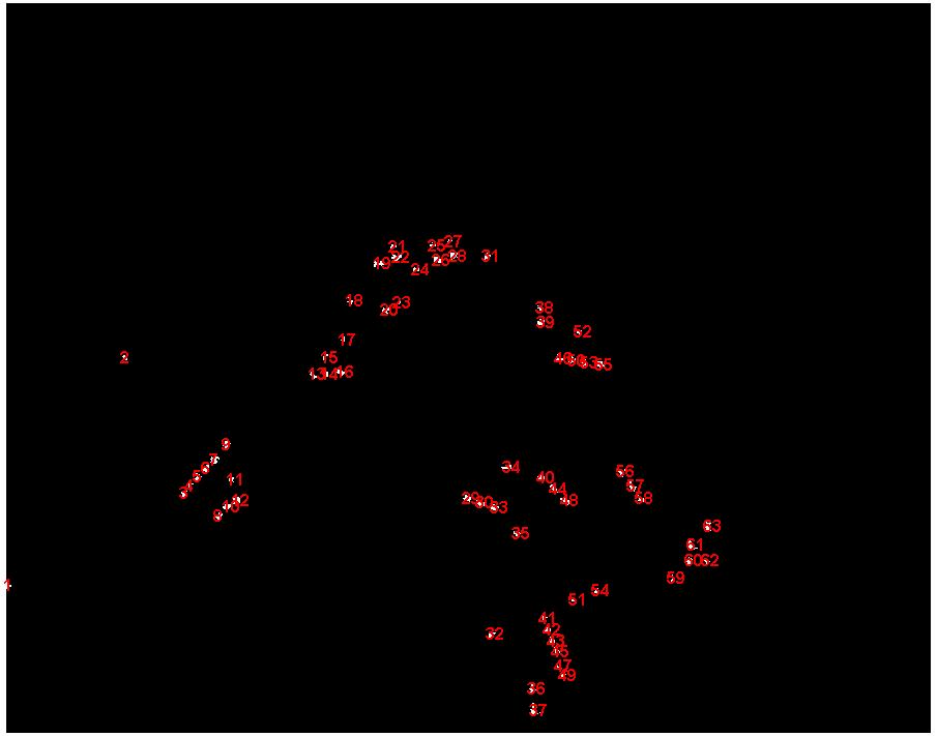


Morphological level detection

# Automatic detection and characteristic extraction algorithm

Detection of hollow parts of archaeological structures

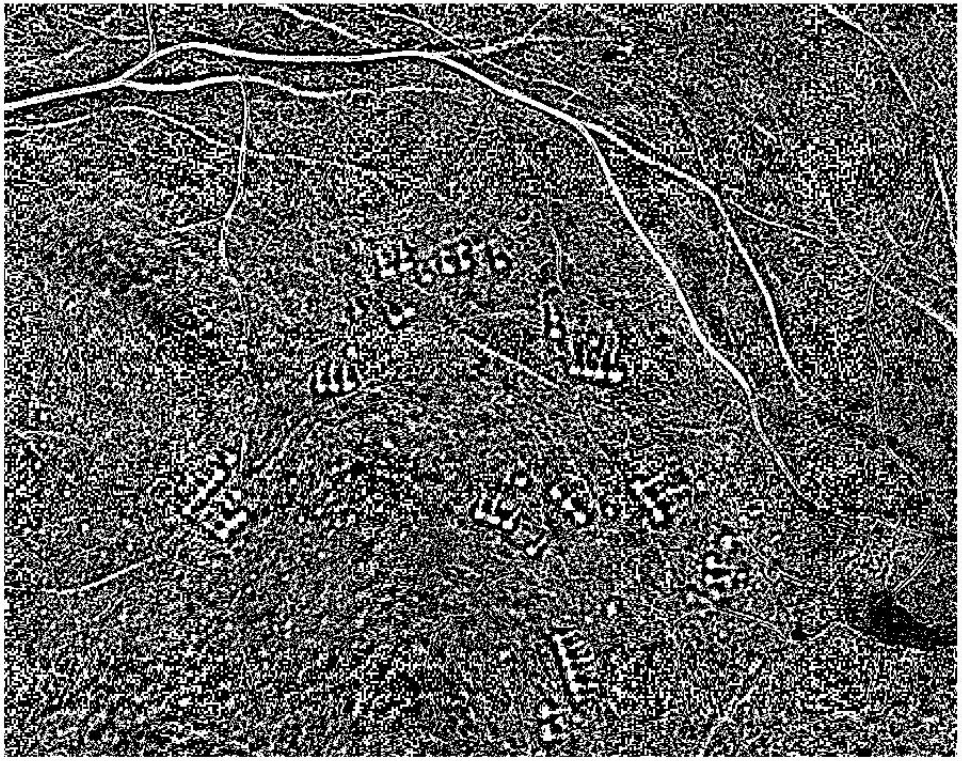




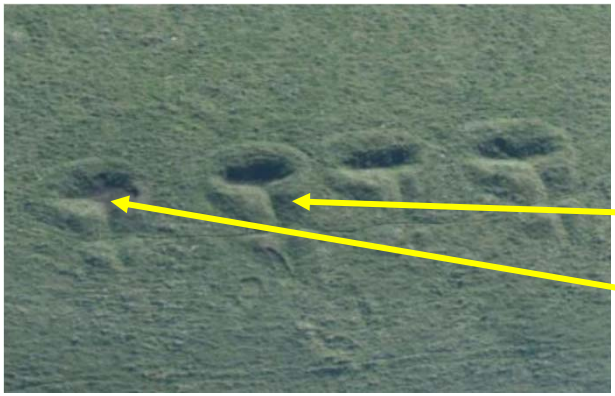
# Automatic detection and characteristic extraction algorithm

Detection of hollow parts of archaeological structures

Detection of all the elements corresponding to a negative altitude ( hollow + corridor)



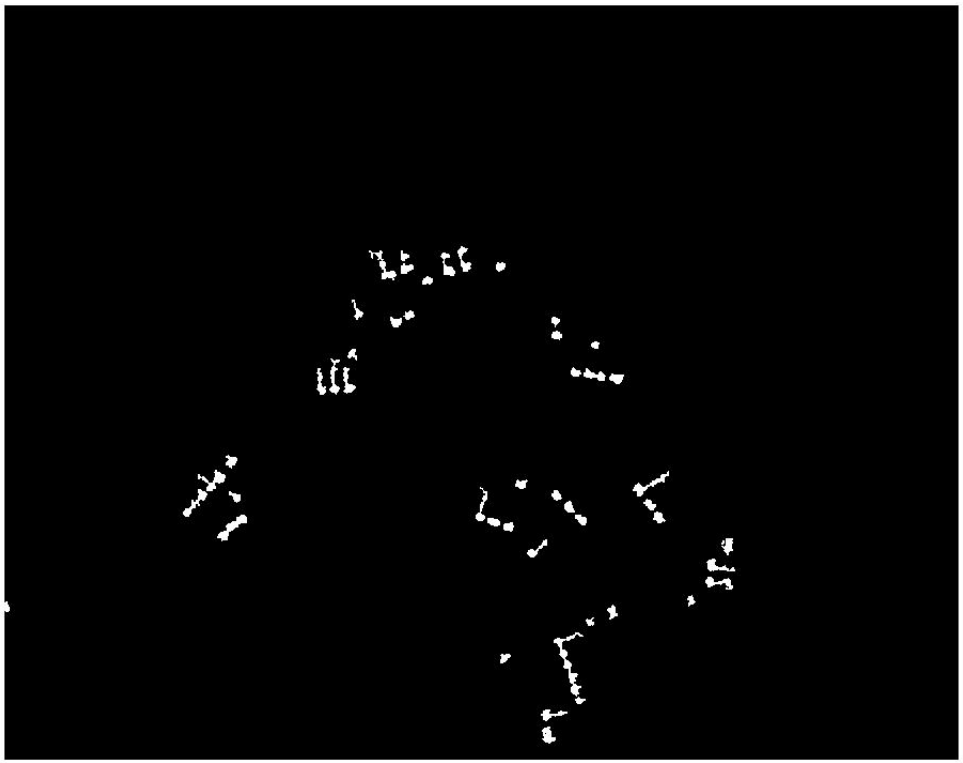
It includes hollow parts and corridors



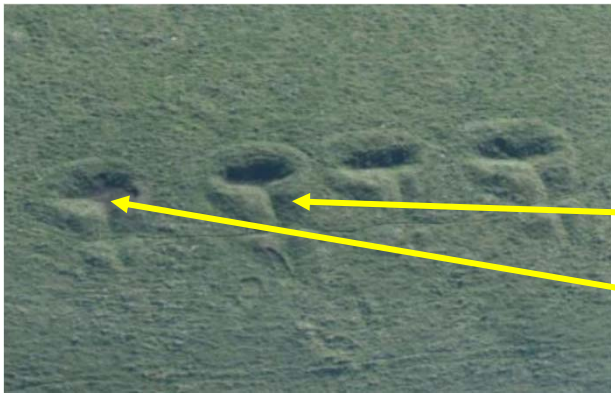

# Automatic detection and characteristic extraction algorithm

Detection of hollow parts of archaeological structures

Detection of all the elements corresponding to a negative altitude ( hollow + corridor)



It includes hollow parts and corridors

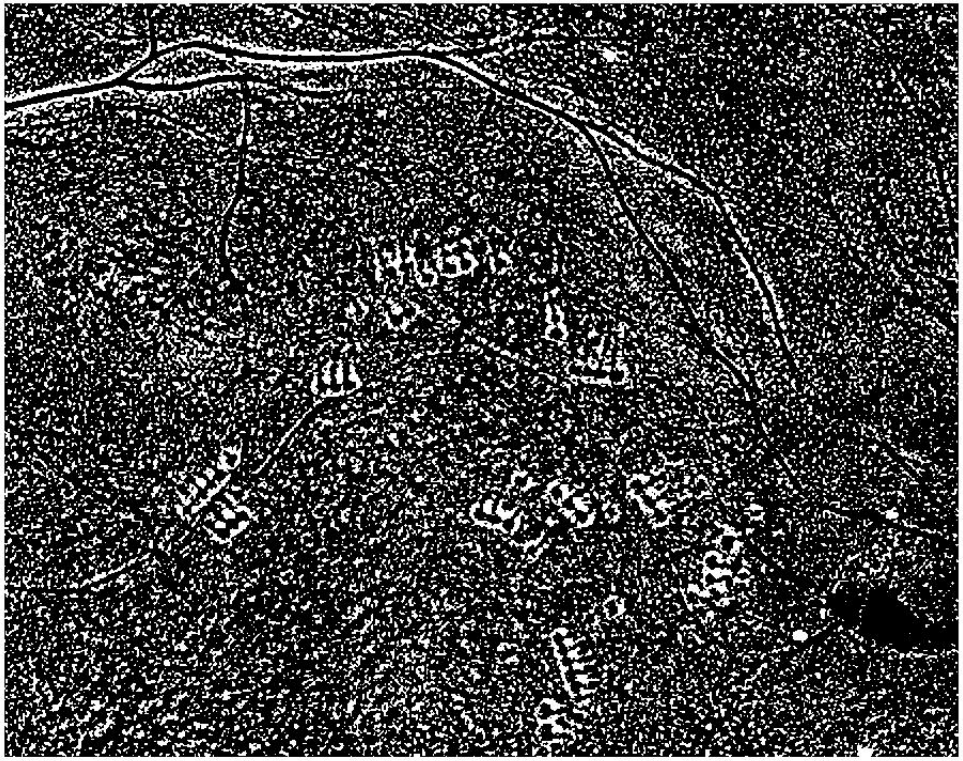



# Automatic detection and characteristic extraction algorithm

Detection of hollow parts of archaeological structures

Detection of all the elements corresponding to a negative altitude ( hollow + corridor)

Detection of all the elements corresponding to a positive altitude (ridges)



Ridges

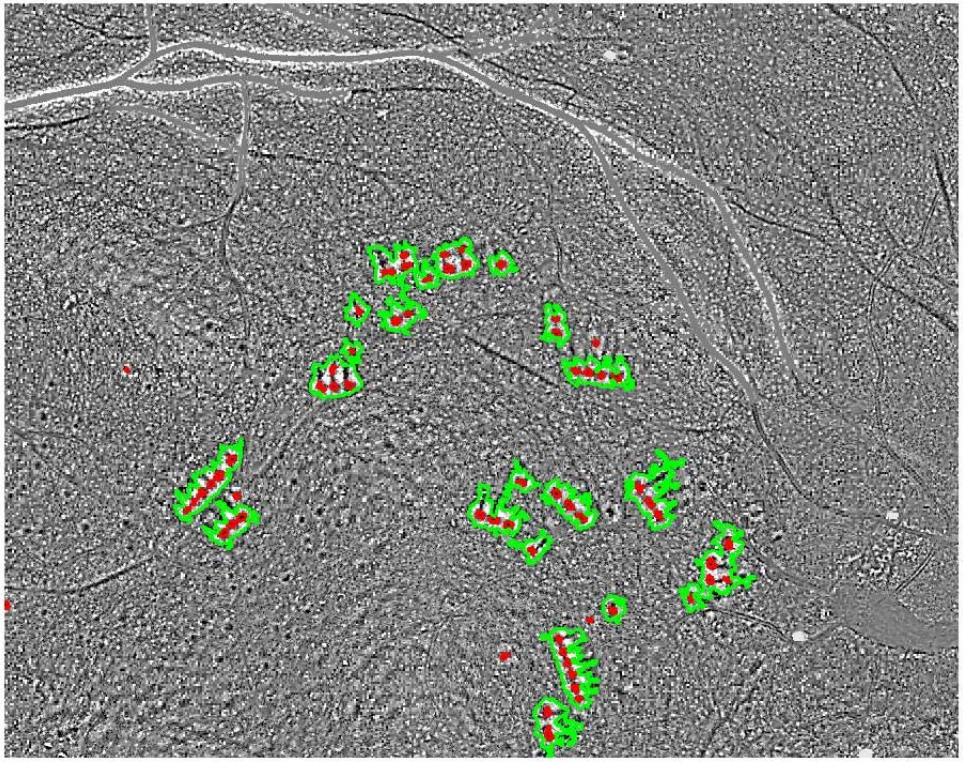
# Automatic detection and characteristic extraction algorithm

Detection of hollow parts of archaeological structures

Detection of all the elements corresponding to a negative altitude ( hollow + corridor)

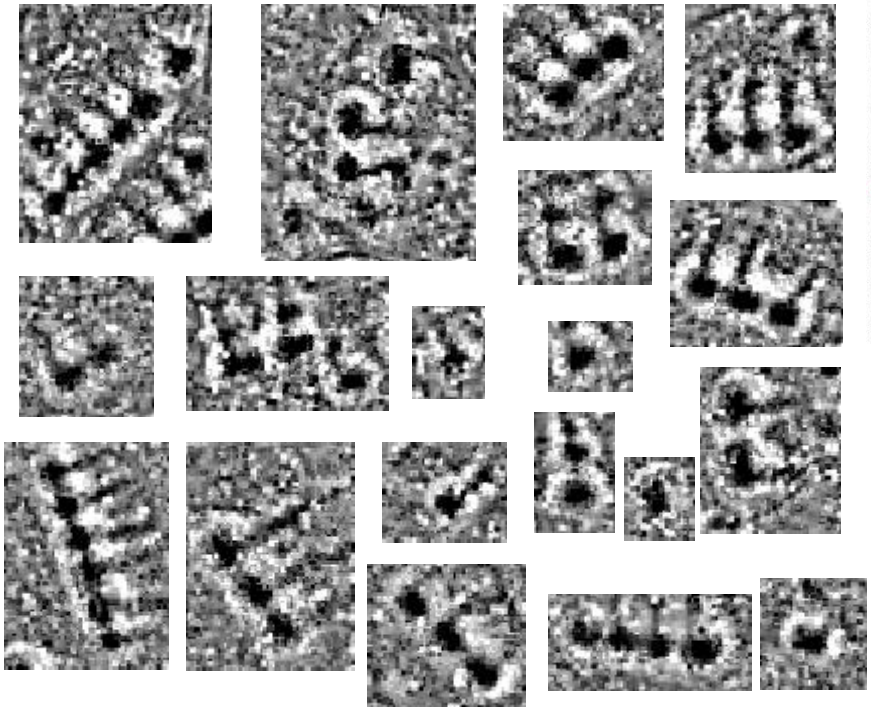
Detection of all the elements corresponding to a positive altitude (ridges)

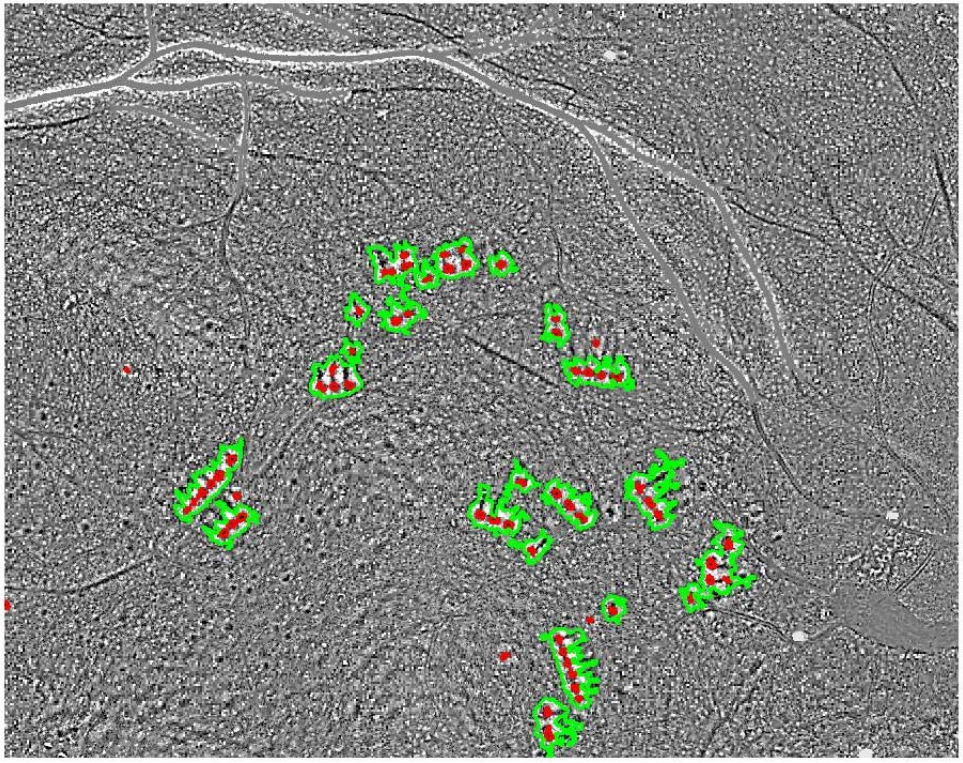
Fusion of all the elements to define the complete structure



# Automatic detection and characteristic extraction algorithm

Extraction of sub images for each complete structure

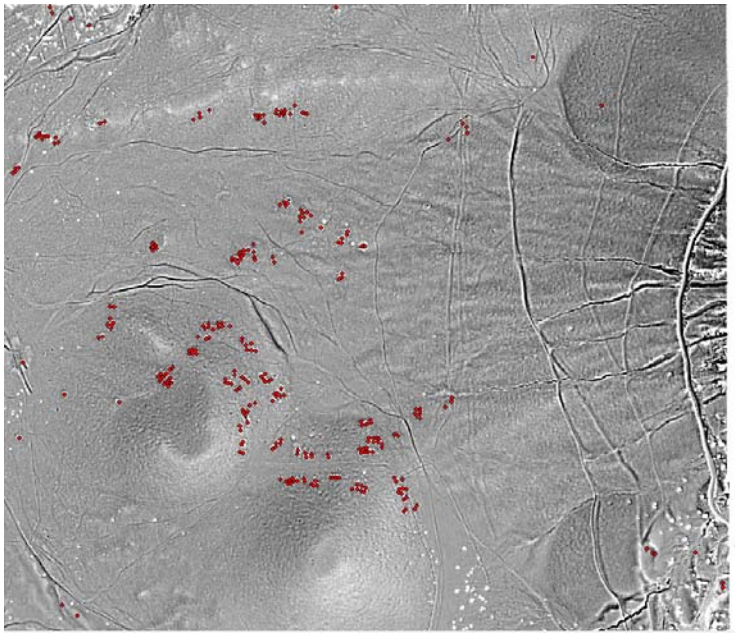




# Automatic detection and characteristic extraction algorithm

Extraction of sub images for each complete structure

Creation of a database with all geometric characteristics



Table

DETECTION_AUTO_JP

| FID | Shape * | ID | X | Y |
|---|---|---|---|---|
| 0 | Point | 1 | 695225.231 | 6519374.017 |
| 1 | Point | 2 | 695230.897667 | 6519382.967 |
| 2 | Point | 3 | 695231.206 | 6519375.792 |
| 3 | Point | 4 | 695236.291976 | 6519384.693829 |
| 4 | Point | 5 | 695238.245706 | 6518821.472882 |
| 5 | Point | 6 | 695246.221741 | 6518978.711444 |
| 6 | Point | 7 | 695272.948391 | 6519448.288739 |
| 7 | Point | 8 | 695276.731 | 6519449.945571 |
| 8 | Point | 9 | 695280.575828 | 6519456.404931 |
| 9 | Point | 10 | 695282.13725 | 6519450.98575 |
| 10 | Point | 11 | 695286.283632 | 6519442.933667 |
| 11 | Point | 12 | 695288.024103 | 6519450.292862 |
| 12 | Point | 13 | 695293.742905 | 6519450.314619 |
| 13 | Point | 14 | 695299.731 | 6519449.782385 |
| 14 | Point | 15 | 695302.008778 | 6519718.378111 |
| 15 | Point | 16 | 695306.342111 | 6519706.611444 |
| 16 | Point | 17 | 695311.451 | 6519434.787 |
| 17 | Point | 18 | 695314.739065 | 6519445.637968 |
| 18 | Point | 19 | 695320.182613 | 6519437.589581 |
| 19 | Point | 20 | 695327.981 | 6518473.767 |
| 20 | Point | 21 | 695332.984846 | 6518911.474692 |
| 21 | Point | 22 | 695346.318302 | 6519694.798746 |
| 22 | Point | 23 | 695358.638407 | 6518451.39663 |
| 23 | Point | 24 | 695385.00551 | 6519680.865039 |
| 24 | Point | 25 | 695406.639163 | 6519477.175163 |
| 25 | Point | 26 | 695403.008778 | 6519030.822556 |
| 26 | Point | 27 | 695411.856 | 6519032.589368 |
| 27 | Point | 28 | 695417.231 | 6519479.71782 |
| 28 | Point | 29 | 695423.256 | 6519056.742 |
| 29 | Point | 30 | 695427.625737 | 6519069.477526 |

1 (0 sur 282 sélectionnés)

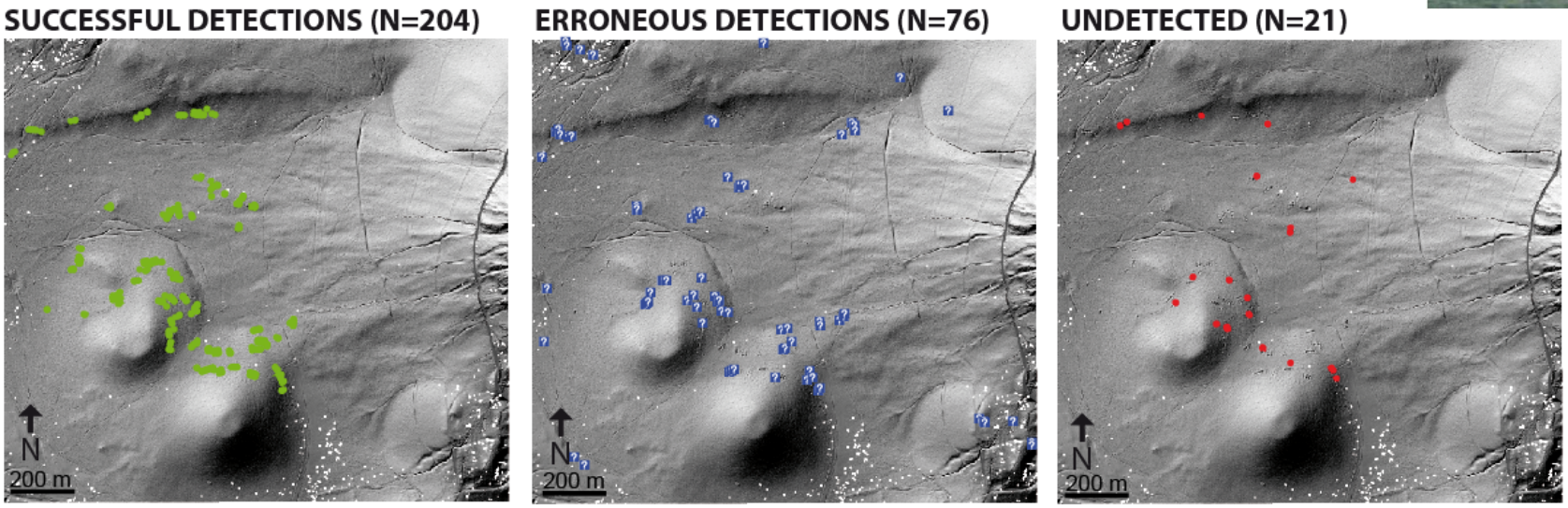
DETECTION_AUTO_JP

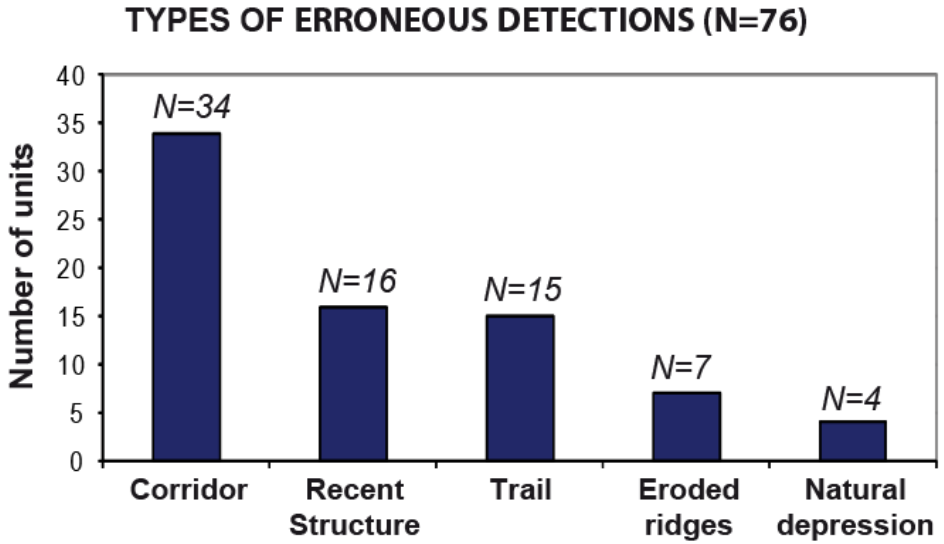
Total computation time : 276 s ( 4 min 36)

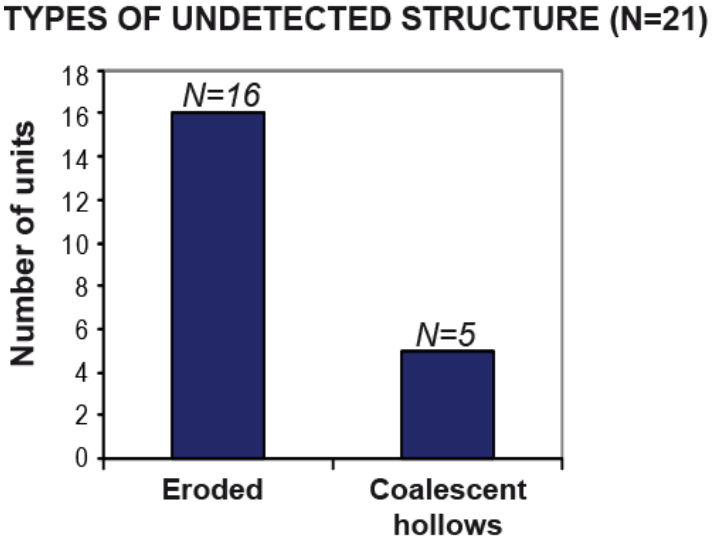
# Conclusion – Further research

Quantitative interpretation (only for the hollow part : elementary structure)

Expert detection : 225 structures (Results obtained by E. Roussel)



# Conclusion

- The efficiency of the automatic detection has been demonstrated.
- Only 9.3 % of the structure have been undetected, and 76 % of them correspond to eroded elements (some elements, very eroded and close to each other, have been detected as just one element).
- 94.7 % of erroneous detections correspond to other archaeological or anthropological features.

# Further research

- Improvement of the algorithm efficiency (less erroneous detection).

# Conclusion

- The efficiency of the automatic detection has been demonstrated.
- Only 9.3 % of the structure have been undetected, and 76 % of them correspond to eroded elements (some elements, very eroded and close to each other, have been detected as just one element).
- 94.7 % of erroneous detections correspond to other archaeological or anthropological features.

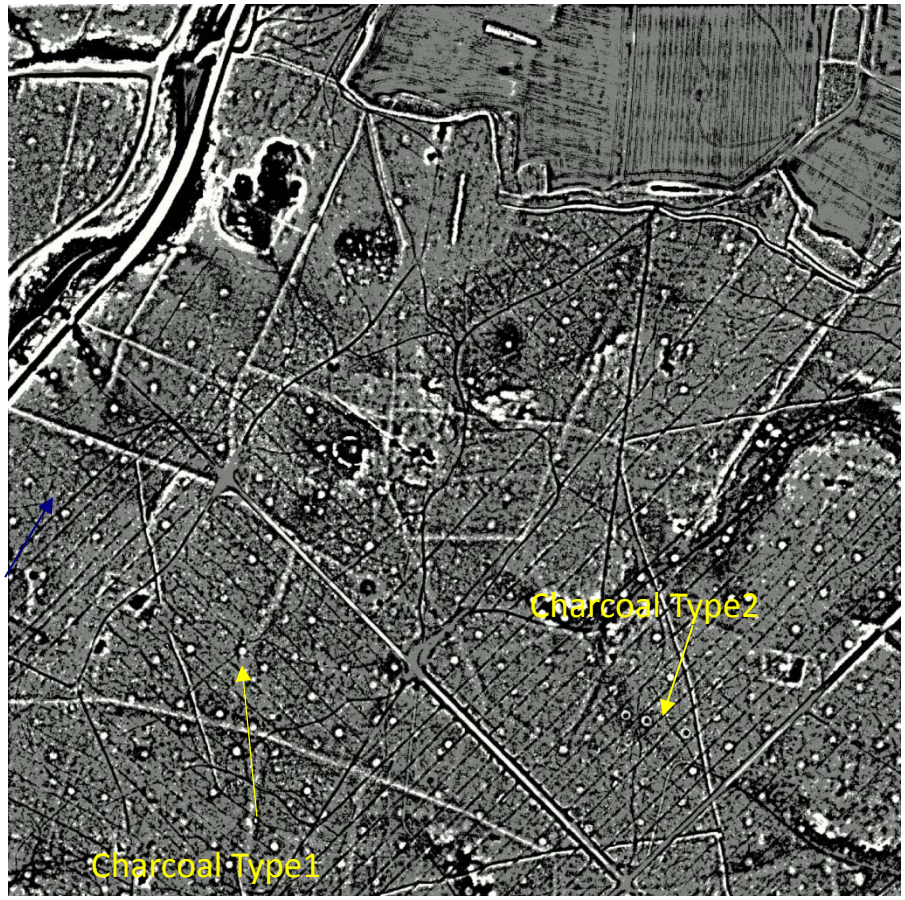
# Further research

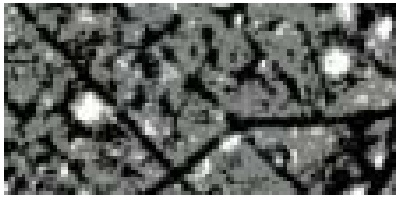
- Improvement of the algorithm efficiency (less erroneous detection).
- Application for other archaeological structures (example of charcoal kiln, easier to identify).

# Application for other archaeological structures (example of charcoal kiln, **Charente - France)**

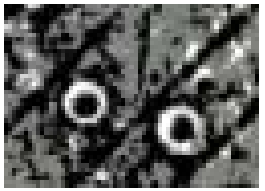
**Graziella Rassat, Rémi Crouzevialle, Fabien Cerbelaud**

DTM



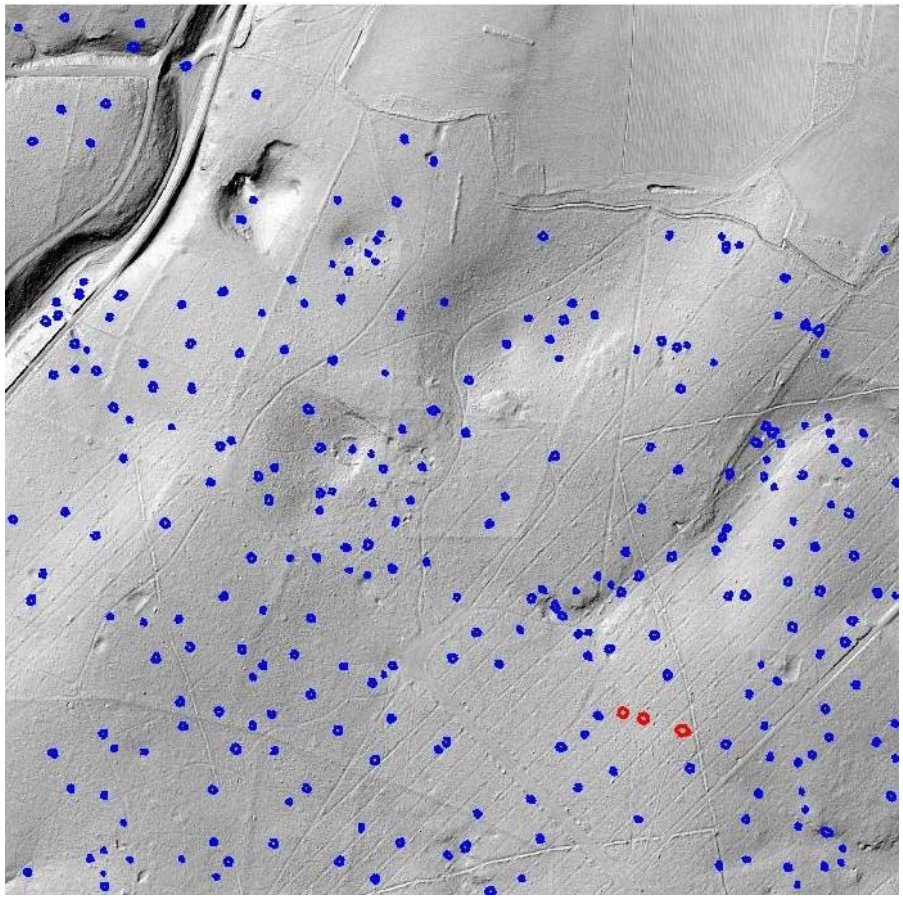



LRM

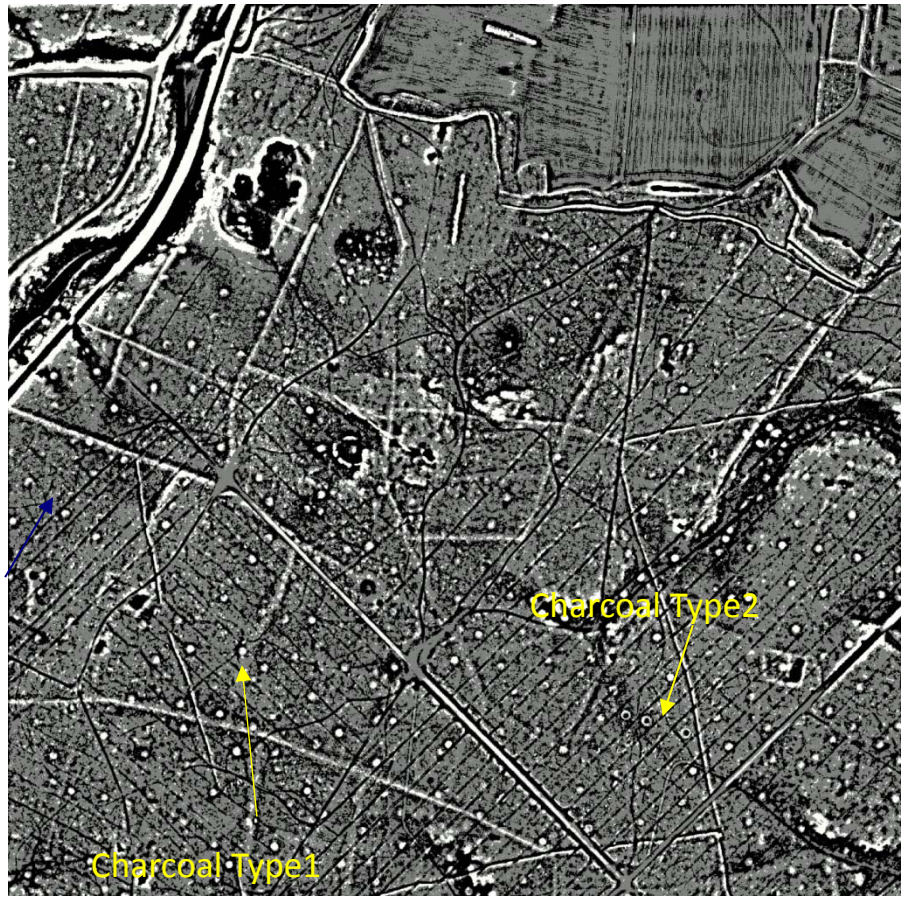


# Application for other archaeological structures (example of charcoal kiln, **Charente - France)**

**Graziella Rassat, Rémi Crouzevialle, Fabien Cerbelaud**



Results of automatic detection




LRM

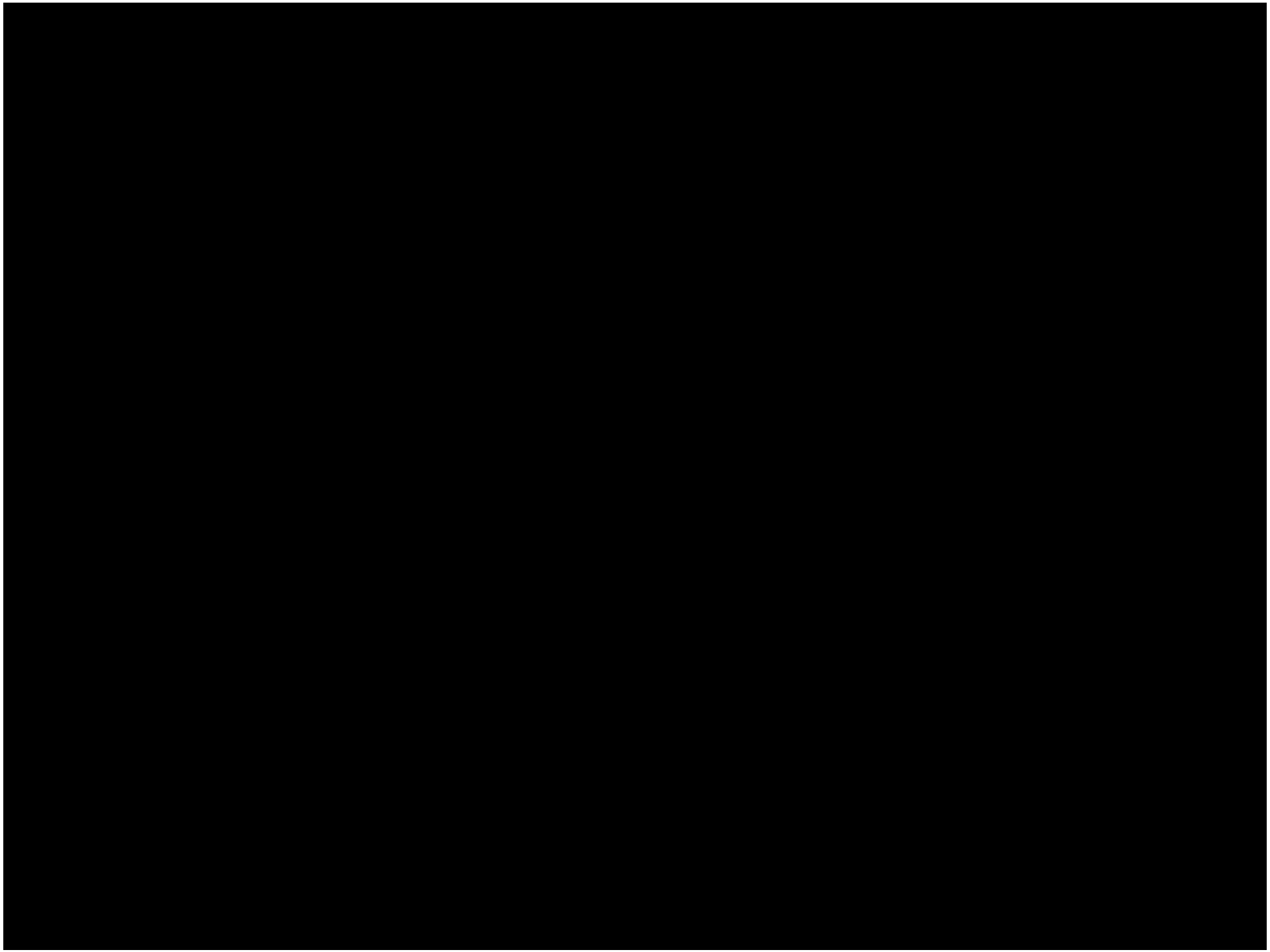
# Conclusion

- The efficiency of the automatic detection has been demonstrated.
- Only 9.3 % of the structure have been undetected, and 76 % of them correspond to eroded elements (some elements, very eroded and close to each other, have been detected as just one element).
- 94.7 % of erroneous detections correspond to other archaeological or anthropological features.

# Further research

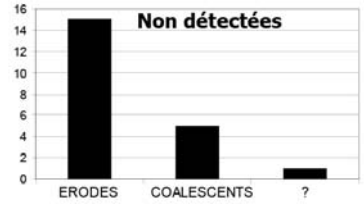
- Improvement of the algorithm efficiency (less erroneous detection).
- Application for other archaeological structures (example of charcoal kiln, easier to identify).
- Development of automatic detection and morphologic extraction directly from the 3D point cloud, and so with no modifications due to filtering and more precision.

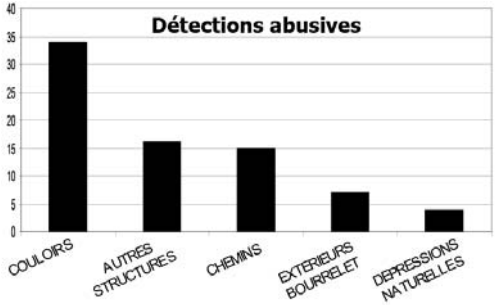
# Thank you very much for your attention !



## Vérification de la pertinence des données
## Détection et comptage des structures

Détection experte : 225
Détection automatique : 285

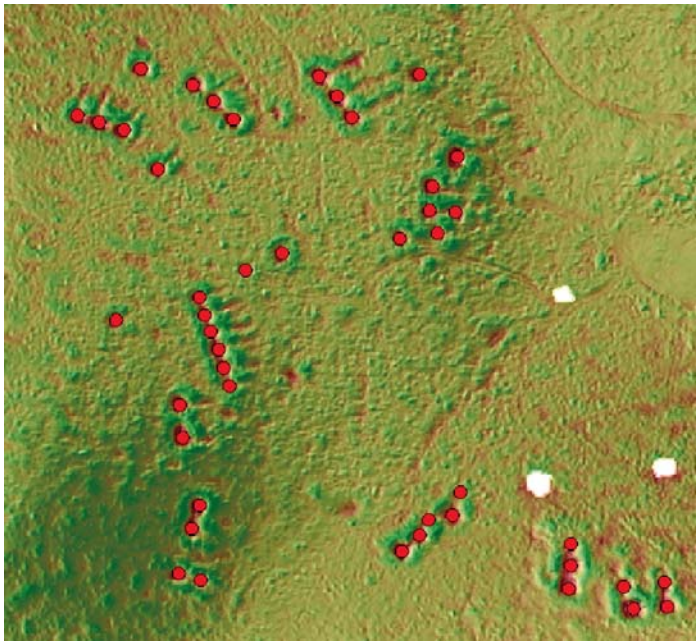


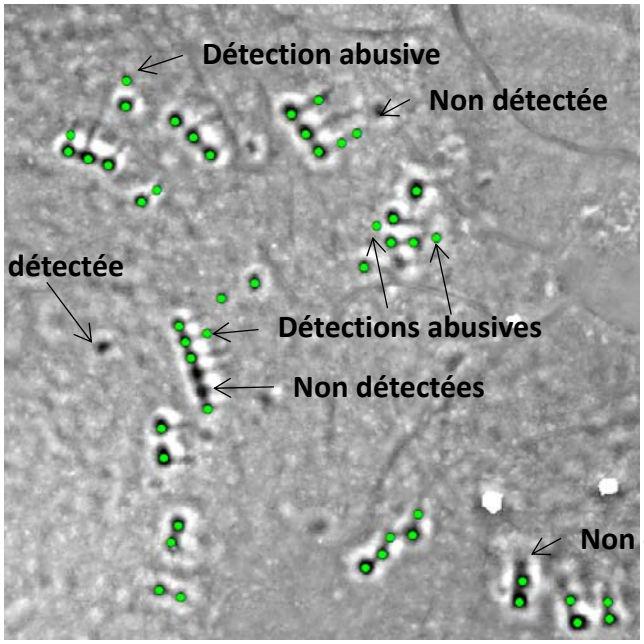




Parmi les **225** structures identifiées par expertise, **204 sont détectées automatiquement (Taux de succès : 91%)**

**Les non-détectées** (21) correspondent à des formes très érodées (15) ou coalescentes (5)

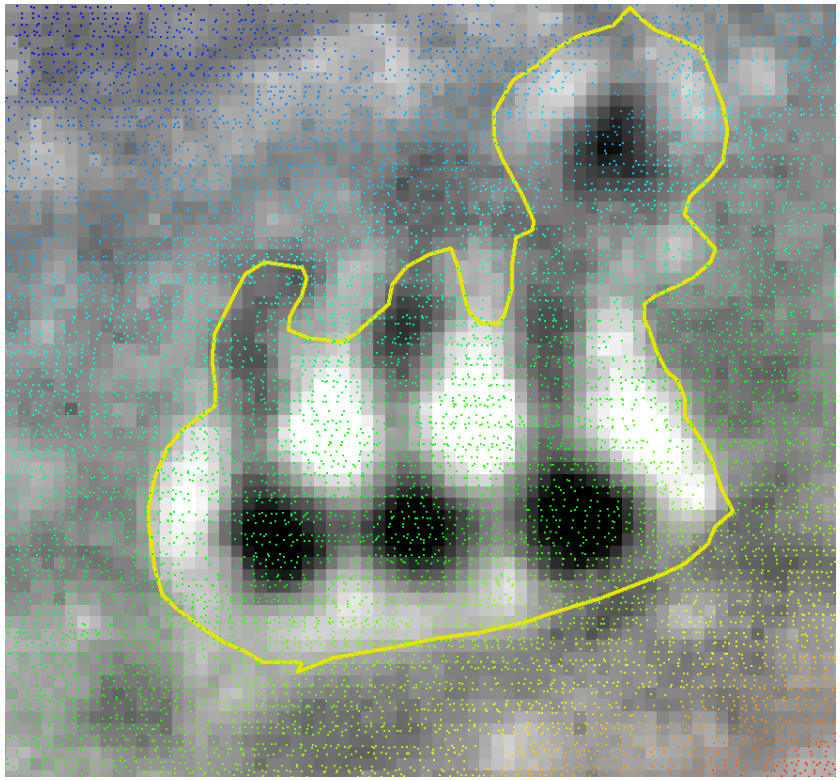
**Les détections abusives** (76) sont identifiées comme :
• des formes annexes aux cellules (couloirs d'accès : 34) ou dérivées (dépressions périphériques : 6)
• d'autres structures anthropiques non caractérisées (16), des tronçons de chemin (15)
• des dépressions naturelles (4)



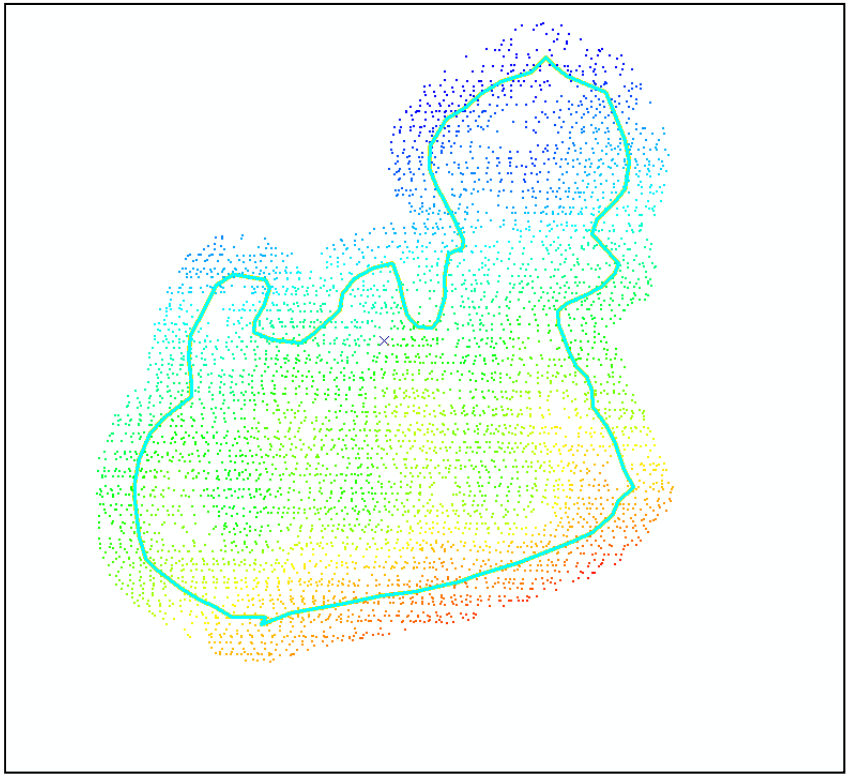


Utilisation des polygones de contour automatisé pour revenir aux données sources (nuage de points LiDAR)

Superposition de la couche polygone automatisé sur le nuage de points Lidar

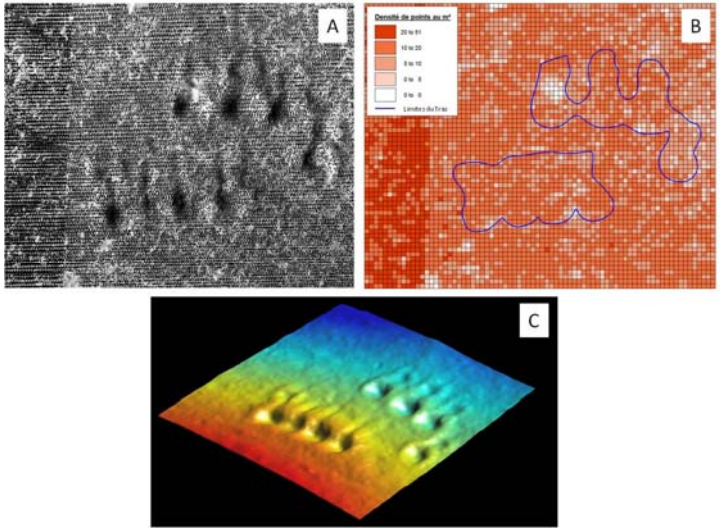


Sélection des points LiDAR à l'intérieur du polygone (zone tampon de 2 m)

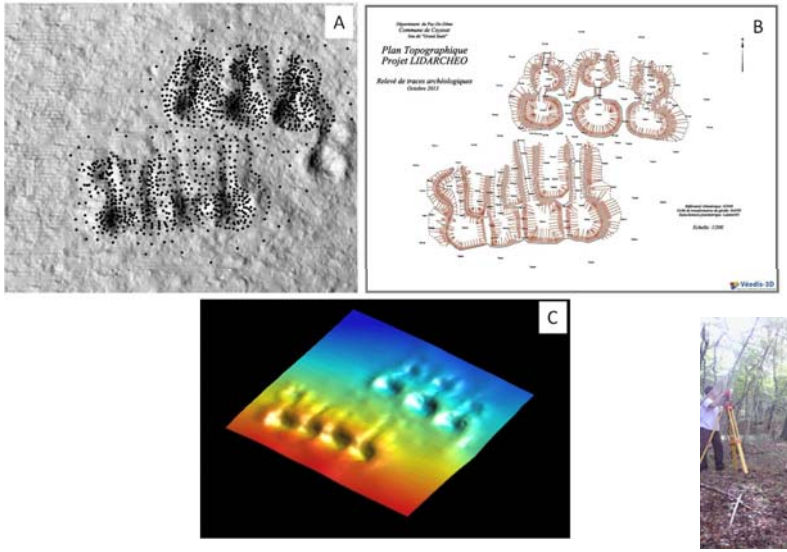


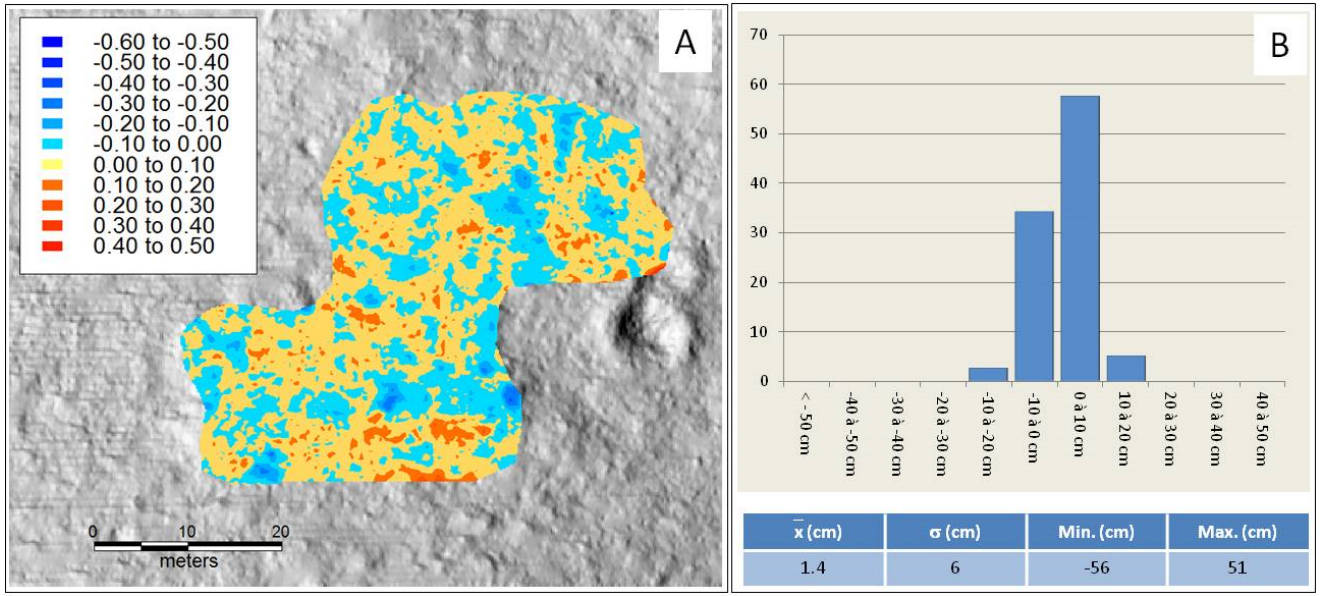
# Phase 1 : vérification de la qualité des données sol

## MNT issu du LiDAR




## MNT issu d'un levé terrain



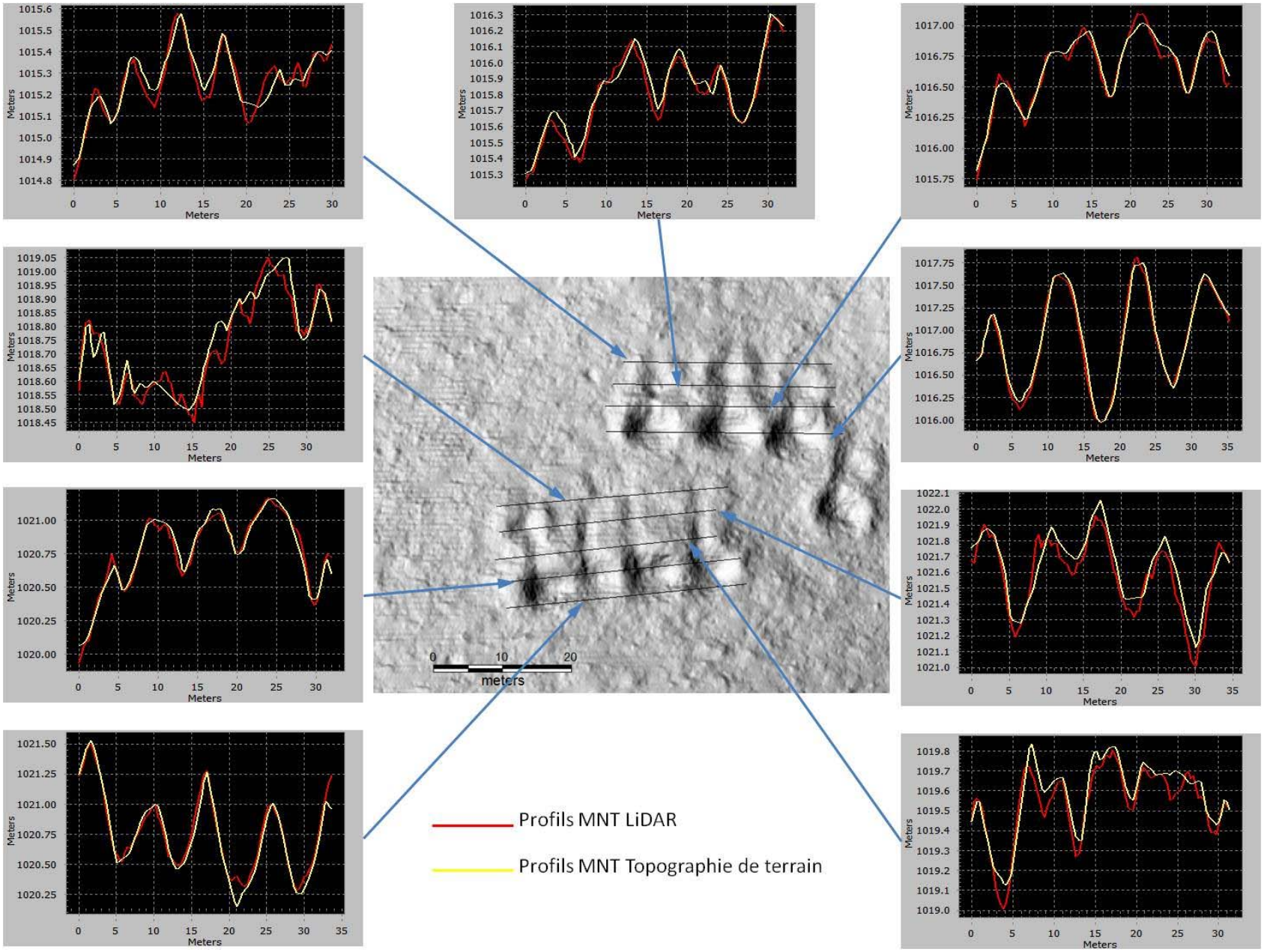







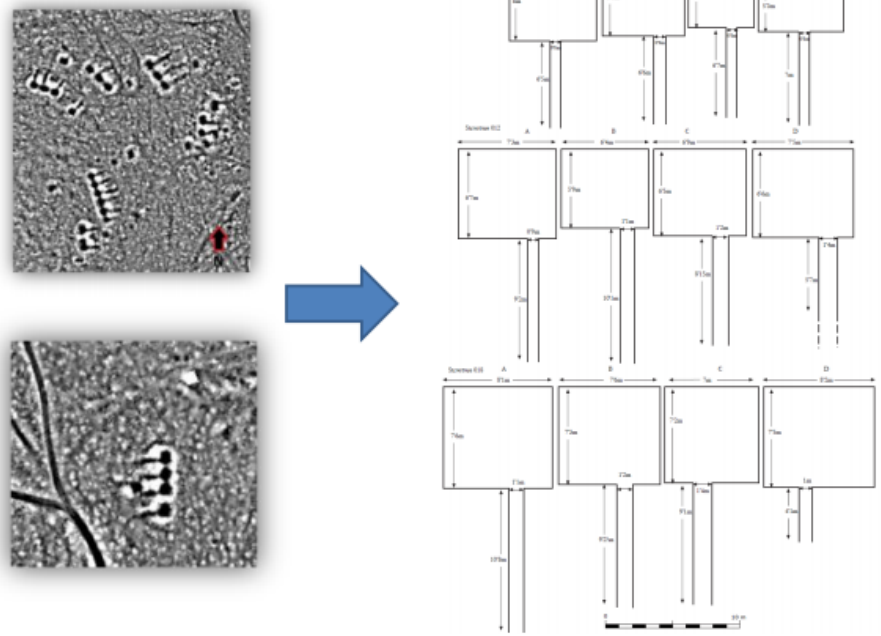
| $\bar{x}$ (cm) | σ (cm) | Min. (cm) | Max. (cm) |
|---|---|---|---|
| 1.4 | 6 | -56 | 51 |

# Phase 1 : vérification de la qualité des données sol



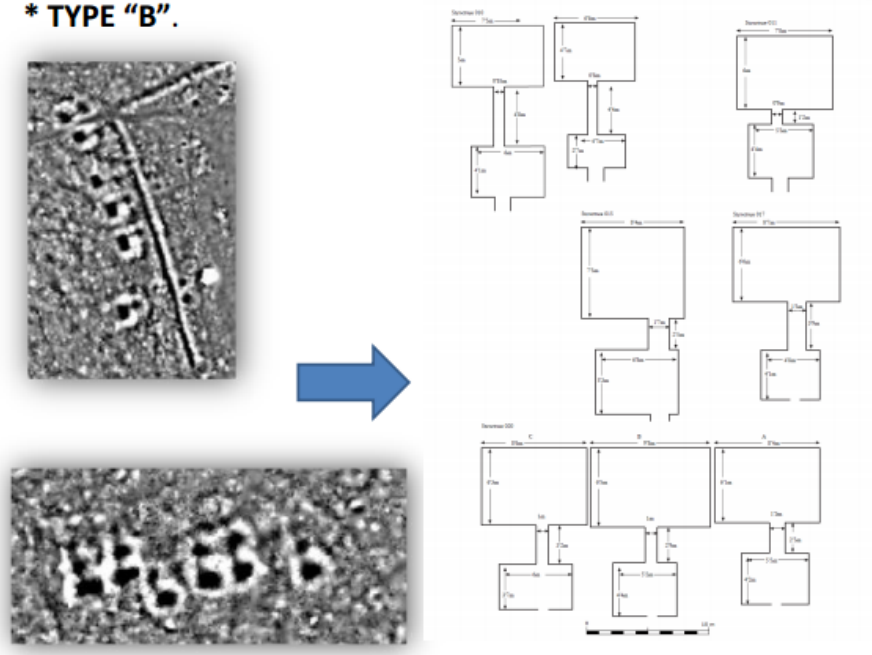
**Archaeomorphological analysis has allowed us to establish different types of agro-pastoral structures that have then been verified by archaeological surveys. 2 main morphological types have been identified**, based on different structural features that could be associated with **different typologies, functionalities and / or chronologies.**

*** TYPE "A".**



**Type "A" is characterized by the alignment of multiple units comprising a rectangular or square room connected to a long and narrow access corridor.** These structures are hollowed in the ground. The average measures of the rooms are 6'5/7 m (W) x 5'5/6'5 m (L) and 1'5 m (W) x 9 m (L) for the corridors.

*** TYPE "B".**

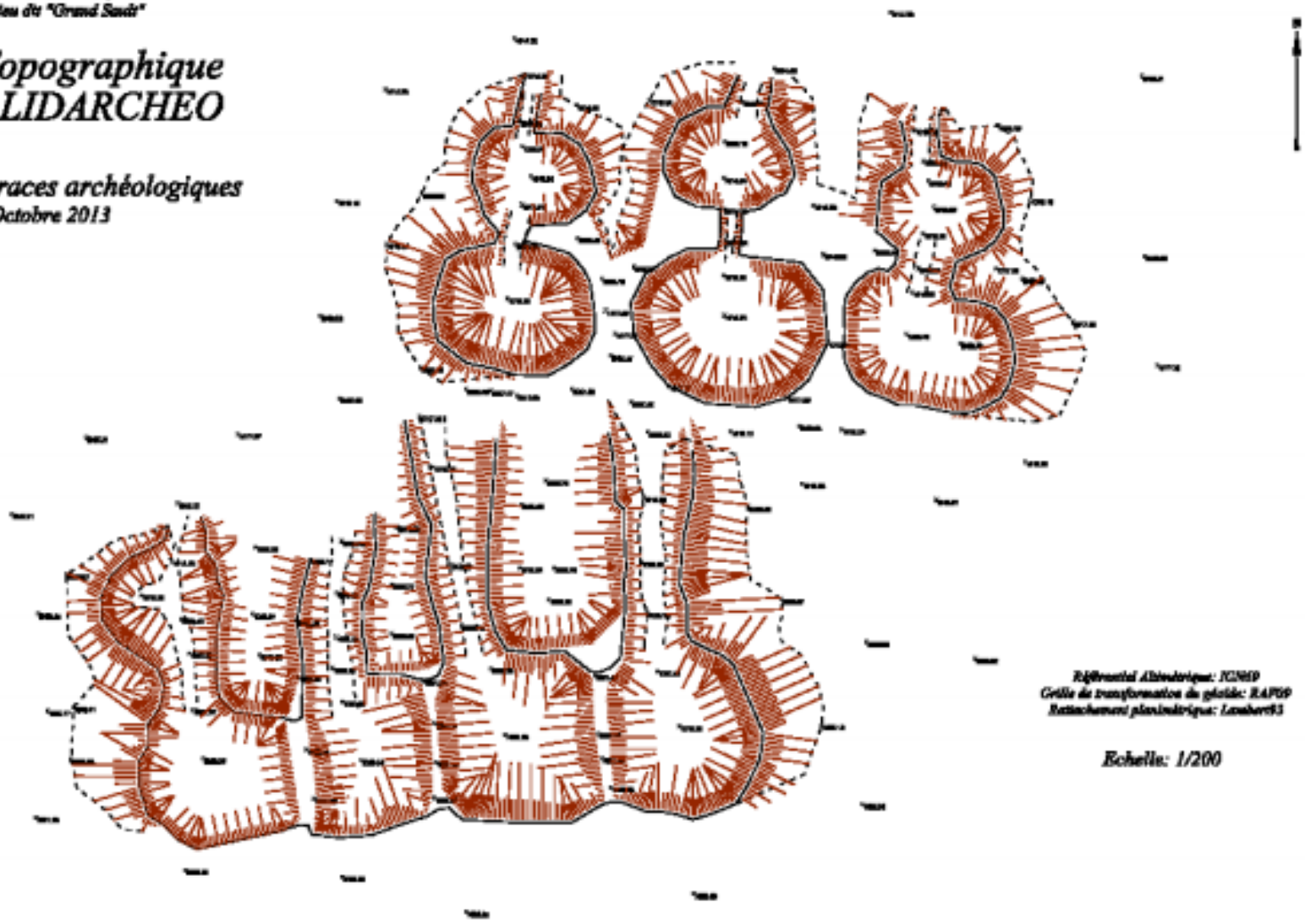


**Type "B" is characterized by structures with two rooms: one room of smaller dimensions which gives access to a second larger room across a short hallway or access space.** These structures are mainly located in single format and rarely in groups. Measuring averages are: 6'5 (W) x 5'5 (L) for the big room; 4'5/5'% (W) x 4 (L) for the small room; and 1'40 (W) x 2 (L) for the hallway. These structures are also hollowed in the ground.

Département du Puy-De-Dôme
Commune de Ceyssat
lieu dit "Grand Sault"

# Plan Topographique
# Projet LIDARCHEO

## Relevé de traces archéologiques
Octobre 2013



Référentiel Altimétrique: IGN69
Grille de transformation du géoïde: RAF09
Rattachement planimétrique: Lambert93

Echelle: 1/200