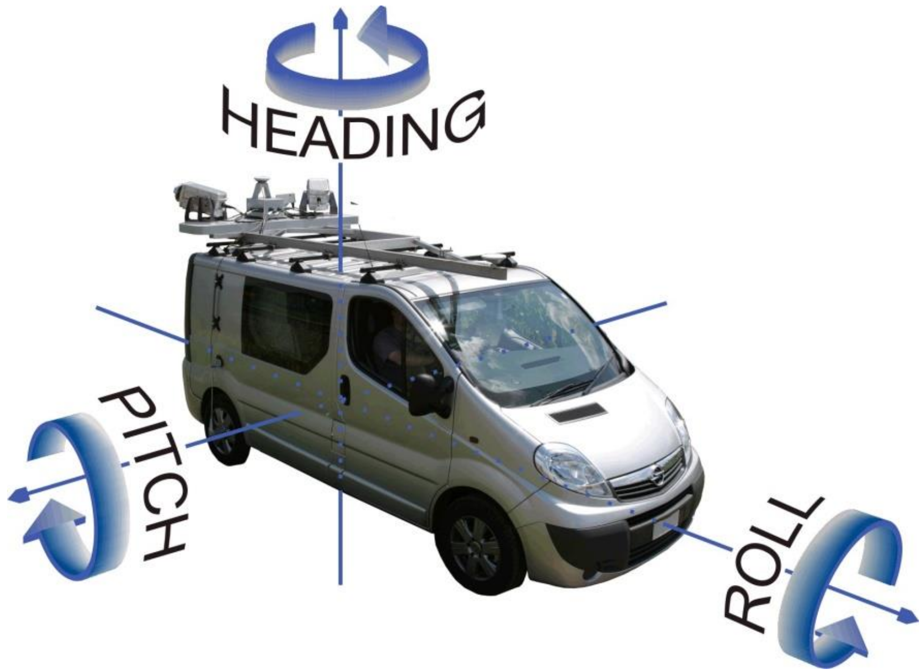
PLS and GPR

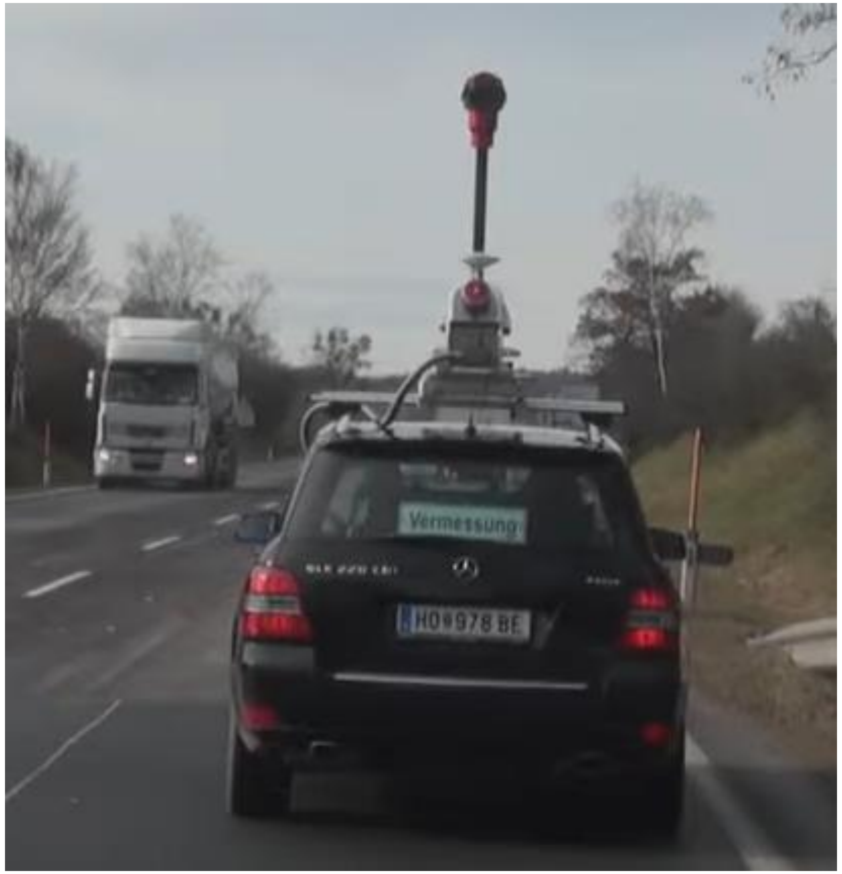
e) Mobile mapping system, MMS

	With GNSS signal	1 minute without GNSS signal
X,Y (m)	0.020	0.100
Z (m)	0.050	0.120
Tilt (°)	0.005	0.020
Rolling (°)	0.020	0.020

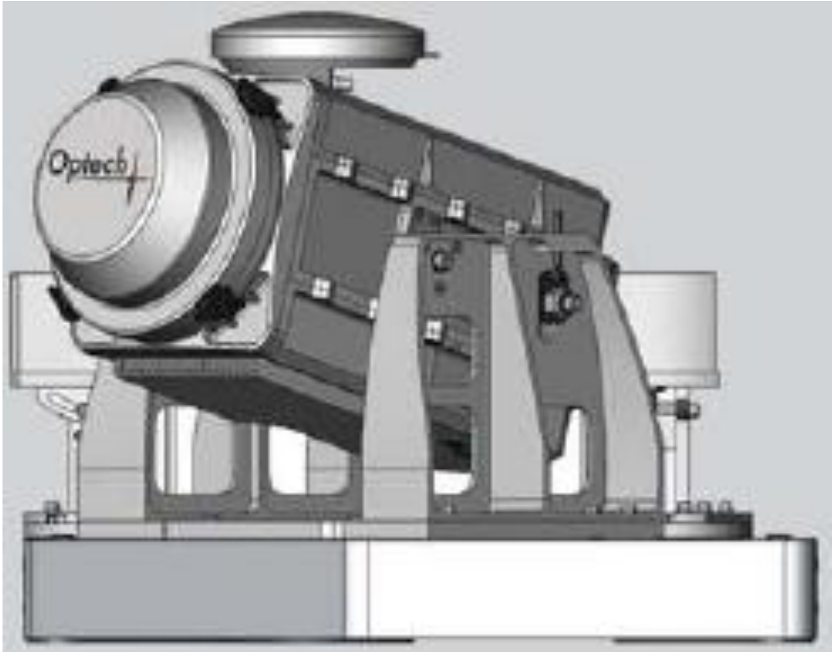


Applanix POSLV 4202 Trimble Zephyr GNSS receivers, DMI (Distance Measuring Indicator), IMU (Inertial Measuring Unit, gyroscopes + accelerometers)

New technologies:
mobile mapping devices- carried by a person, on a car or other vehicle



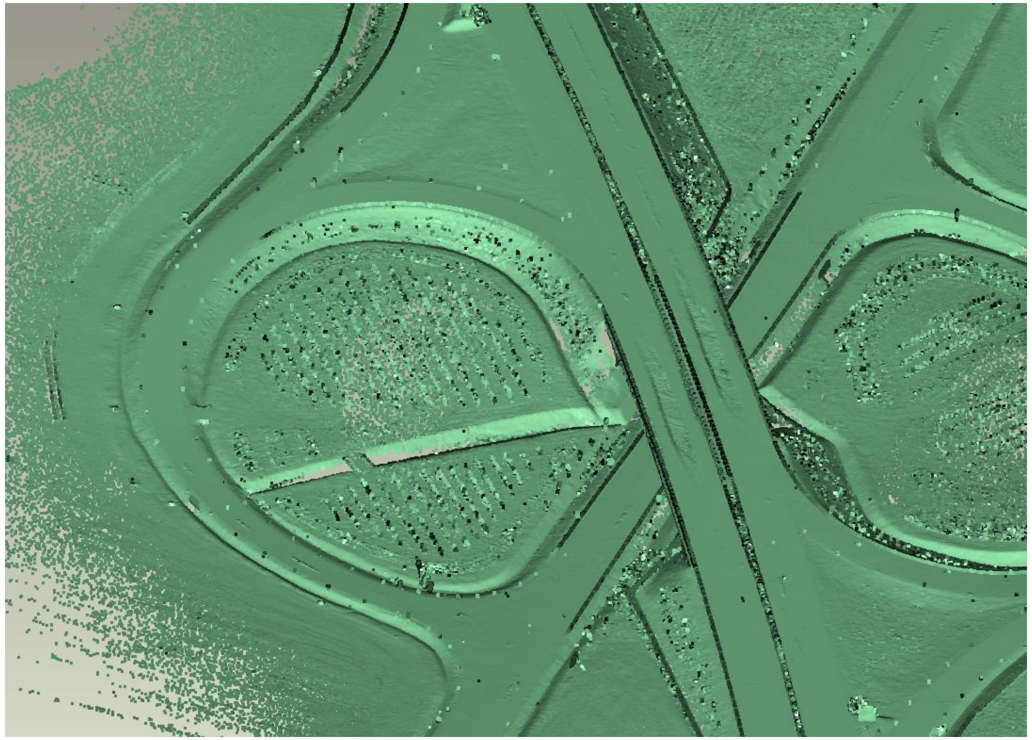
MMS

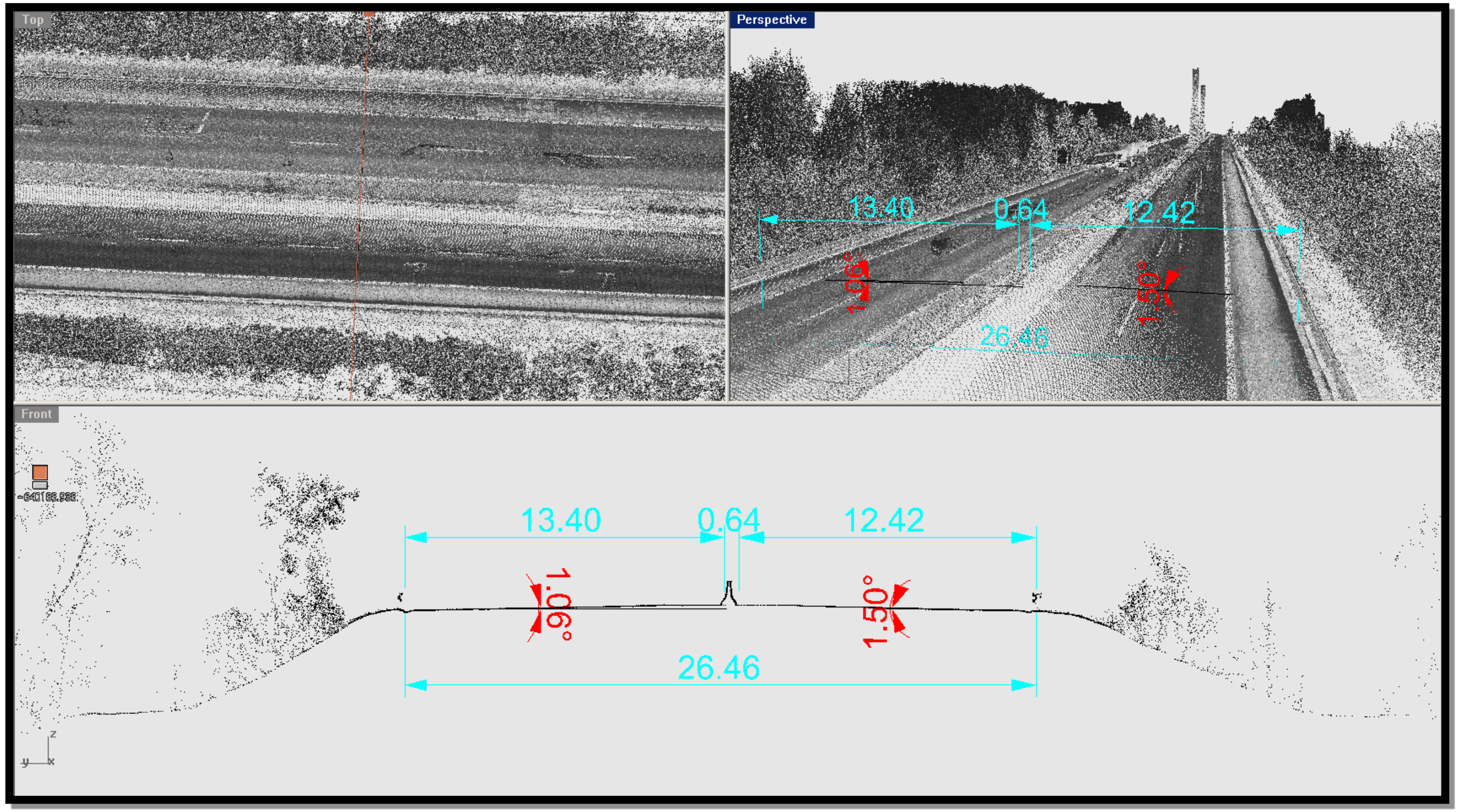


System LYNX, 2010

Sample data - absolute accuracy of points +/- 5 cm (Geovap Pardubice)

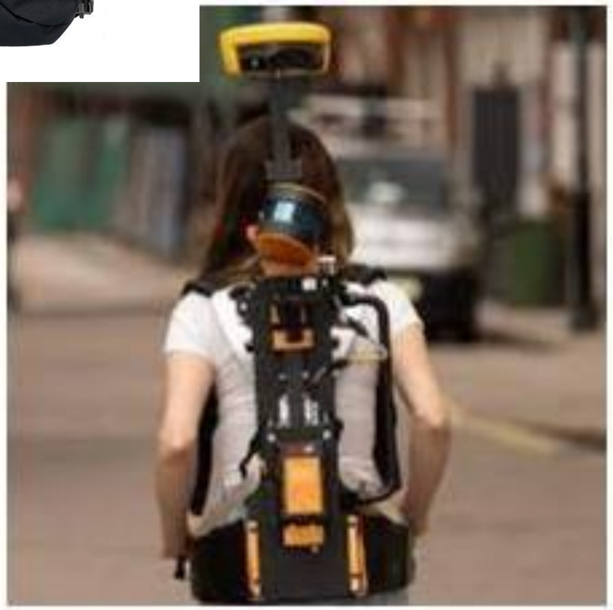
Mobile mapping system (MMS)

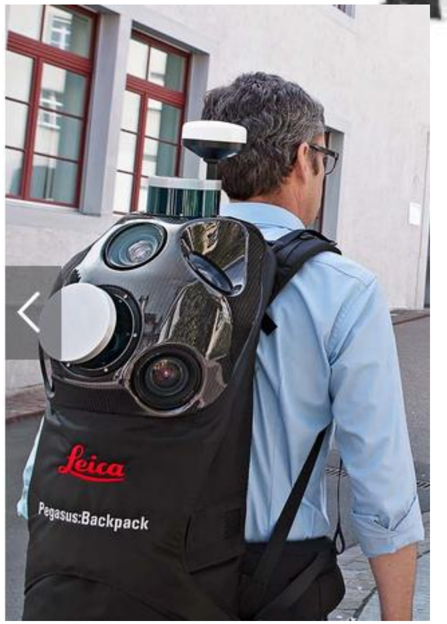




Personal laser system, PLS

PLS backpack





PLS – hand-held

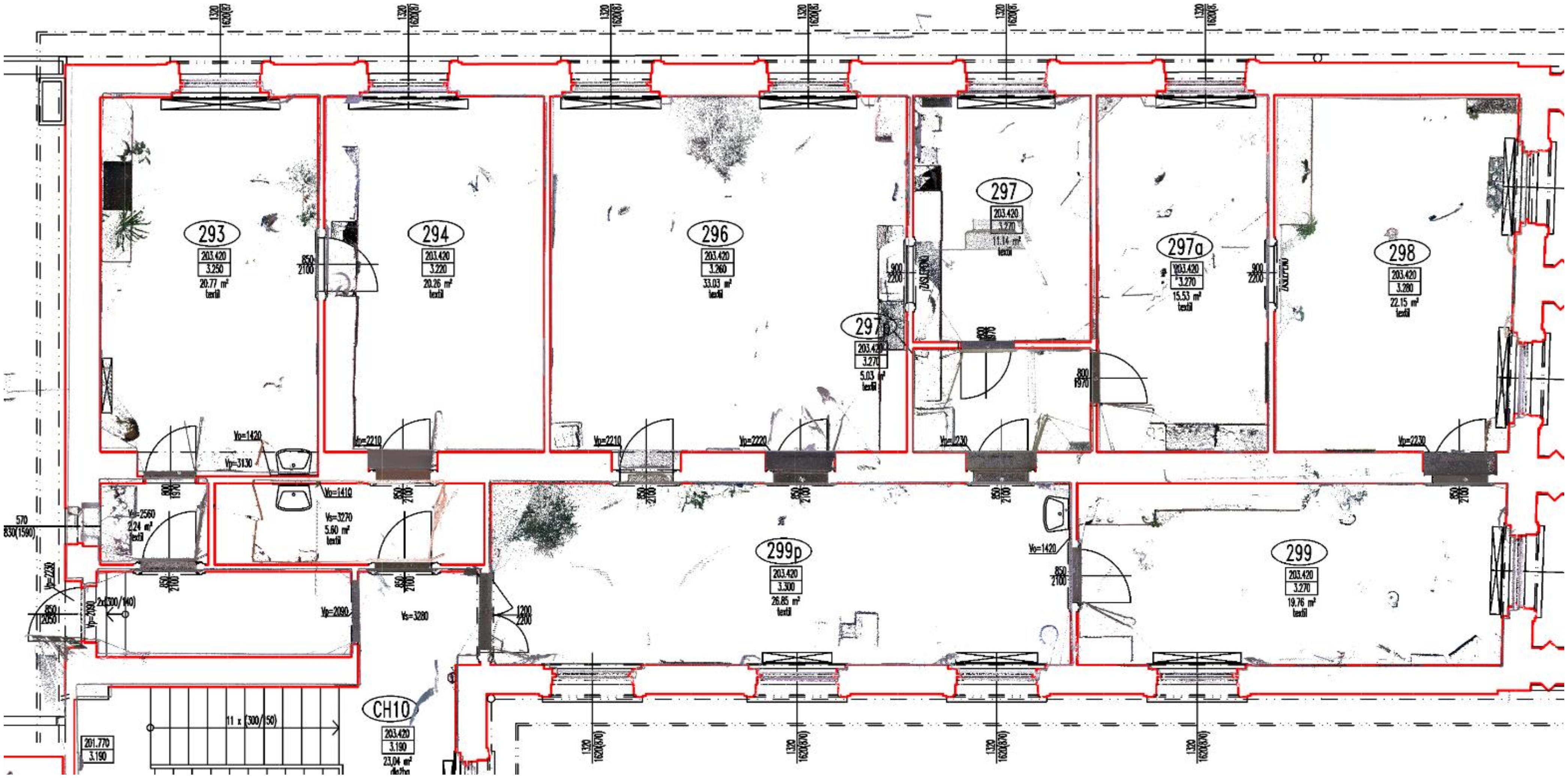
laser backpack, 2010

A portable, laser backpack for 3-D mapping has been developed at the University of California, Berkeley where it is being hailed as a breakthrough technology capable of producing fast, automatic and realistic 3-D mapping of even difficult interior environments. Credit: Credit: John Kua, University of California, Berkeley

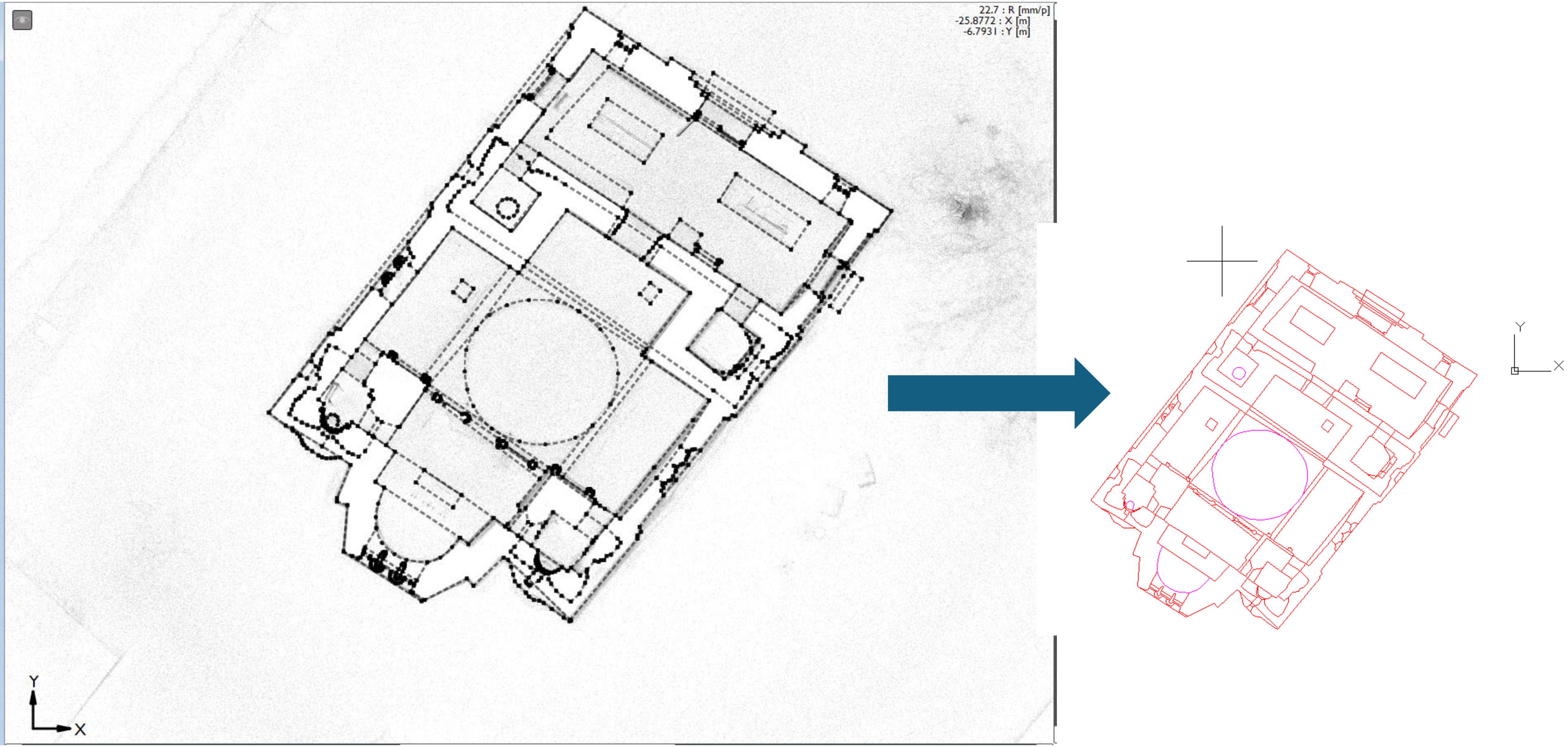
Leica BLK2GO, 2020

- SLAM technology
- Handheld
- Light and very fast
- Range (0.5 m—25 m)

- Operated via mobile app BLK2GO live app
  - Only for trajectory checking



293
203.420
3.250
20.77 m²
textil
294
203.420
3.220
20.26 m²
textil
296
203.420
3.260
33.03 m²
textil
297
203.420
3.270
11.14 m²
textil
297a
203.420
3.270
15.53 m²
textil
298
203.420
3.280
22.15 m²
textil
299p
203.420
3.300
26.85 m²
textil
299
203.420
3.270
19.76 m²
textil
CH10
203.420
3.190
23.04 m²
dlažba
201.770
3.190
11 x (300/150)
2.24 m²
textil
5.60 m²
textil
Vs=3270
Vs=2560
Vs=3280
Vp=1420
Vp=3130
Vp=1410
Vp=2210
Vp=2220
Vp=2230
Vp=2090
Vo=1420


22.7 : R [mm/p]
-25.8772 : X [m]
-6.7931 : Y [m]
Y
X
Y
X

Faro orbis

New trend: low-cost technology and istruments:

Videophotogrammetry or smart-phone photogrammetry

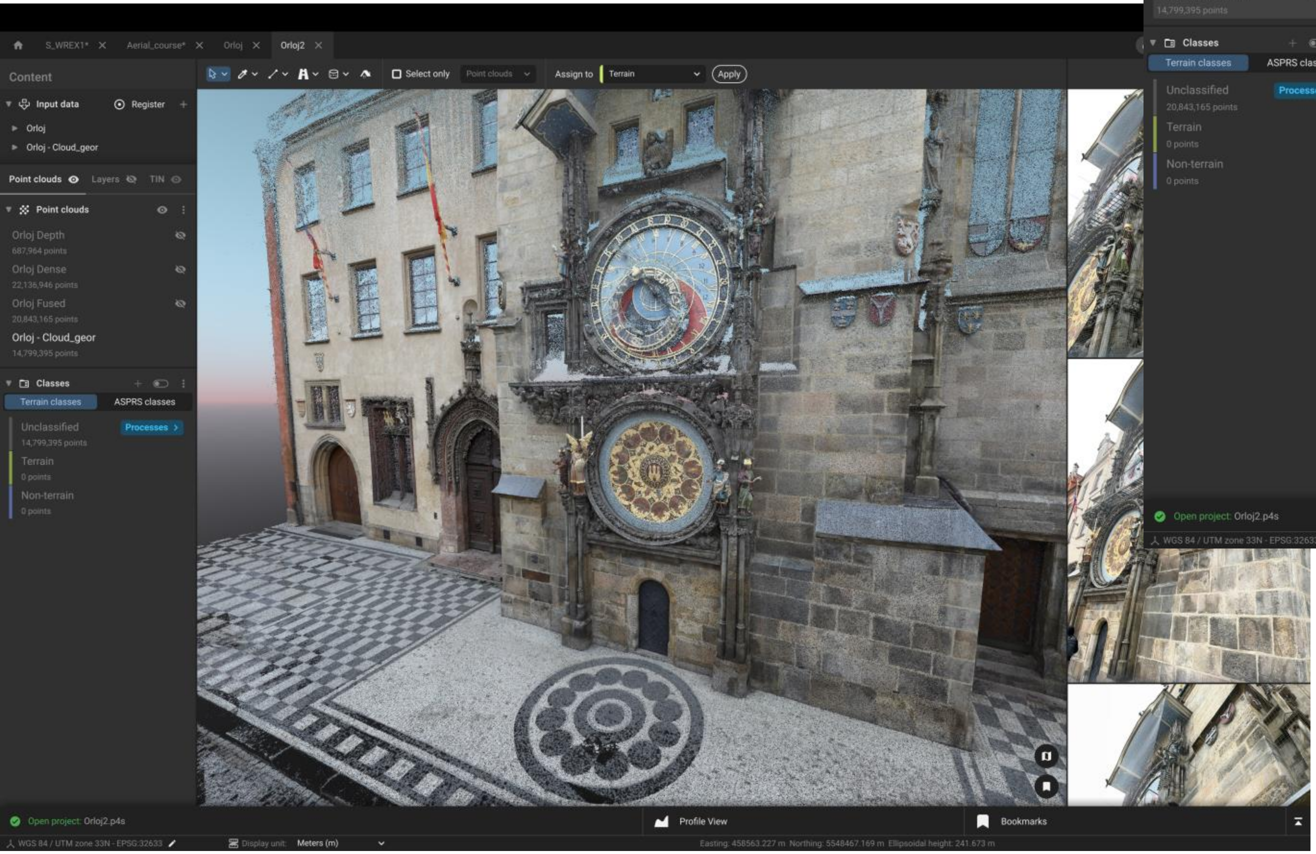
Smart phones with GNSS RTK device - ideal with lidar sensor

PIX4D

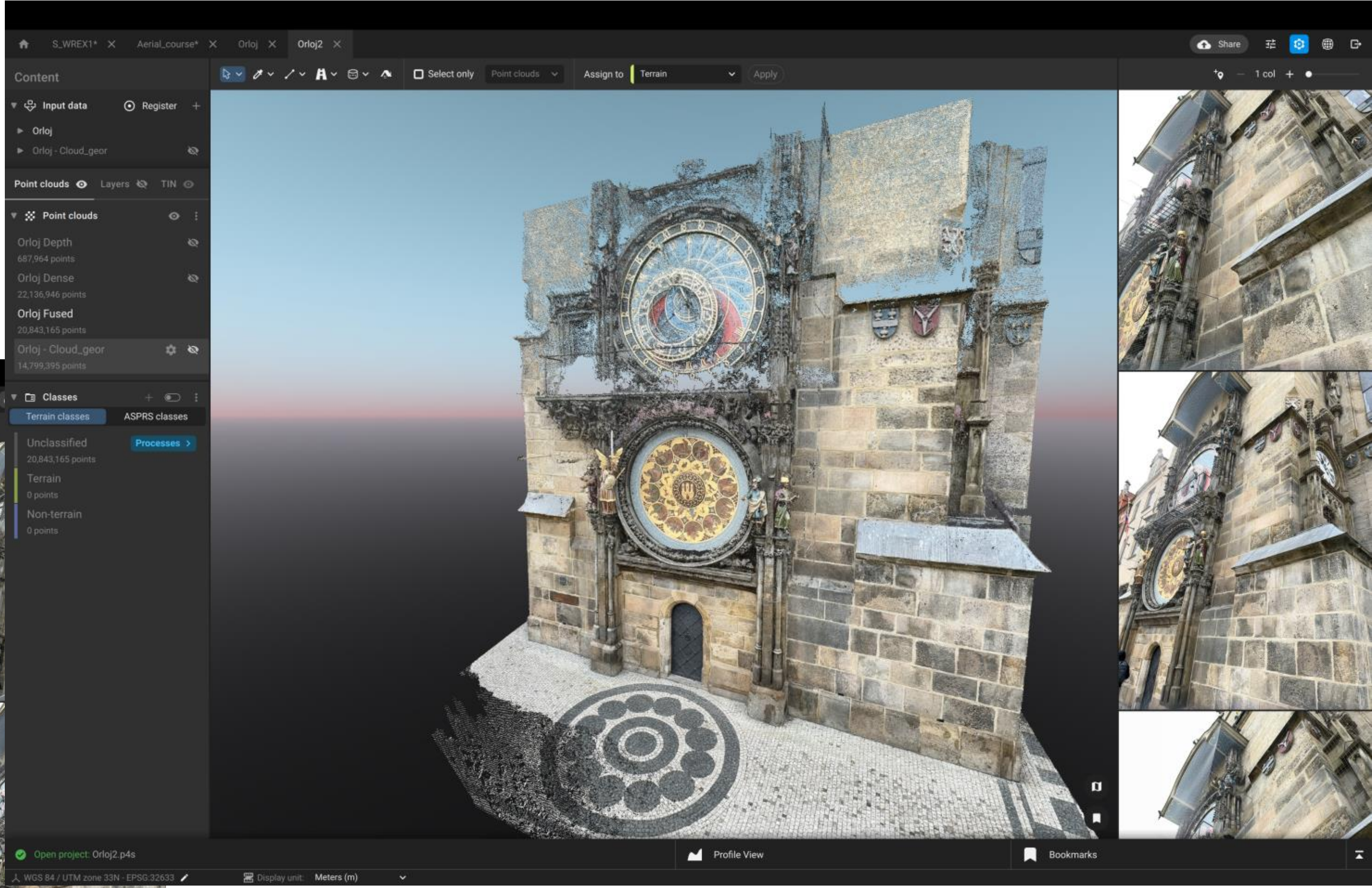
The viDoc RTK rover for PIX4Dcatch is specially designed for accurately capturing 3D spaces from the ground with selected iOS devices equipped **with LiDAR sensors**, but also works with other selected models, including Android devices.

The viDoc RTK rover with PIX4Dcat

Faro

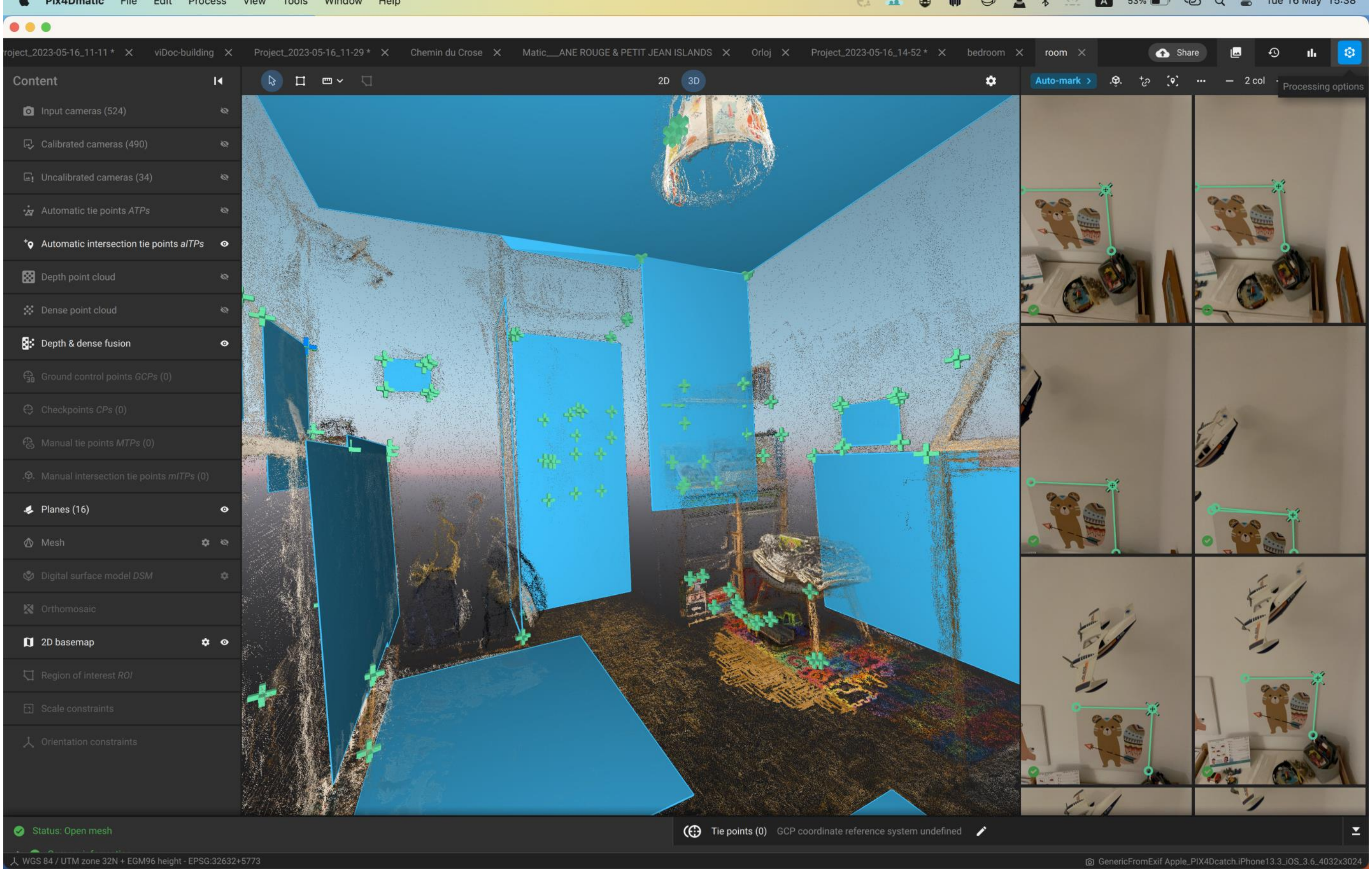


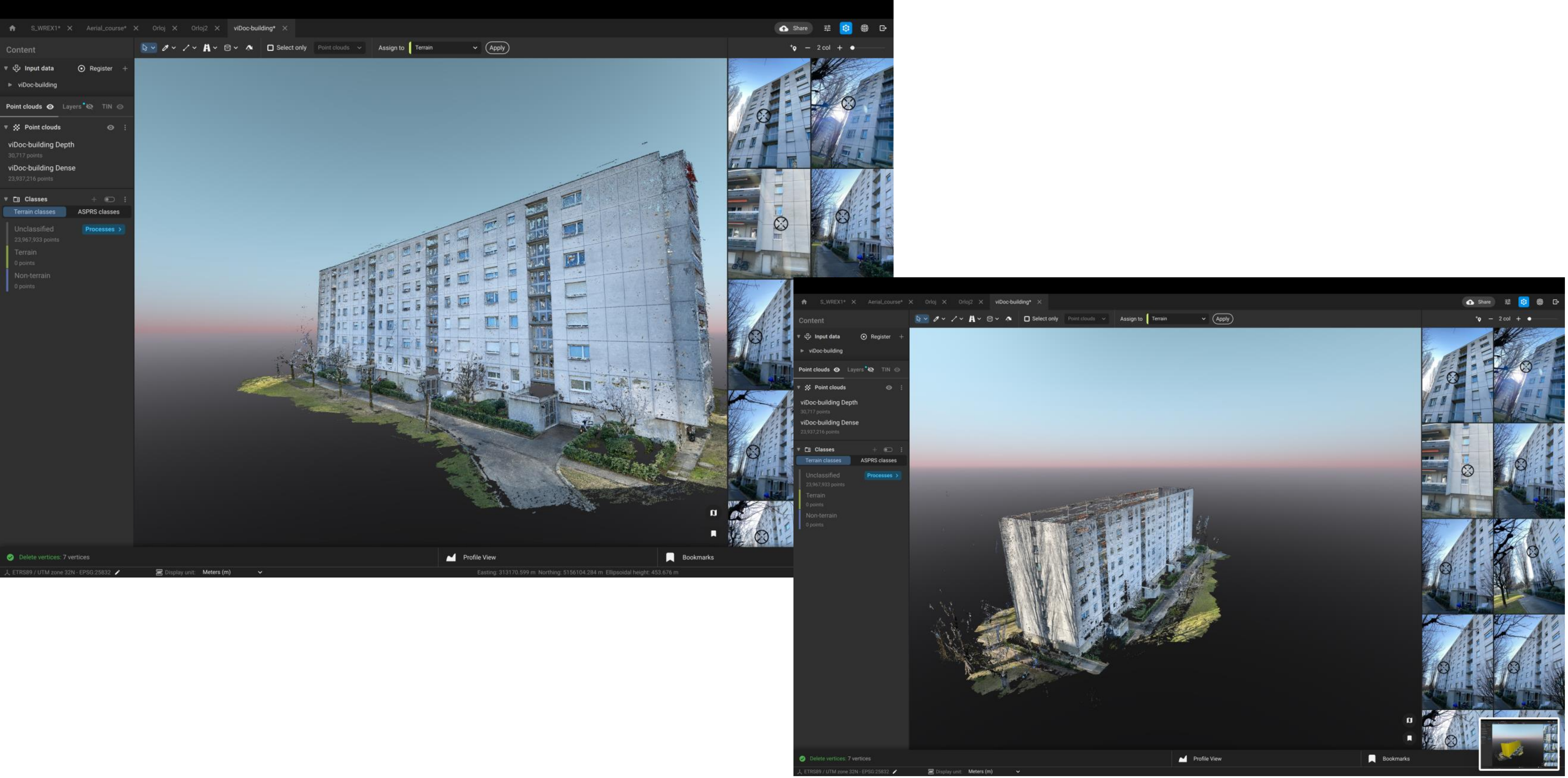
S_WREX1*
Aerial_course*
Orloj
Orloj2
Select only
Point clouds
Assign to
Terrain
Apply
Content
Input data
Register
Orloj
Orloj - Cloud_geor
Point clouds
Layers
TIN
Point clouds
Orloj Depth
687,964 points
Orloj Dense
22,136,946 points
Orloj Fused
20,843,165 points
Orloj - Cloud_geor
14,799,395 points
Classes
Terrain classes
ASPRS classes
Unclassified
Processes
14,799,395 points
Terrain
0 points
Non-terrain
0 points
Open project: Orloj2.p4s
Profile View
Bookmarks
WGS 84 / UTM zone 33N - EPSG:32633
Display unit:
Meters (m)
Easting: 458563.227 m Northing: 5548467.169 m Ellipsoidal height: 241.673 m

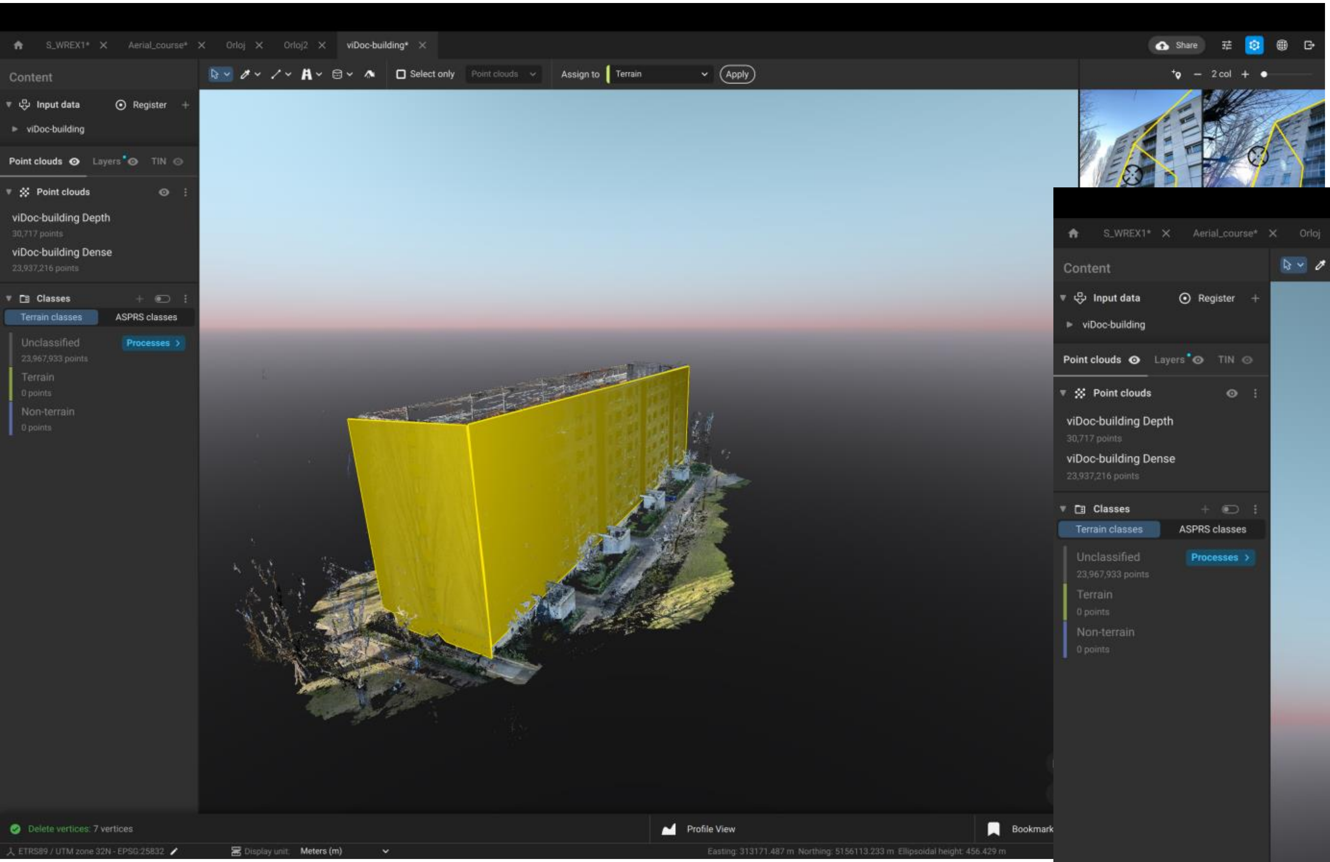


S_WREX1*
Aerial_course*
Orloj
Orloj2
Share
Content
Select only
Point clouds
Assign to
Terrain
Apply
1 col
Input data
Register
Orloj
Orloj - Cloud_geor
Point clouds
Layers
TIN
Point clouds
Orloj Depth
687,964 points
Orloj Dense
22,136,946 points
Orloj Fused
20,843,165 points
Orloj - Cloud_geor
14,799,395 points
Classes
Terrain classes
ASPRS classes
Unclassified
Processes
20,843,165 points
Terrain
0 points
Non-terrain
0 points
Open project: Orloj2.p4s
Profile View
Bookmarks
WGS 84 / UTM zone 33N - EPSG:32633
Display unit:
Meters (m)

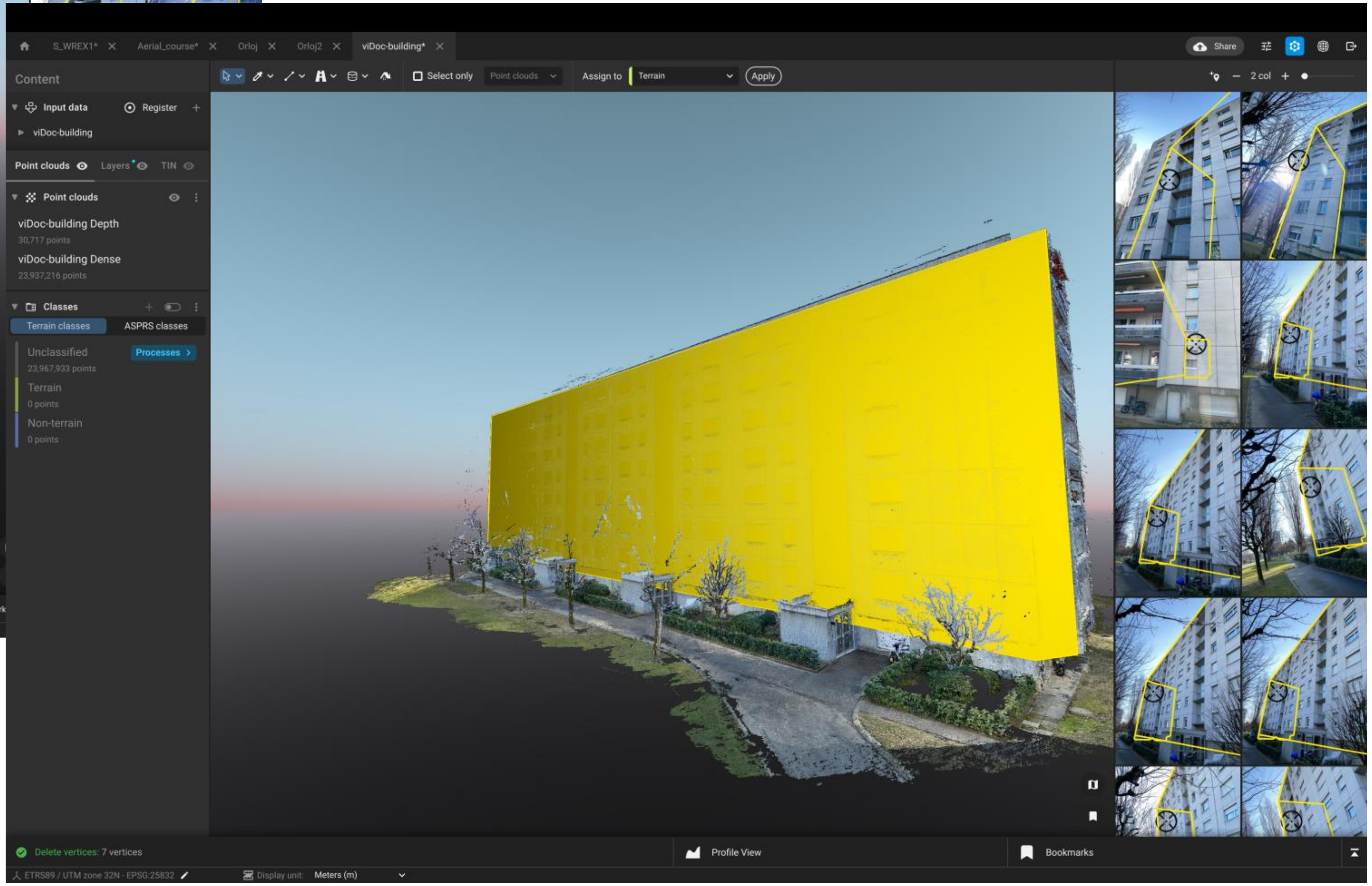
viDOC


File
Edit
Process
View
Tools
Window
Help
roject_2023-05-16_11-11 *
viDoc-building
Project_2023-05-16_11-29 *
Chemin du Crose
Matic__ANE ROUGE & PETIT JEAN ISLANDS
Orloj
Project_2023-05-16_14-52 *
bedroom
room
Share
Content
2D
3D
Auto-mark
2 col
Processing options
Input cameras (524)
Calibrated cameras (490)
Uncalibrated cameras (34)
Automatic tie points ATPs
Automatic intersection tie points aITPs
Depth point cloud
Dense point cloud
Depth & dense fusion
Ground control points GCPs (0)
Checkpoints CPs (0)
Manual tie points MTPs (0)
Manual intersection tie points mITPs (0)
Planes (16)
Mesh
Digital surface model DSM
Orthomosaic
2D basemap
Region of interest ROI
Scale constraints
Orientation constraints
Status: Open mesh
Tie points (0)
GCP coordinate reference system undefined
WGS 84 / UTM zone 32N + EGM96 height - EPSG:32632+5773
GenericFromExif Apple_PIX4Dcatch.iPhone13.3_iOS_3.6_4032x3024


S_WREX1*
Aerial_course*
Orloj
Orloj2
viDoc-building*
Share
Select only
Point clouds
Assign to
Terrain
Apply
2 col
Content
Input data
Register
viDoc-building
Point clouds
Layers
TIN
Point clouds
viDoc-building Depth
30,717 points
viDoc-building Dense
23,937,216 points
Classes
Terrain classes
ASPRS classes
Unclassified
23,967,933 points
Processes
Terrain
0 points
Non-terrain
0 points
Delete vertices: 7 vertices
Profile View
Bookmarks
ETRS89 / UTM zone 32N - EPSG:25832
Display unit:
Meters (m)
Easting: 313170.599 m Northing: 5156104.284 m Ellipsoidal height: 453.676 m



S_WREX1*
Aerial_course*
Orloj
Orloj2
viDoc-building*
Share
Content
Select only
Point clouds
Assign to
Terrain
Apply
2 col
Input data
Register
viDoc-building
Point clouds
Layers
TIN
viDoc-building Depth
30,717 points
viDoc-building Dense
23,937,216 points
Classes
Terrain classes
ASPRS classes
Unclassified
23,967,933 points
Processes
Terrain
0 points
Non-terrain
0 points
Delete vertices: 7 vertices
Profile View
ETRS89 / UTM zone 32N - EPSG:25832
Display unit:
Meters (m)
Easting: 313171.487 m Northing: 5156113.233 m Ellipsoidal height: 456.429 m

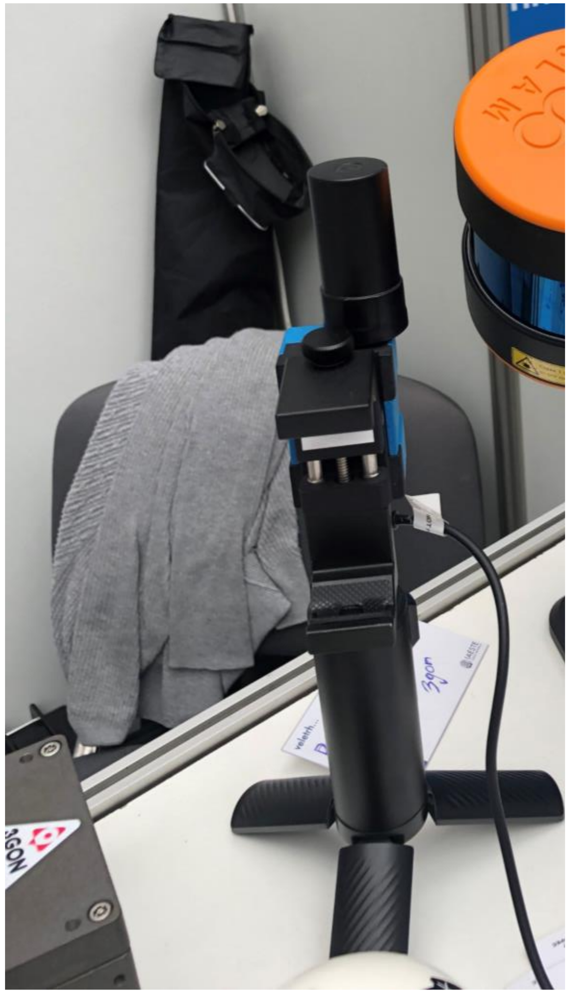


S_WREX1*
Aerial_course*
Orloj
Orloj2
viDoc-building*
Share
Content
Select only
Point clouds
Assign to
Terrain
Apply
2 col
Input data
Register
viDoc-building
Point clouds
Layers
TIN
viDoc-building Depth
30,717 points
viDoc-building Dense
23,937,216 points
Classes
Terrain classes
ASPRS classes
Unclassified
23,967,933 points
Processes
Terrain
0 points
Non-terrain
0 points
Delete vertices: 7 vertices
Profile View
Bookmarks
ETRS89 / UTM zone 32N - EPSG:25832
Display unit:
Meters (m)

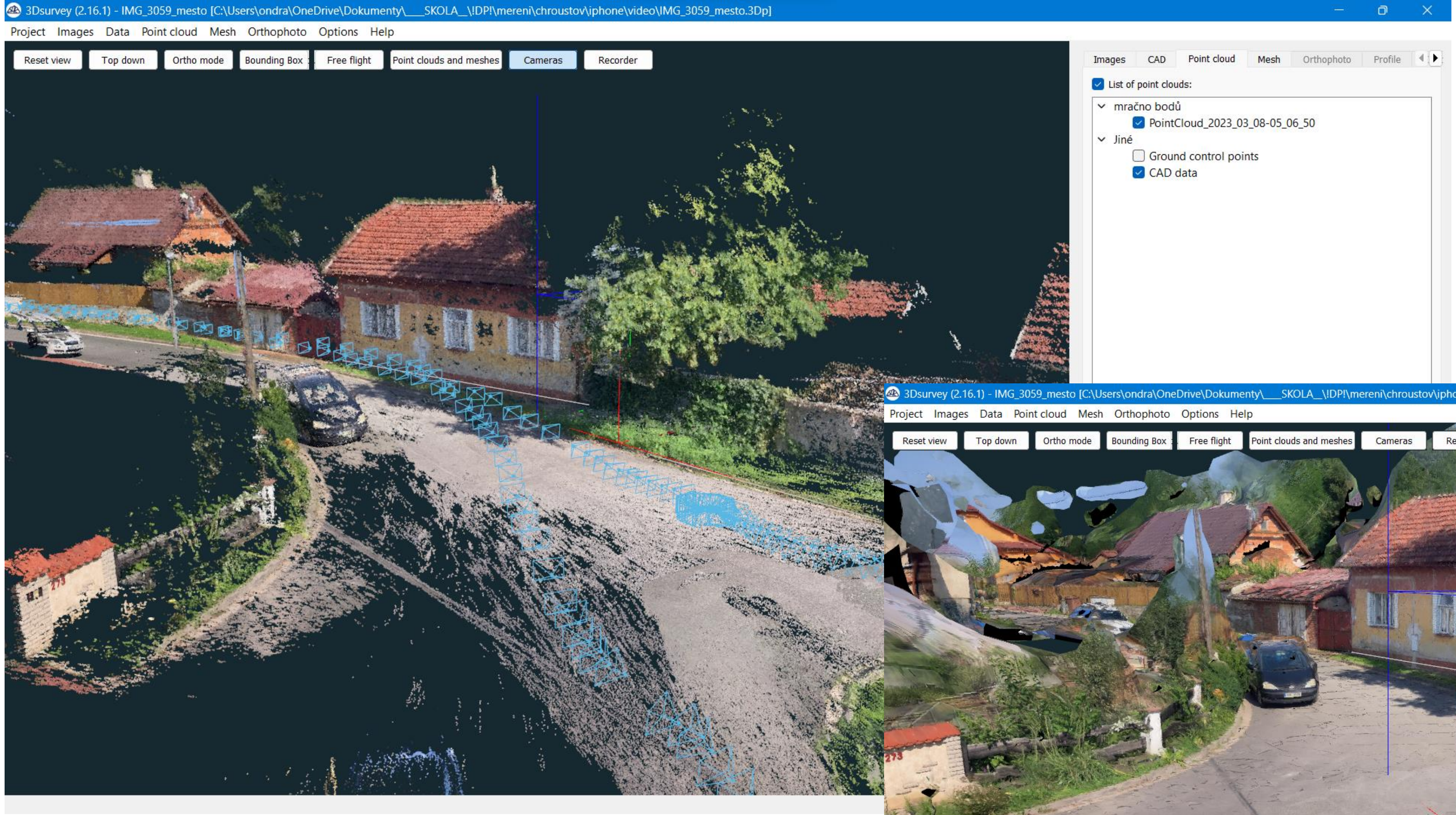
3D Survay

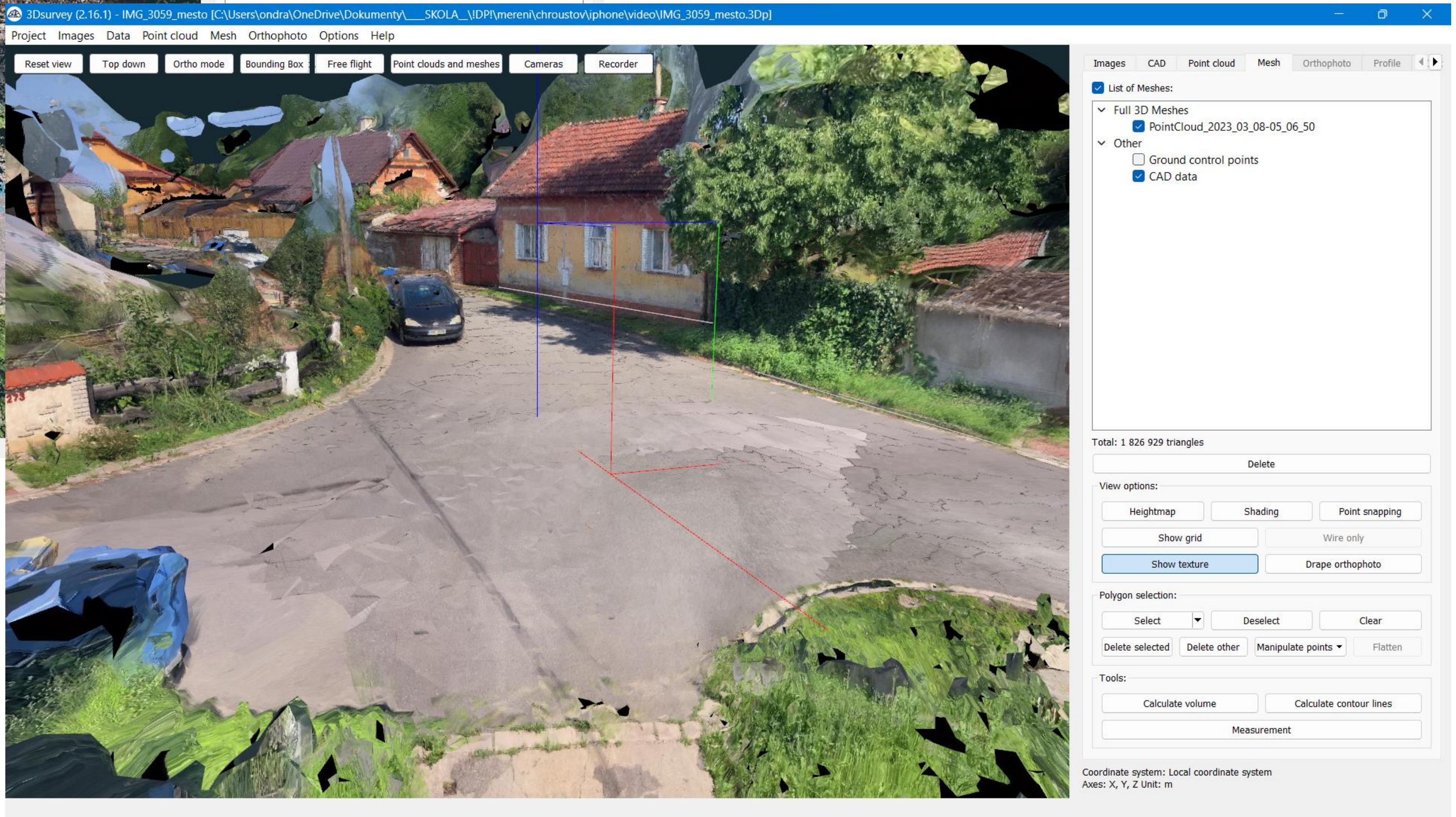
3Dsurvey

Smart phone with GNSS RTK

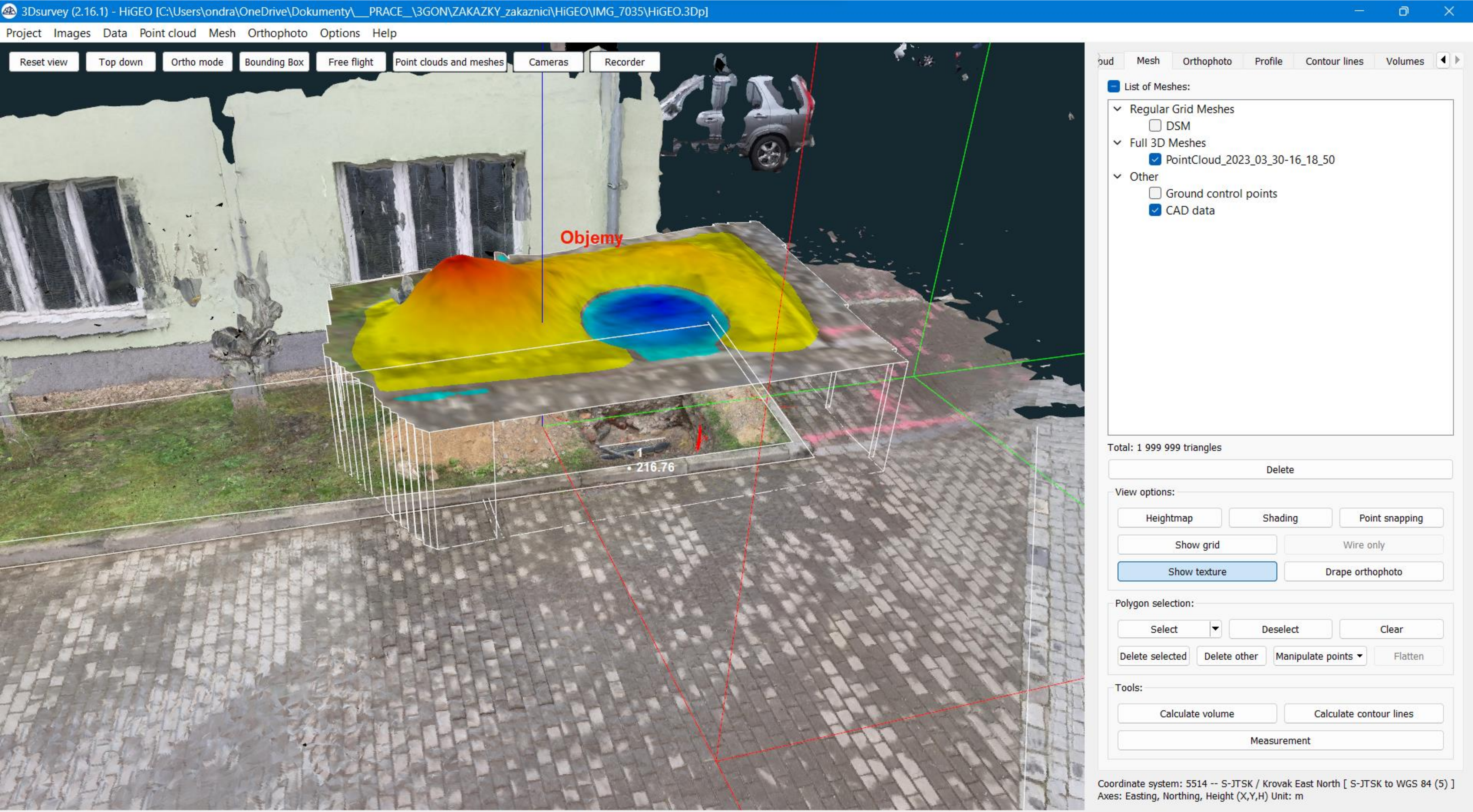


videophotogrammetry





videophotogrammetry


3Dsurvey (2.16.1) - HiGEO [C:\Users\ondra\OneDrive\Dokumenty__PRACE__\3GON\ZAKAZKY_zakaznici\HiGEO\IMG_7035\HiGEO.3Dp]
Project
Images
Data
Point cloud
Mesh
Orthophoto
Options
Help
Reset view
Top down
Ortho mode
Bounding Box
Free flight
Point clouds and meshes
Cameras
Recorder
Objemy
1
216.76
oud
Mesh
Orthophoto
Profile
Contour lines
Volumes
List of Meshes:
Regular Grid Meshes
DSM
Full 3D Meshes
PointCloud_2023_03_30-16_18_50
Other
Ground control points
CAD data
Total: 1 999 999 triangles
Delete
View options:
Heightmap
Shading
Point snapping
Show grid
Wire only
Show texture
Drape orthophoto
Polygon selection:
Select
Deselect
Clear
Delete selected
Delete other
Manipulate points
Flatten
Tools:
Calculate volume
Calculate contour lines
Measurement
Coordinate system: 5514 -- S-JTSK / Krovak East North [S-JTSK to WGS 84 (5)]
Axes: Easting, Northing, Height (X,Y,H) Unit: m

3Dsurvey

Aerial image processing software
Version 2.16.1

Report

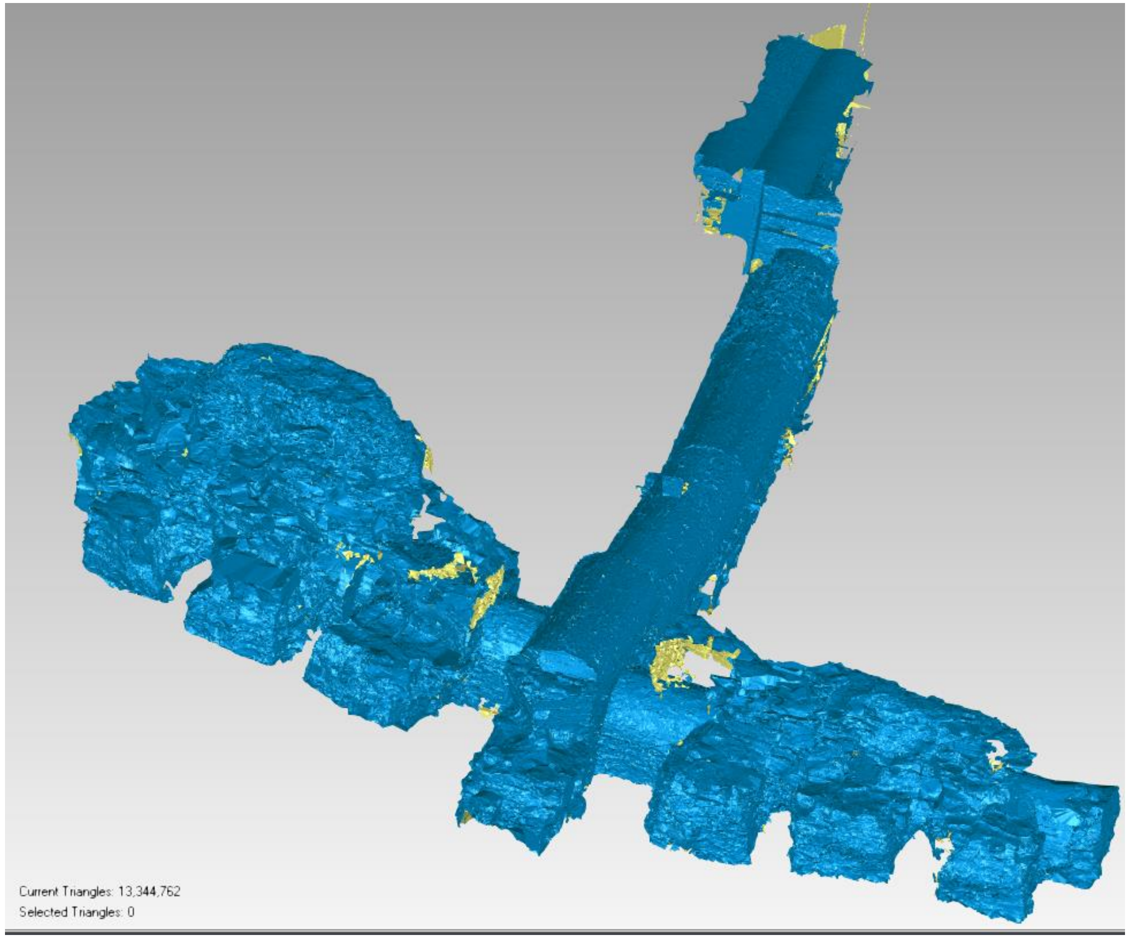
Project:	videoTELC
Date of image acquisition:	No data

Camera model	Resolution	Focal length	Sensor size	Pixel size
No data	2160 × 3840	0mm	No data	No data

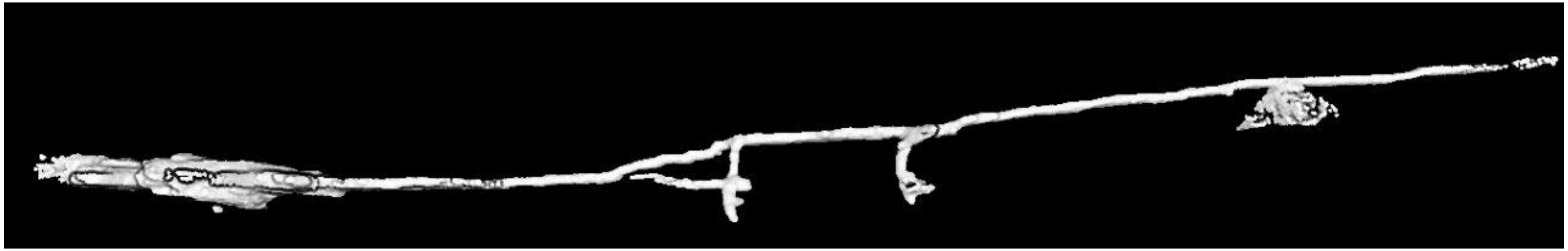
Orthophoto size:	97.94m × 19.21m	**Pixel resolution:**	0.010m

Skorkov

Laser scanning is useful method for underground spaces documentation – here is an example of Historical underground cross corridor and medieval tin mine



mediaval tin mine, Mauritius



We can map on the surface of the Earth, from the air and from space

-What about underwater and under the solid surface of the earth?

You need to use different sensors:

-Radar and magnetometer under the earth's surface (geophysical methods), resistivity method

-Sonar and underwater photography

Georadar GPR (ground penetrating radar)

-Georadar

-Použité zařízení: GSSI SIR - 3000, anténa 400MHz, 200MHz, 1,6GHz; Single-Channel GPR Data Acquisition S

-http://www.geophysical.com (sales@geophysical.com)

-

-http://userpage.fu-berlin.de/~geodyn/instruments/Manual_GSSI_Antennas.pdf

History

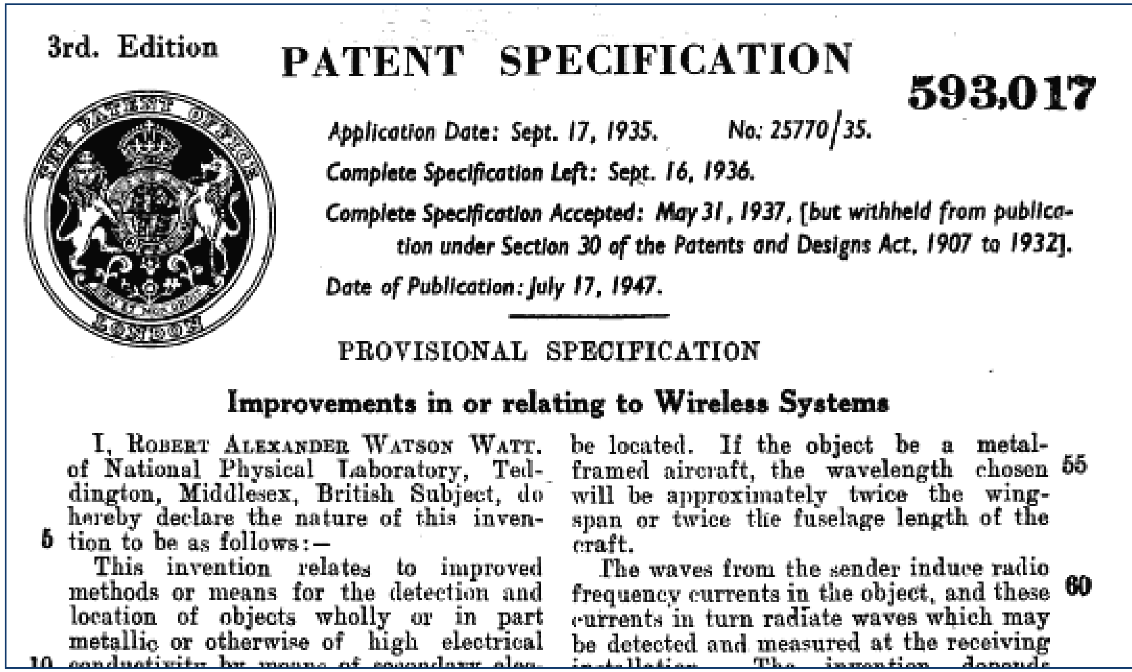
-1935, British physicist Sir Robert Watson-Watt patent

-The device called radar is an acronym for Radio Detection And Ranging

-The first GPR survey by Otto Stern, 1929, measuring the depth of a glacier, forgotten

-1960 John C. Cook, development of

-Morey and Drake founded Geophysical Survey System Inc. - development of GPR



3rd. Edition

PATENT SPECIFICATION

593,017

Application Date: Sept. 17, 1935. No. 25770/35.

Complete Specification Left: Sept. 16, 1936.

Complete Specification Accepted: May 31, 1937, [but withheld from publication under Section 30 of the Patents and Designs Act, 1907 to 1932].

Date of Publication: July 17, 1947.

PROVISIONAL SPECIFICATION

Improvements in or relating to Wireless Systems

I, ROBERT ALEXANDER WATSON WATT, of National Physical Laboratory, Teddington, Middlesex, British Subject, do hereby declare the nature of this invention to be as follows:—

This invention relates to improved methods or means for the detection and location of objects wholly or in part metallic or otherwise of high electrical

be located. If the object be a metal-framed aircraft, the wavelength chosen will be approximately twice the wing-span or twice the fuselage length of the craft.

The waves from the sender induce radio frequency currents in the object, and these currents in turn radiate waves which may be detected and measured at the receiving

GPR

-calculation of vertical resolution and depth

$$d_l \approx 0.5 \times \frac{v}{f_C},$$

Kde je:

d_l... vertikální rozlišovací schopnost,

v... průměrná rychlost,

f_c... frekvence použité antény.

$$h = \frac{v \cdot \tau}{2}$$, kde značí

v...rychlost šíření vlny prostředím,

τ...tranzitní čas.

The dependence of the velocity on the value of the dielectric constant is given below

$$v = \frac{c}{\sqrt{\varepsilon_r}}$$

Kde je:

v... průměrná rychlost,

c... rychlost světla,

ε_r... dielektrická konstanta (permitivita).

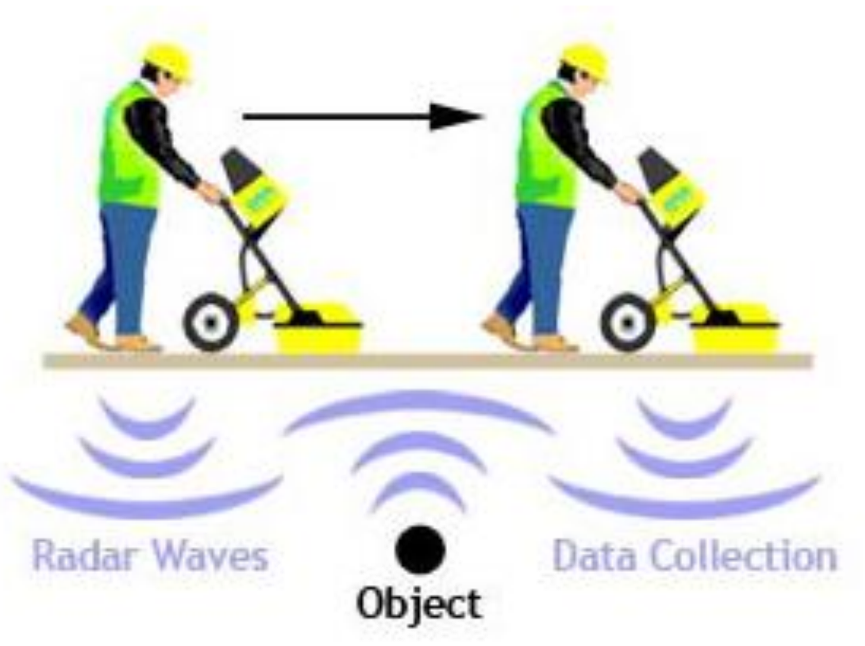
dielektrikum

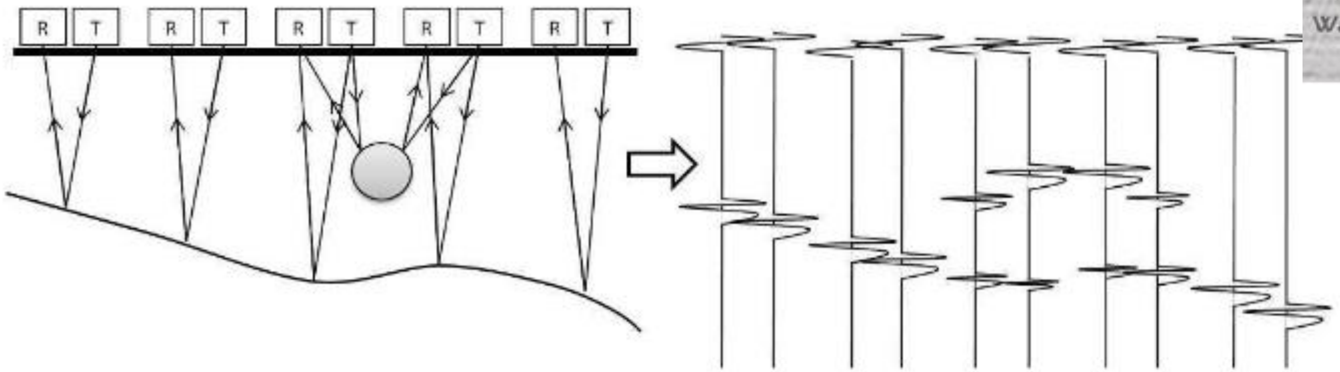
HODNOTY DIELEKTRIKA A VERTIKÁLNÍ ROZLIŠOVACÍ SCHOPNOSTI PRO BĚŽNÉ MATERIÁLY		
Materiál	**Dielektrikum**	**Vertikální rozlišení [cm]**
Vzduch	1	38
Polární led	3,6	20
PVC	3	21
Asfalt	3 - 5	21 – 17
Beton	4 - 11 (5)	19 – 11 (17)
Žula	4 - 7	19 – 14
Pískovec	6	15
Jílovitá břidlice	5 - 15	17 – 9
Vápenec	4 - 8	19 – 13
Čedič	8 -9	13 – 12
Vodou nasycený písek(20% pórovitost)	19 - 24	9 – 7
Půdy a sedimenty	4 - 30	19 – 7
Voda	81	0,4

Dosah GPR

Tabulka doporučených rozsahů pro jednotlivé antény		
Frekvence	Typická maximální hloubka [m]	Typický rozsah [ns]
2,6 Ghz	0,3	10
1,6 Ghz	0,5	10 - 15
900 Mhz	1	11 - 20
400 Mhz	**3**	**20 - 100**
200 Mhz	8	70 - 300
100 Mhz	20	300 - 500

principe





https://www.sciencedirect.com/topics/materials-science/ground-penetrating-radar

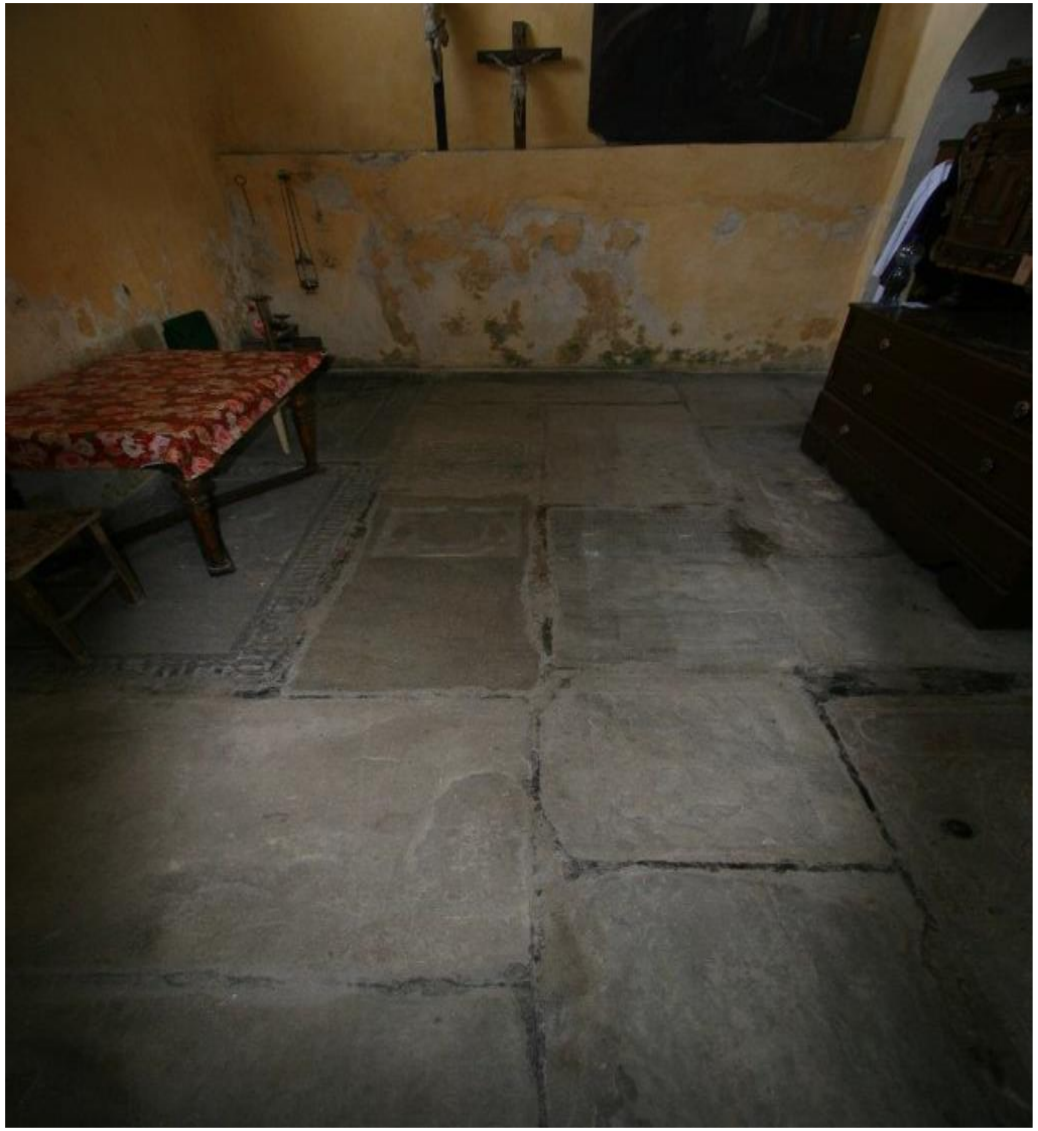
GSSI SIR – 3000

GPR

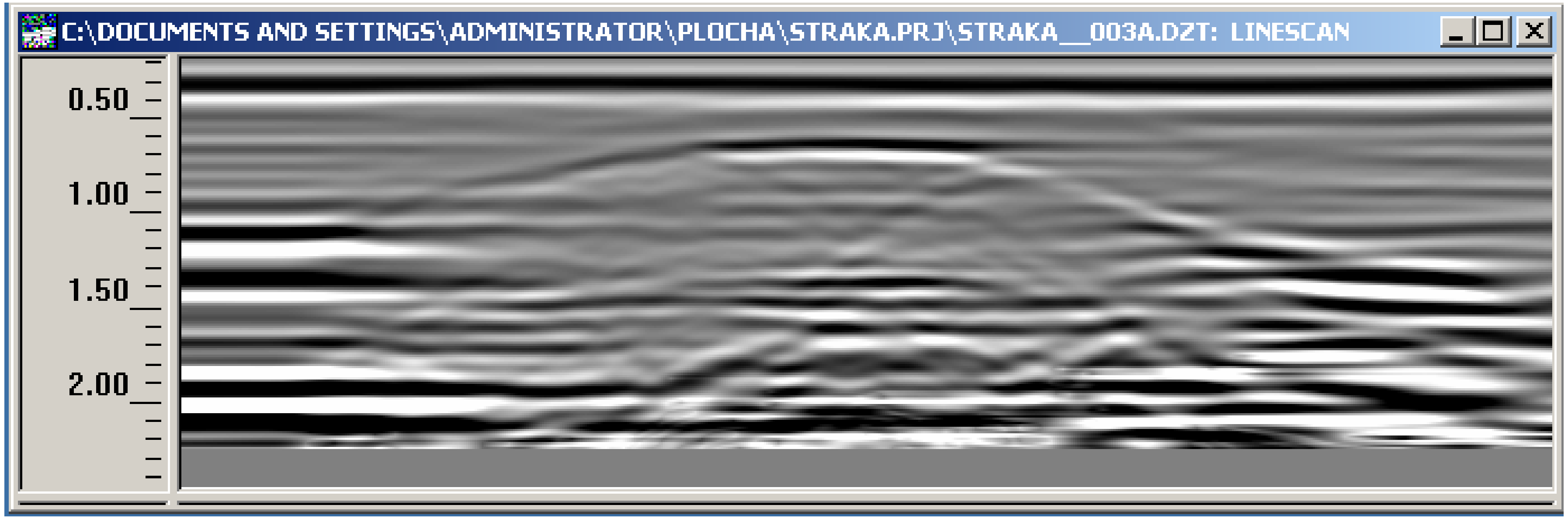
Ground Penetrating Radar (GPR) is a technology based on the analysis of the controlled transmission of electromagnetic waves through the structure or ground under investigation. The transmitter antenna sends out intermittent sinusoidal pulses. The electromagnetic waves travel through the material at a speed dependent on the electromagnetic properties of the substrate under investigation. Subsequently, reflected pulses (with a delay of tens to thousands of nanoseconds) from the interfaces of the different layers, which have different dielectric properties, are picked up by the antenna receiver.-Objects below the surface are commonly manifested as parabolas; their formation is due to radar motion, signal width and reflection. Parabolic regular signals are presented by cylindrical - linear bodies below the surface (e.g. thicker cables, pipes, etc., but in a larger sense also vaults of cellars and remains of buildings).

Unknown crypts of the Church of St. Wenceslas in Strakonice

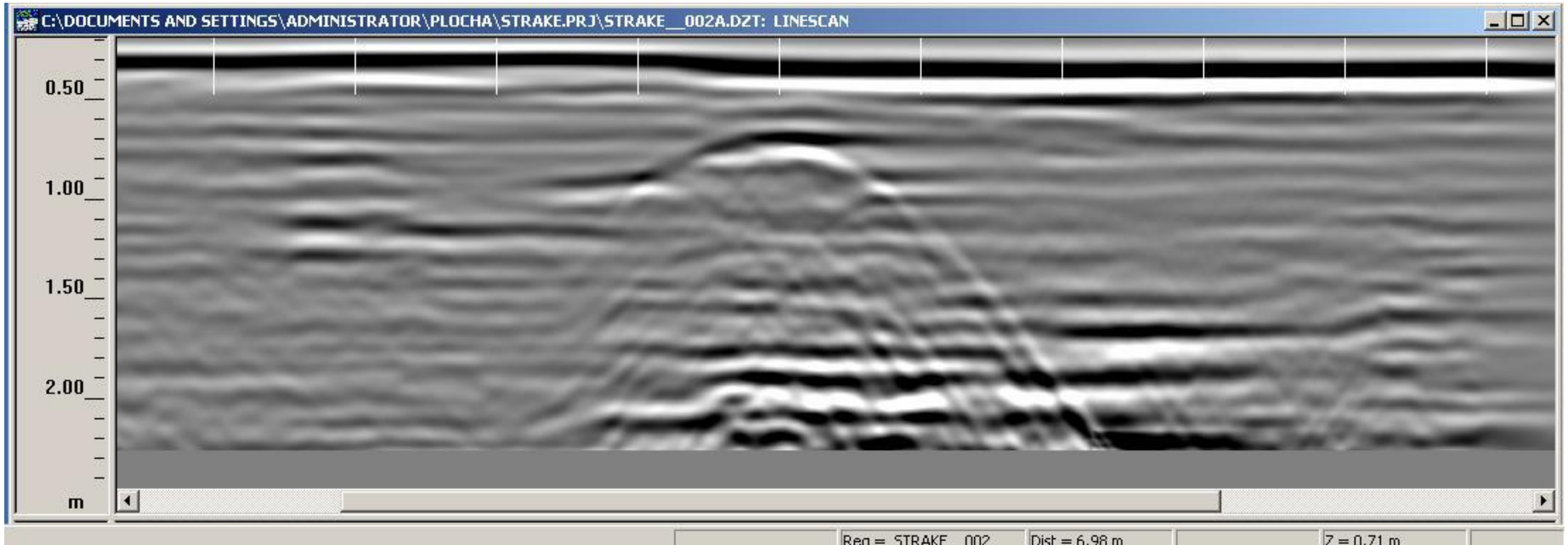
The cemetery church of St. Wenceslas in Strakonice, founded before 1308 by Bavor III.The first mention of the crypt is from 1718, the second from 1738 after the Baroqueization of the church, but no more is known, neither the number nor the location.



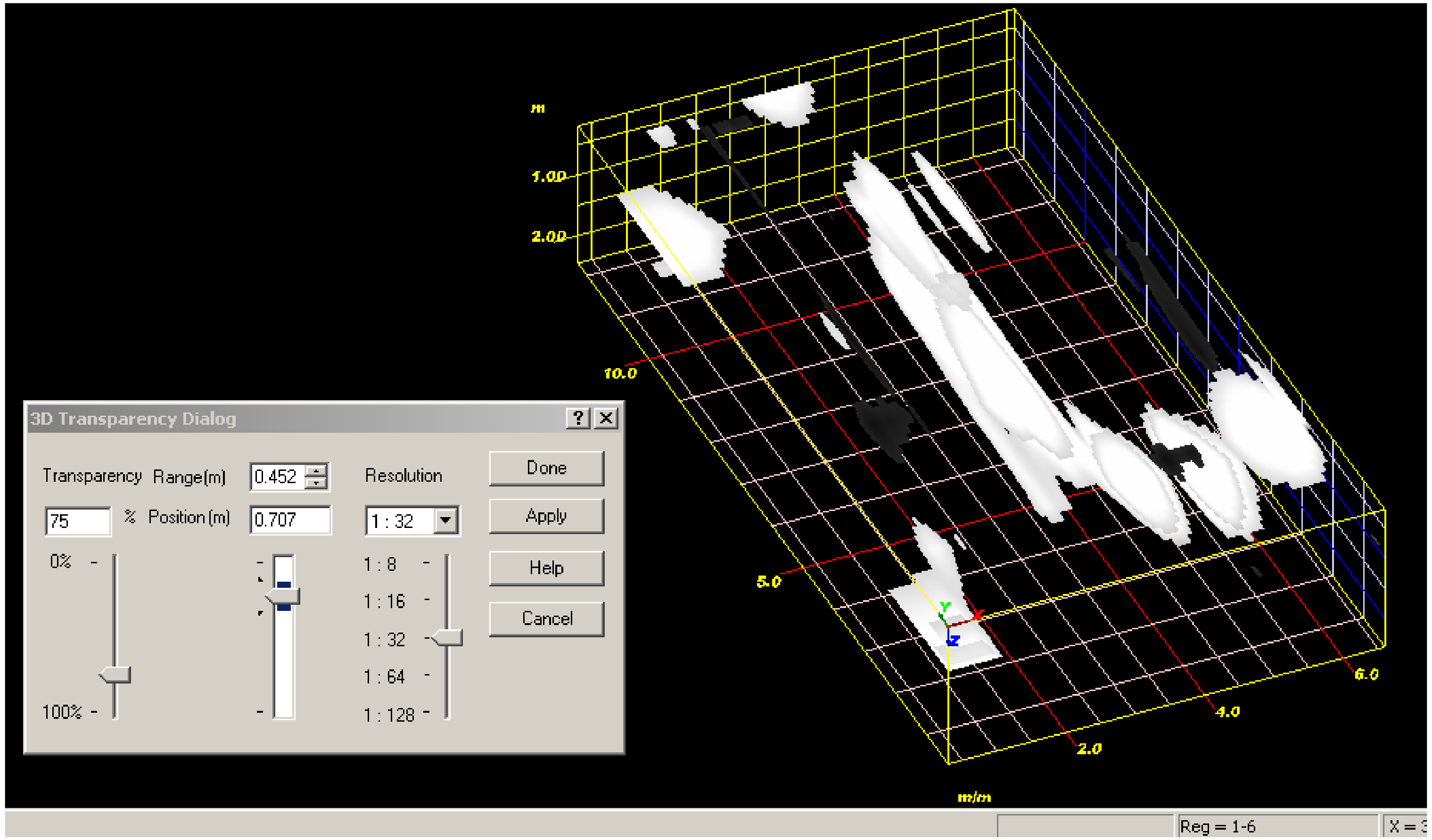
profiles

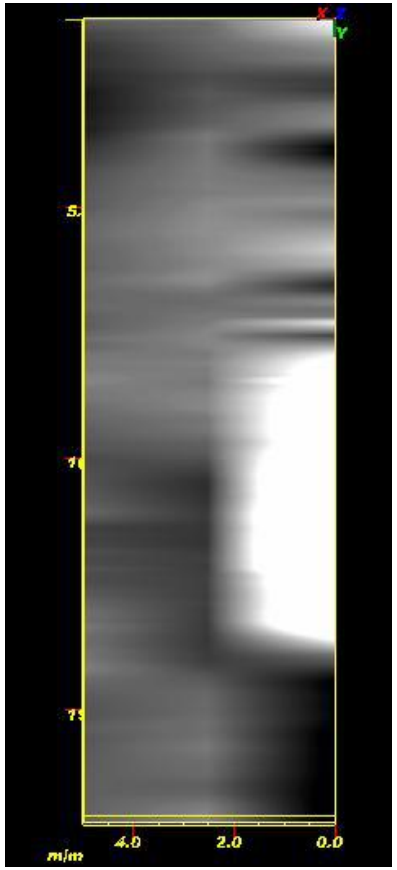


Sakristia and main church space



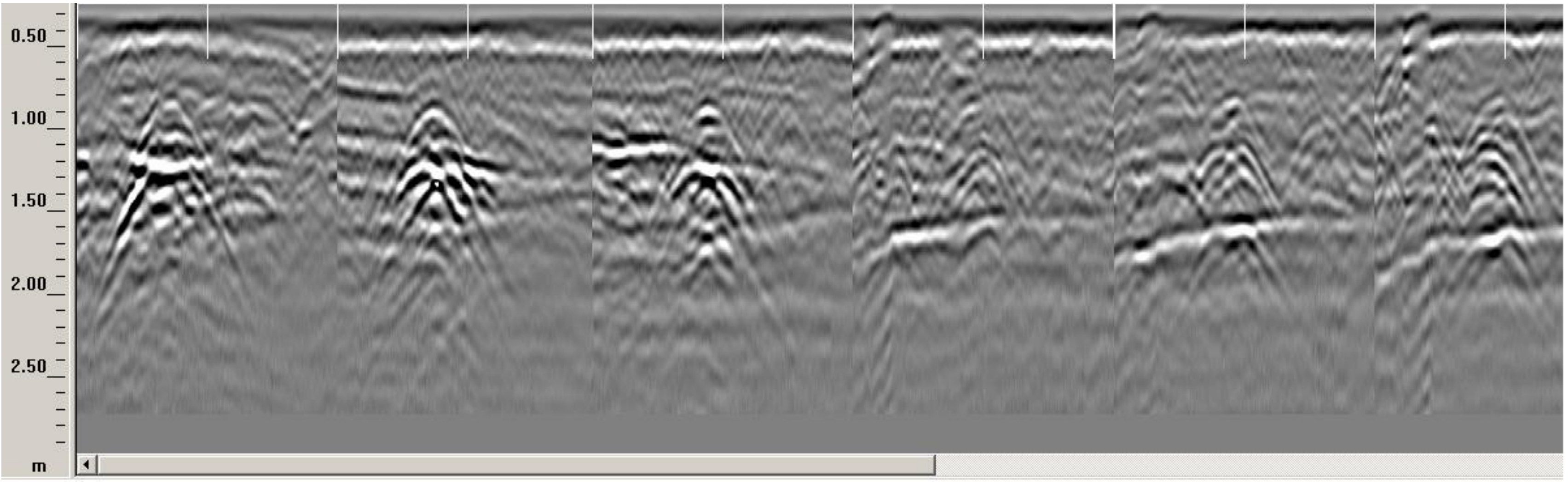
Radan - sw for underground object representation from profiles

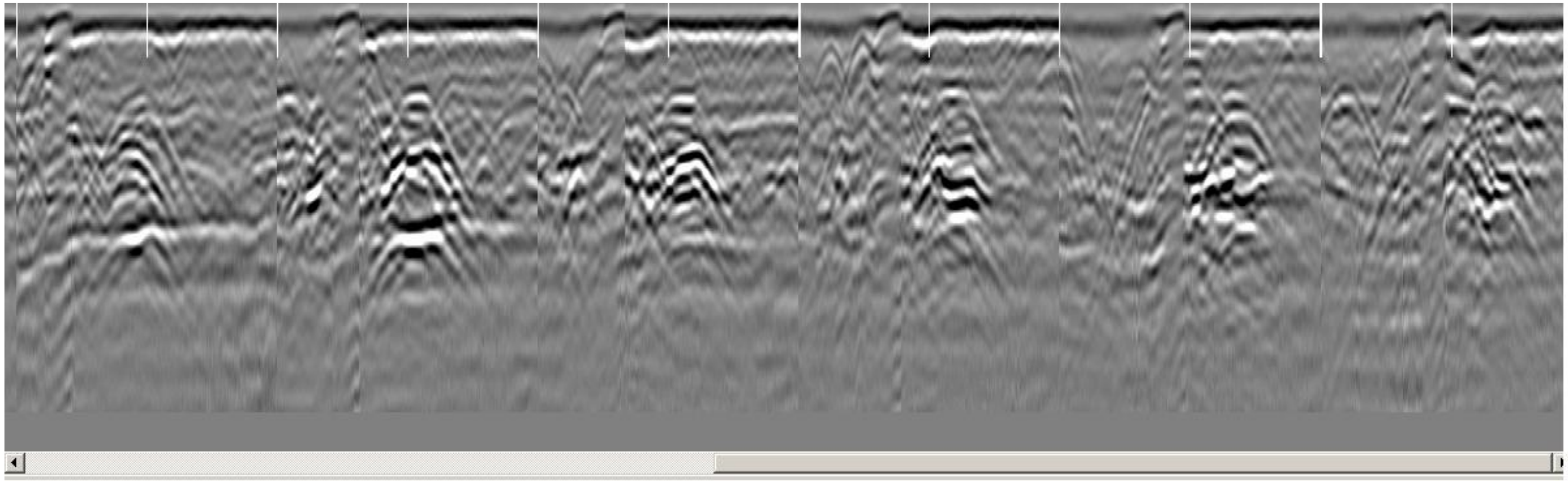




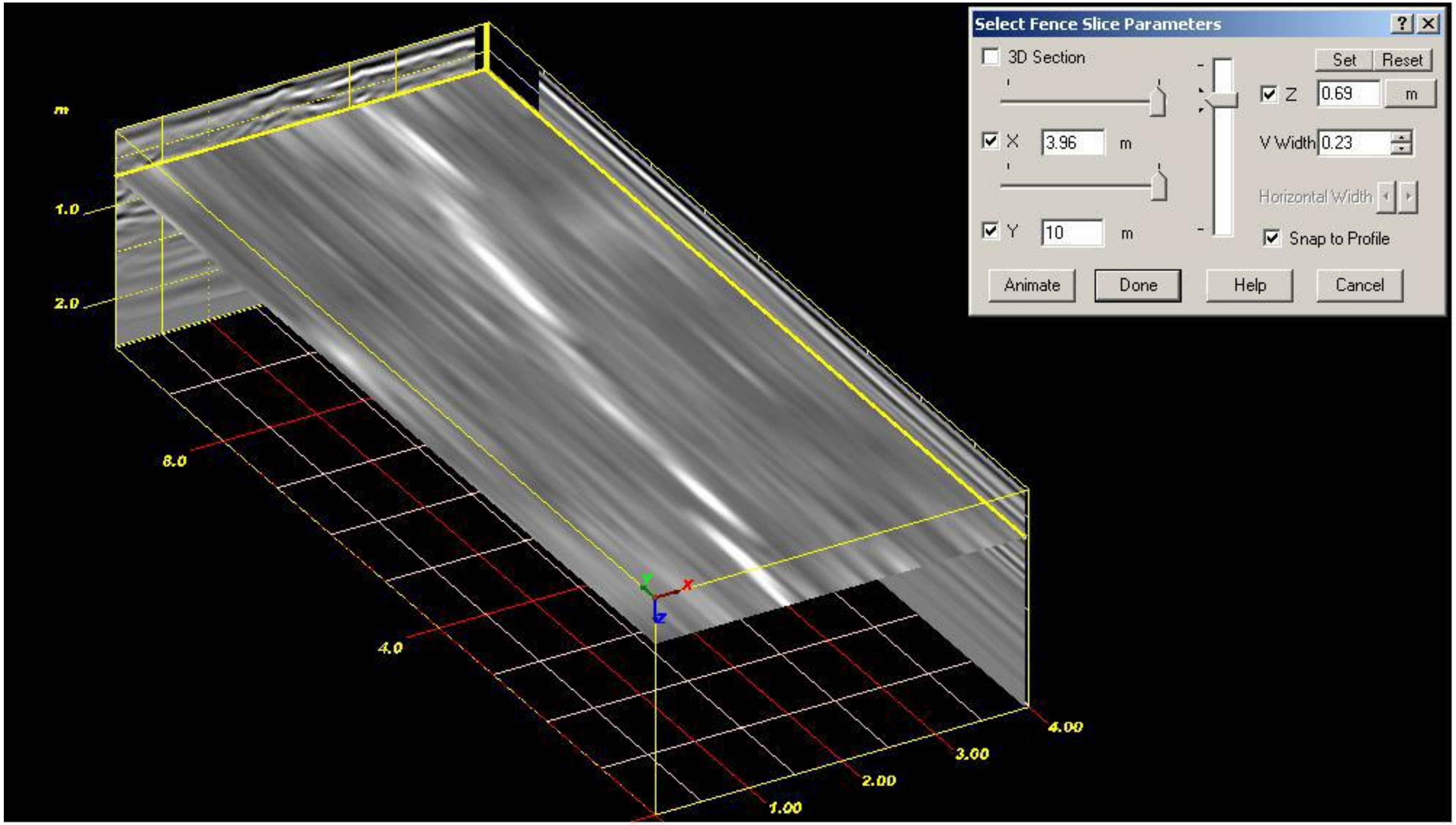
Monastery Teplá

radarogramm





Water intake, depth 0.55m (upper part of the gallery).



Panenský Týnec

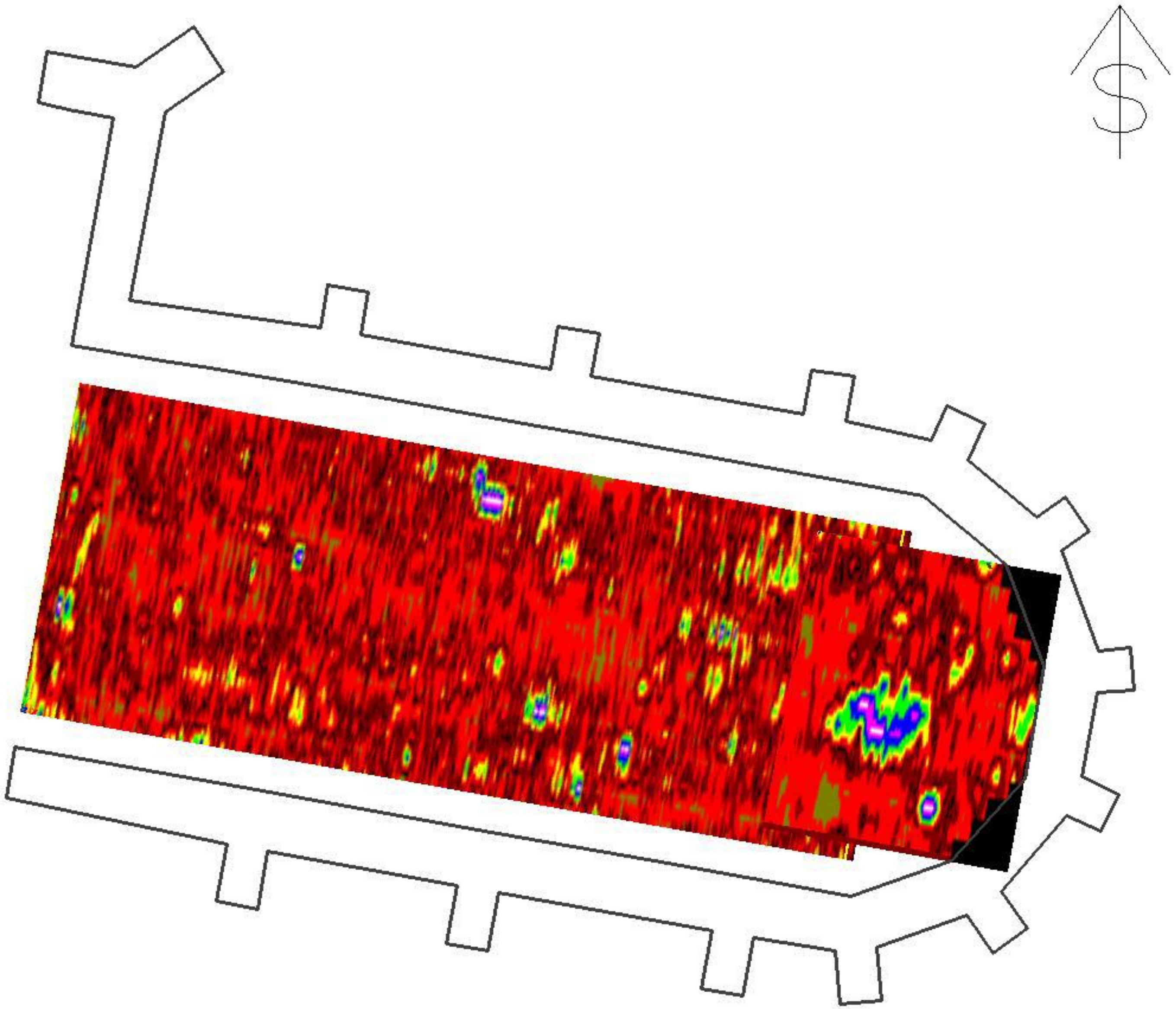
-Týnec is derived from the word Týn or Old Celtic Taun, which means a place fortified with stakes. Virgin - derived from the virgins of the Franciscan Order of the Poor Clares.

The first mention dates back to 1115. Nowadays a well-known excursion spot, connected with an energy centre in an unbuilt Gothic church; a place of frequent wedding ceremonies.

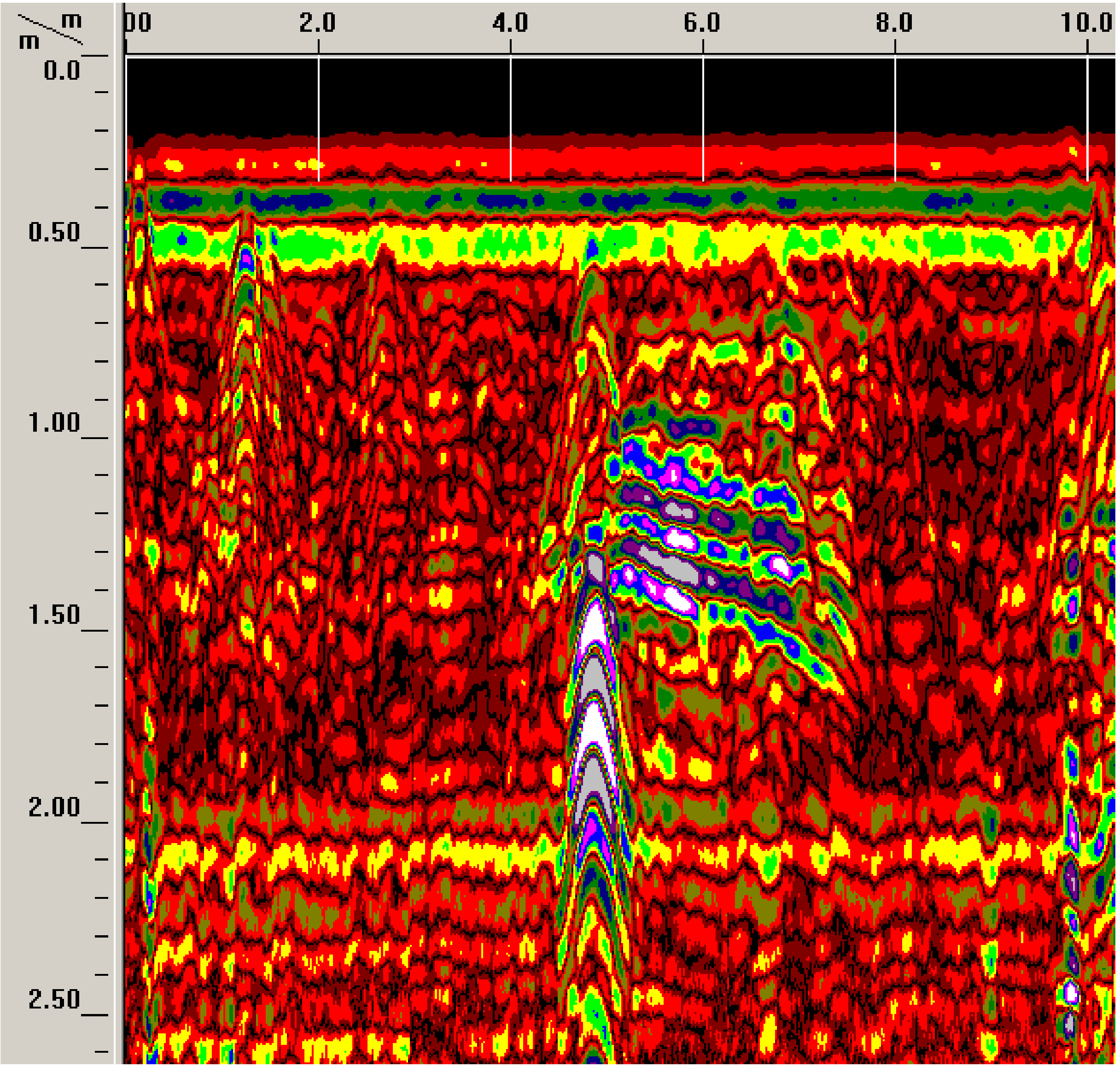
-Geodetic survey of the building and its subsurface exploration as part of the thesis work

-GPR measurements found a subsurface object, probably an unknown tomb, as well as an object in the main nave of the temple.

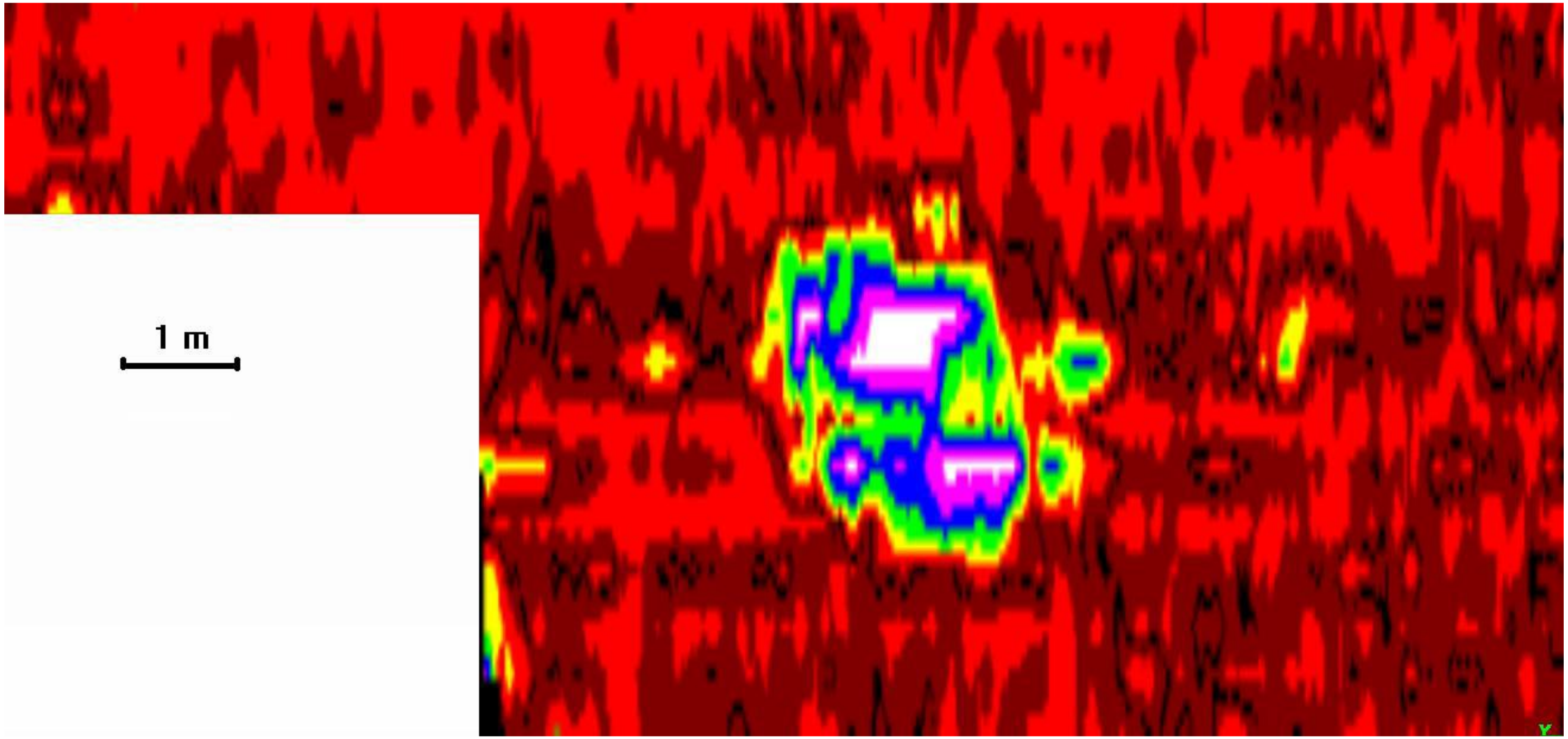
Main part of the church



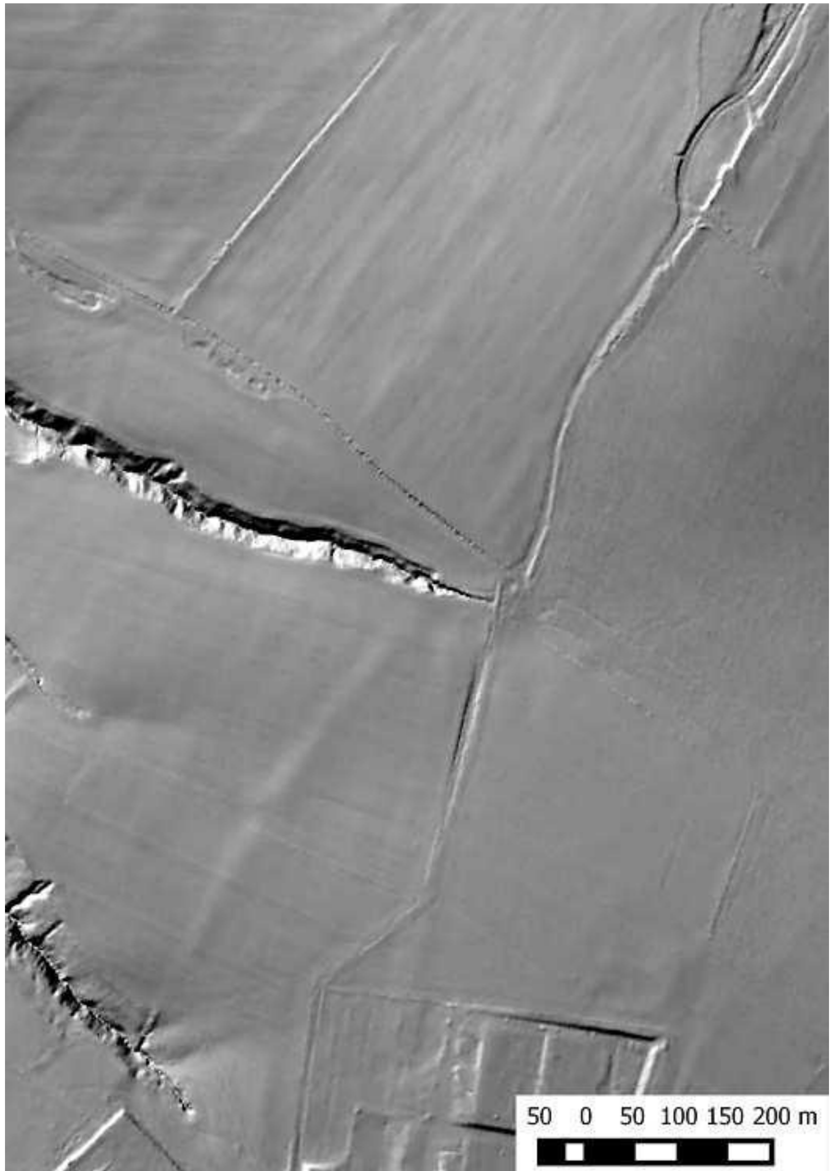
Unknown tomb

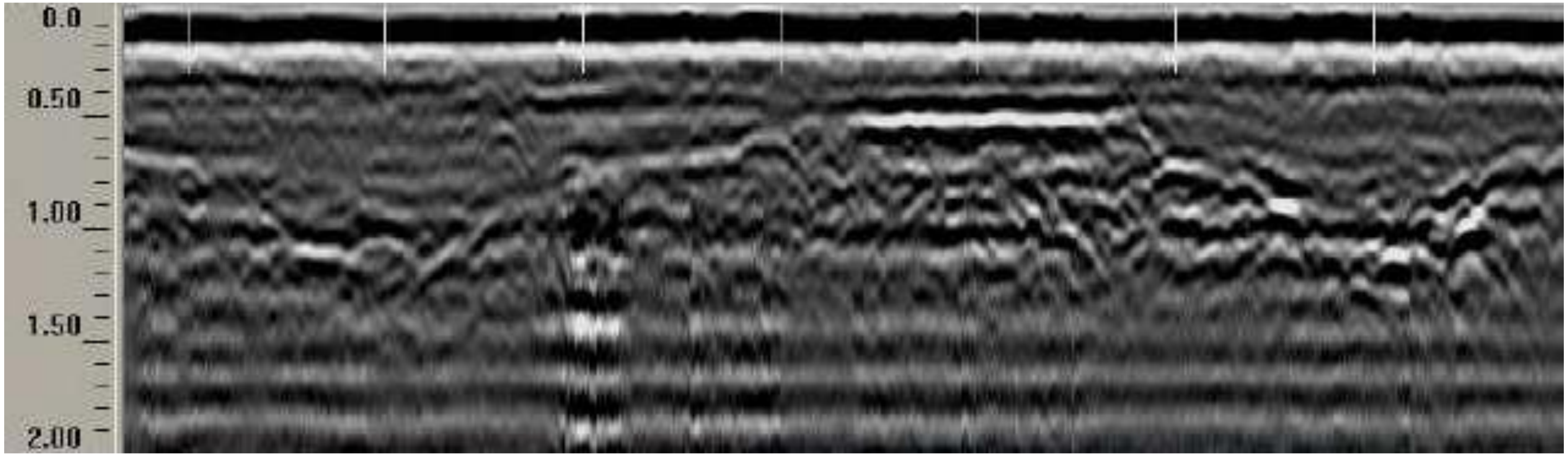


Unknown tomb

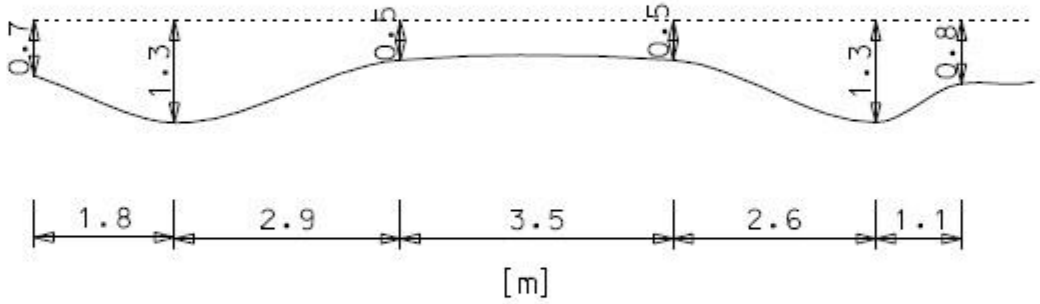


Devil's furrow, Lipany





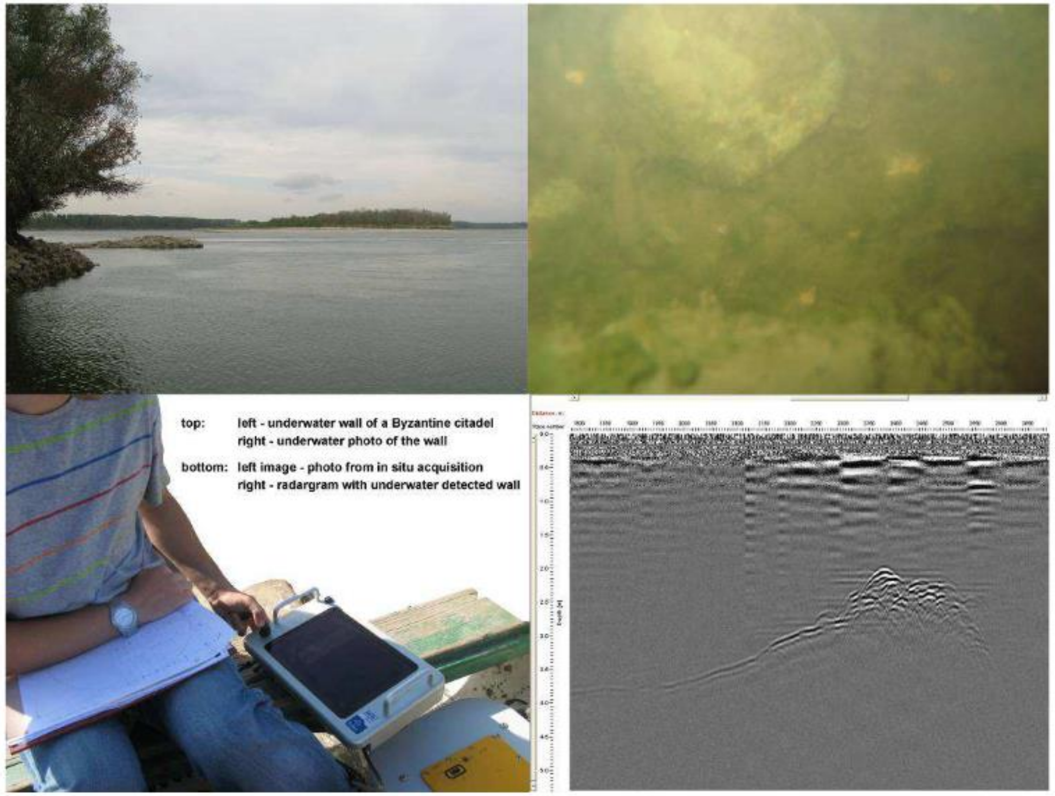
Val a příkopy - řez B



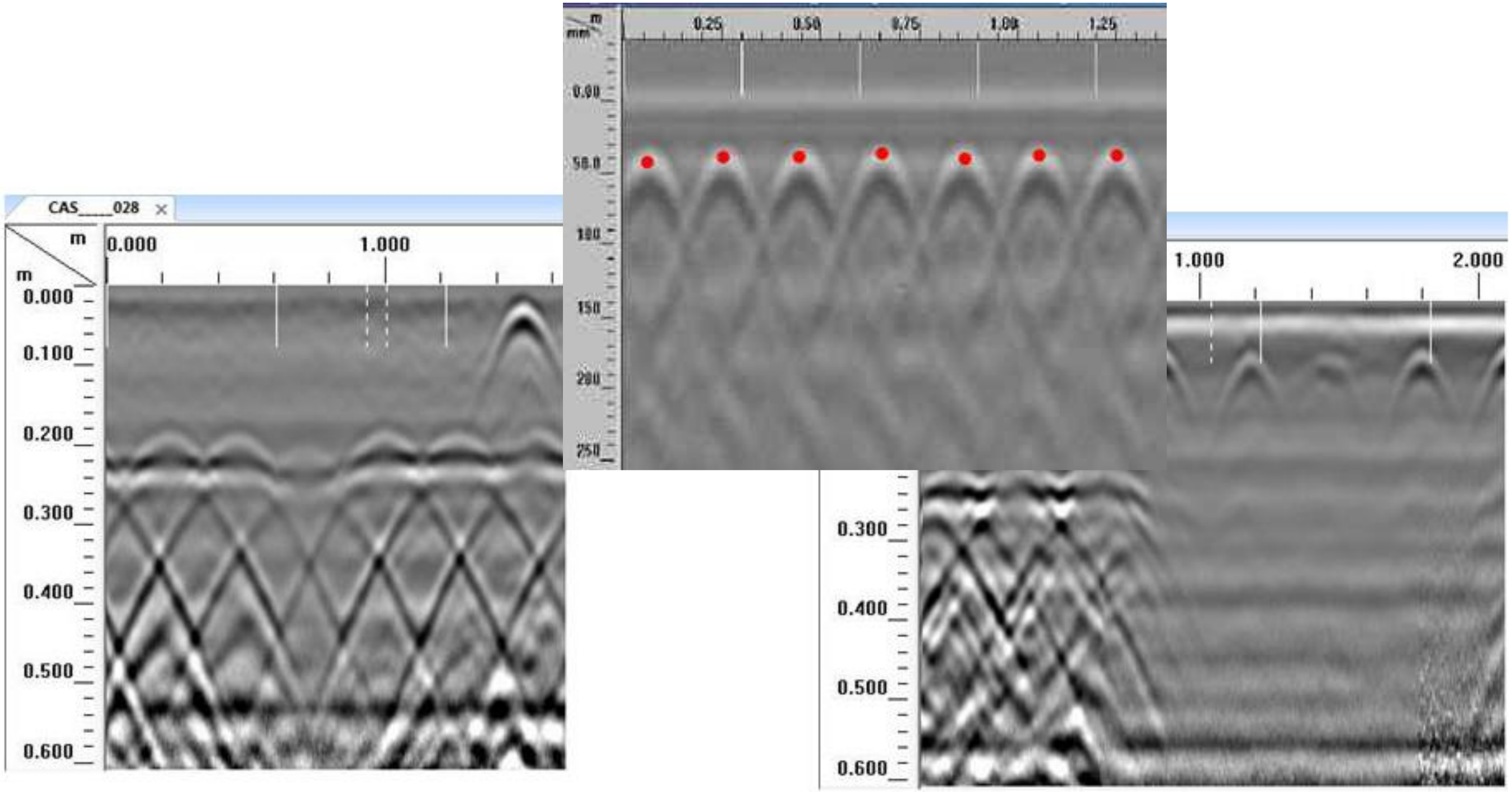
Současný povrch

Útvar odhalený georadarem

Radarogram - Danube, underwater application, val- Byzantine fortress



Survey of concrete elements, 1.6 GHz antenna



Area measurement

the abandoned Roman town of Falerii Novi, located about 50 km north of Rome

https://vedator.org/2020/06/rimske-mesto-detailne-prozkoumano-pomoci-georadaru/

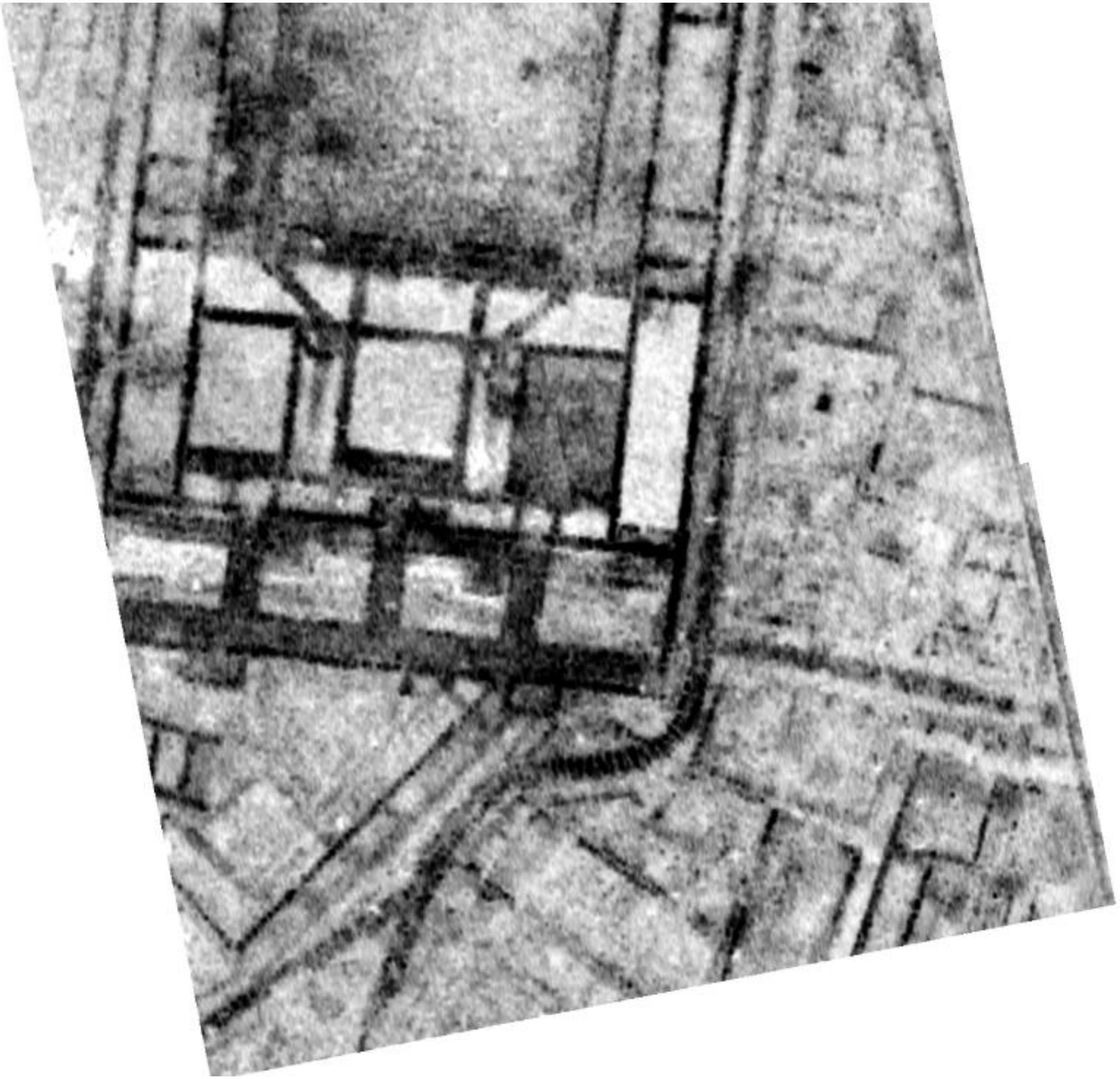
Carnuntum, 40km SE of Vienna, Roman military camp and town

file:///C:/Users/karel/AppData/Local/Temp/Long-term_Integrated_Archaeological_Prospection_at.pdf

Aerial Archaeology

GPR - coupled antennas towed by quad bike

- Roman forum, depth 1,5m, profiles 50cm

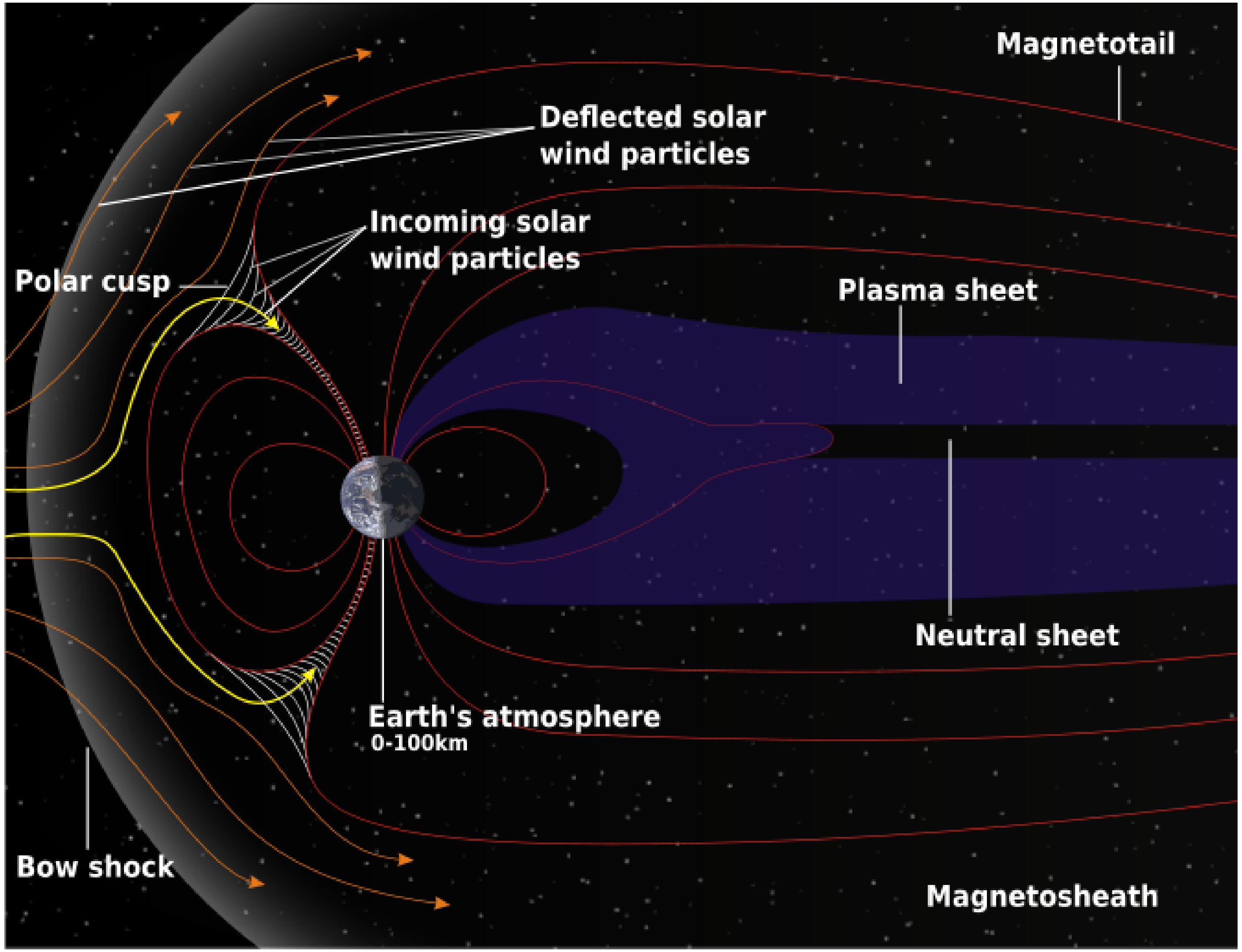


Cesium magnetometr

Magnetometr

- **Magnetometr/gradiometr**
- GEM systems, GSM -19, Overhauser, USA
- Sensitivity: 0.022 nT @ 1 Hz, (0.015 nT option)
- Resolution: 0.01 nT
- Absolute Accuracy: +/- 0.1 nT
- Dynamic Range: 20,000 to 120,000 nT
- Gradient Tolerance: Over 10,000 nT/m
- http://www.gemsys.ca
- The magnetometer is sensitive to subtle changes in magnetism; in the radiometer assembly, two coils are superimposed and a gradient is defined, more sensitive to subtle changes in magnetism. Since everything in our environment is magnetic, subsurface formations can be defined in this way. For example, stone walls, burnt brick formations, etc. The remains of burnt objects again have a different magnetism.

Struktura magnetického pole Země



Protone magnetometr

-Principle: the general principle of this kind of magnetometer is the measurement of the precession frequency of free protons, which is directly proportional to the measured magnetic field.-It allows very precise absolute measurements with a resolution of 0; 1 nT.--The instrument consists of a container filled with a liquid with a high proton concentrationwrapped with a conductor. The measurement cycle consists of an initial proton polarization part and a subsequent measurement.

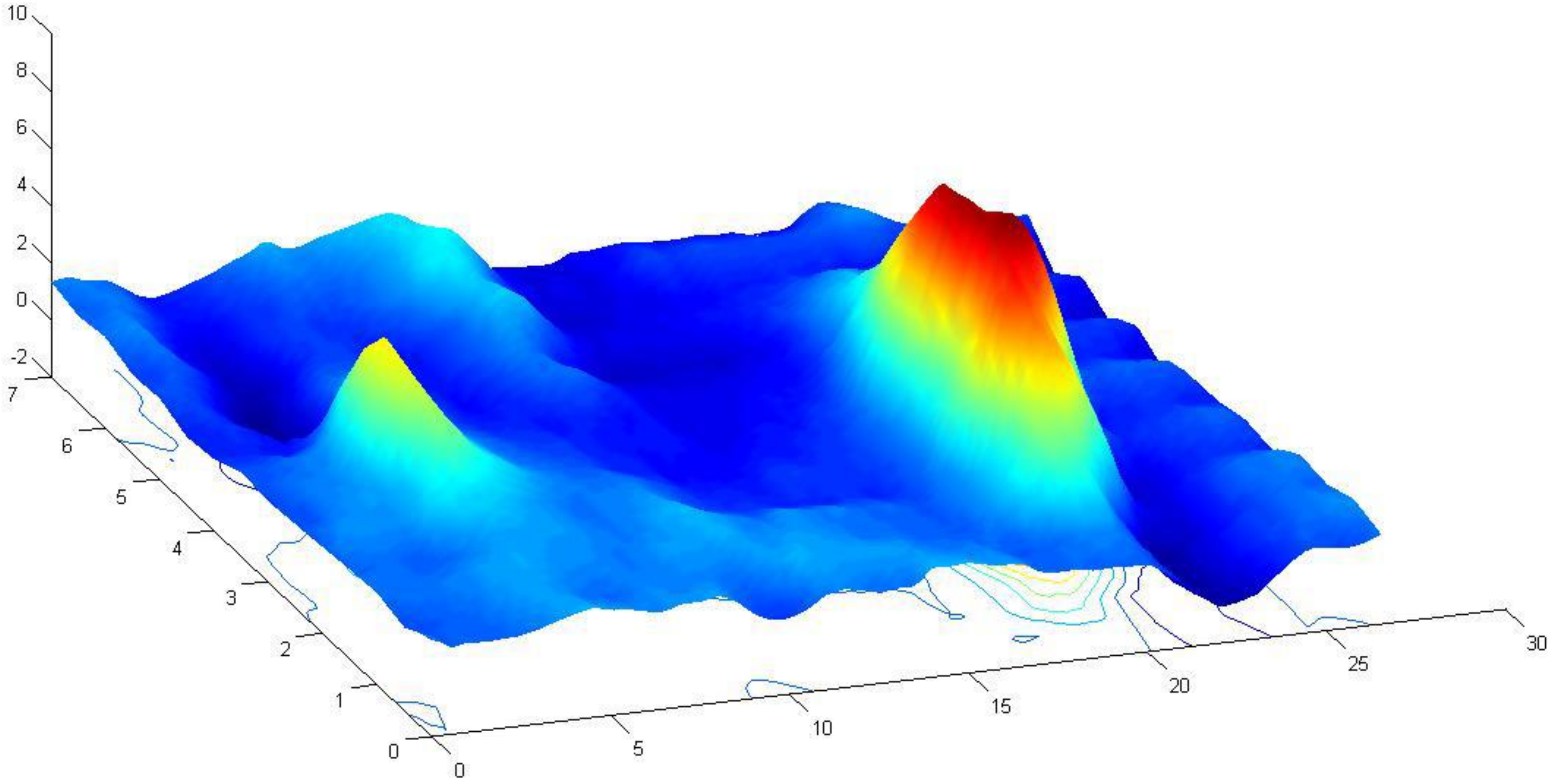
Magnetometer

magnetometer

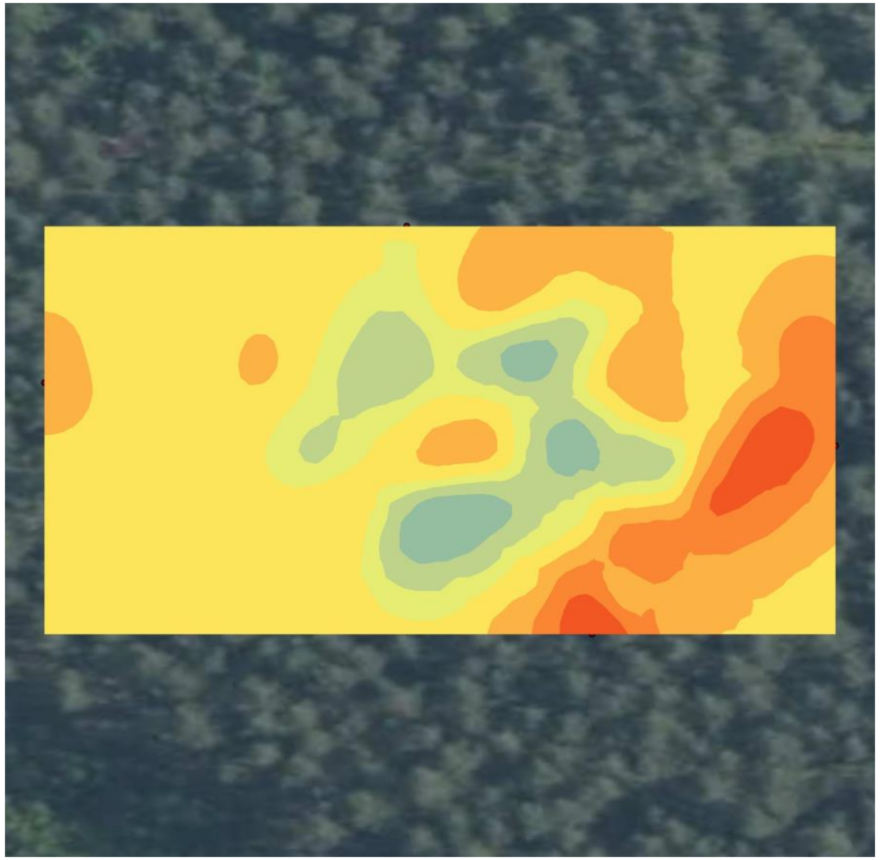
- -Magnetometric and gradient mode-Absolute magnetometer measurement measures the mag.field distribution-Gradient measurement removes local variations of the whole field (2 probes on top of each other and the difference is measured)-The essence of magnetometric measurement is to monitor anomalies caused by underground structures

Archeological application

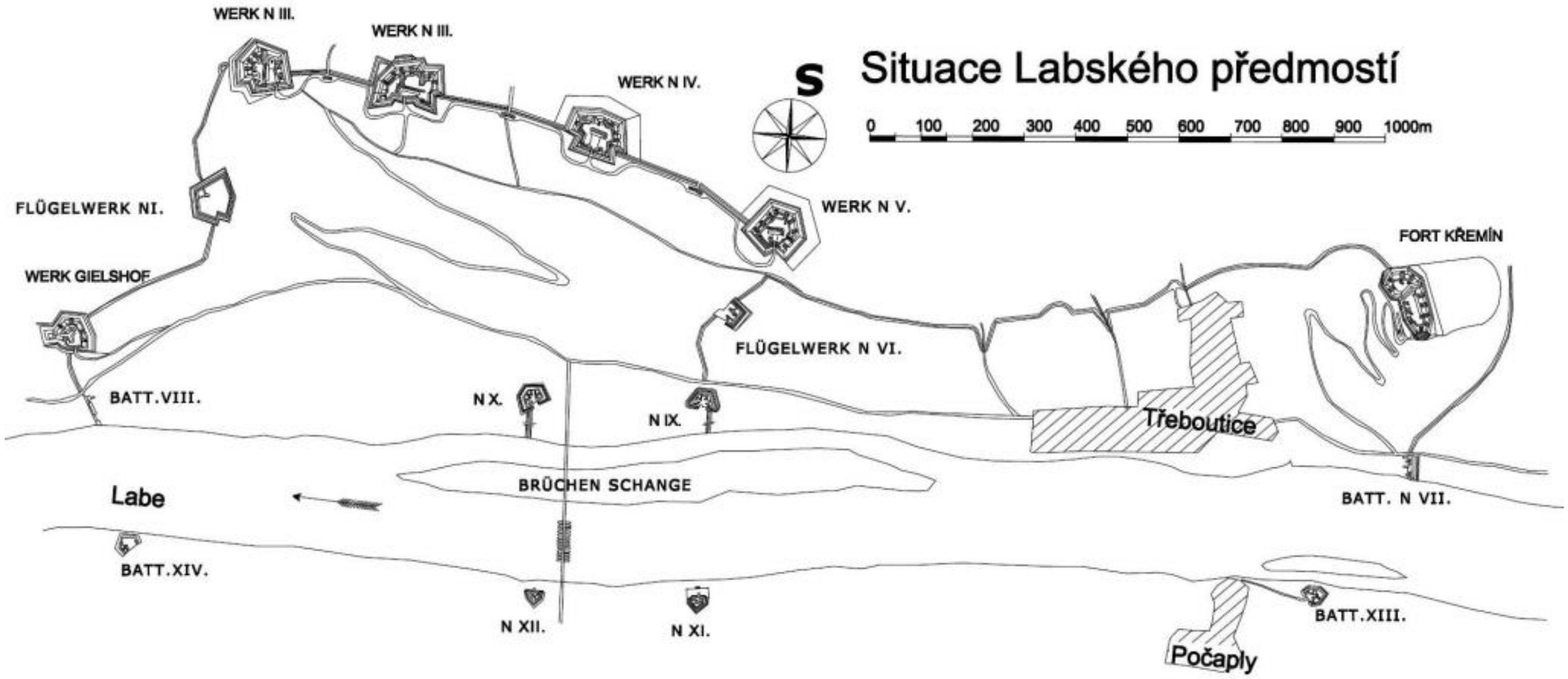
Panenský Týnec – magnetometer measurements, verification of findings



Artillery redoubt Svahy, Thirty Years' War, kriging



Elbe bridgehead, fortifications Prusso-Austrian War

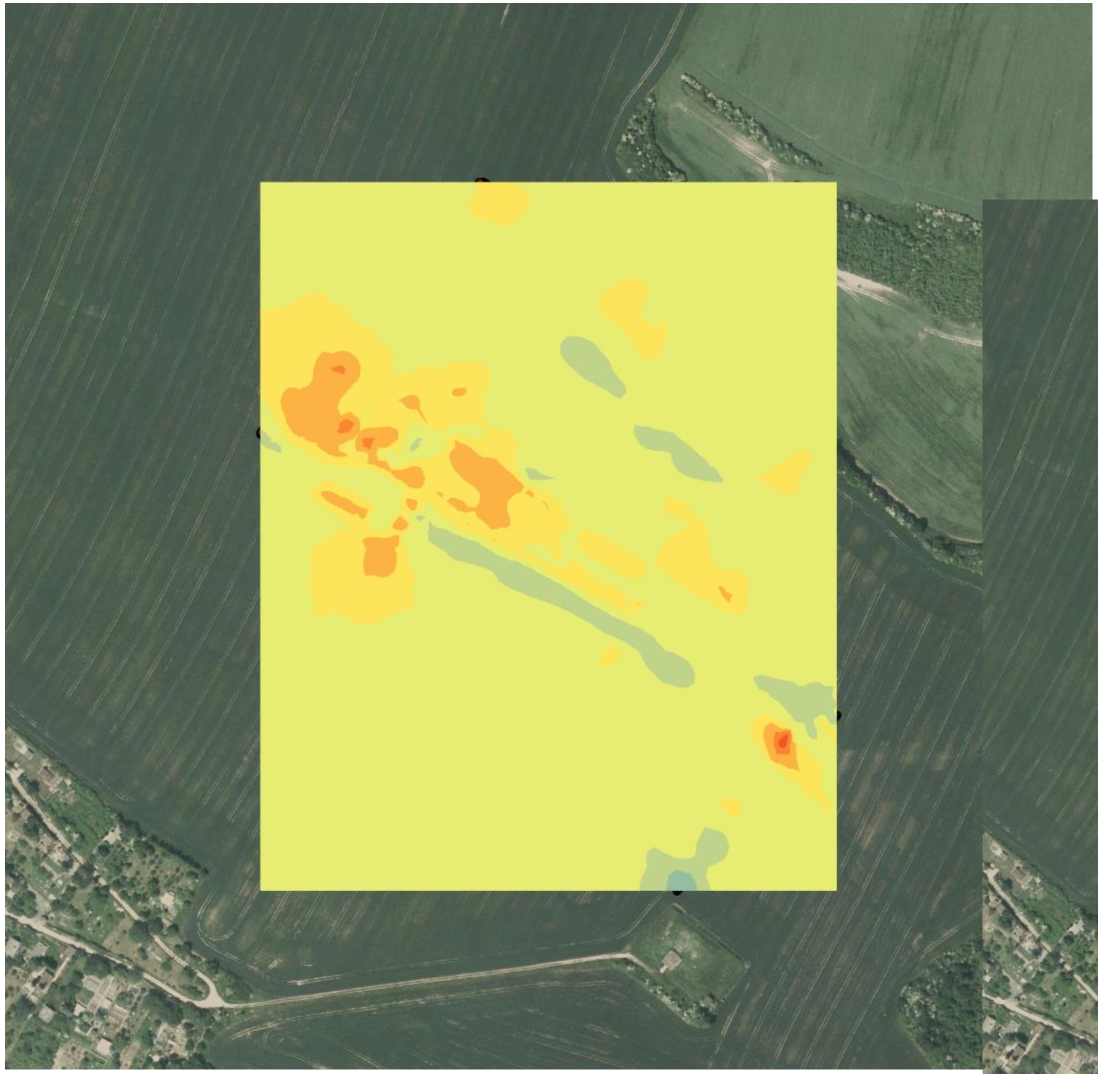


Ortofoto 2002

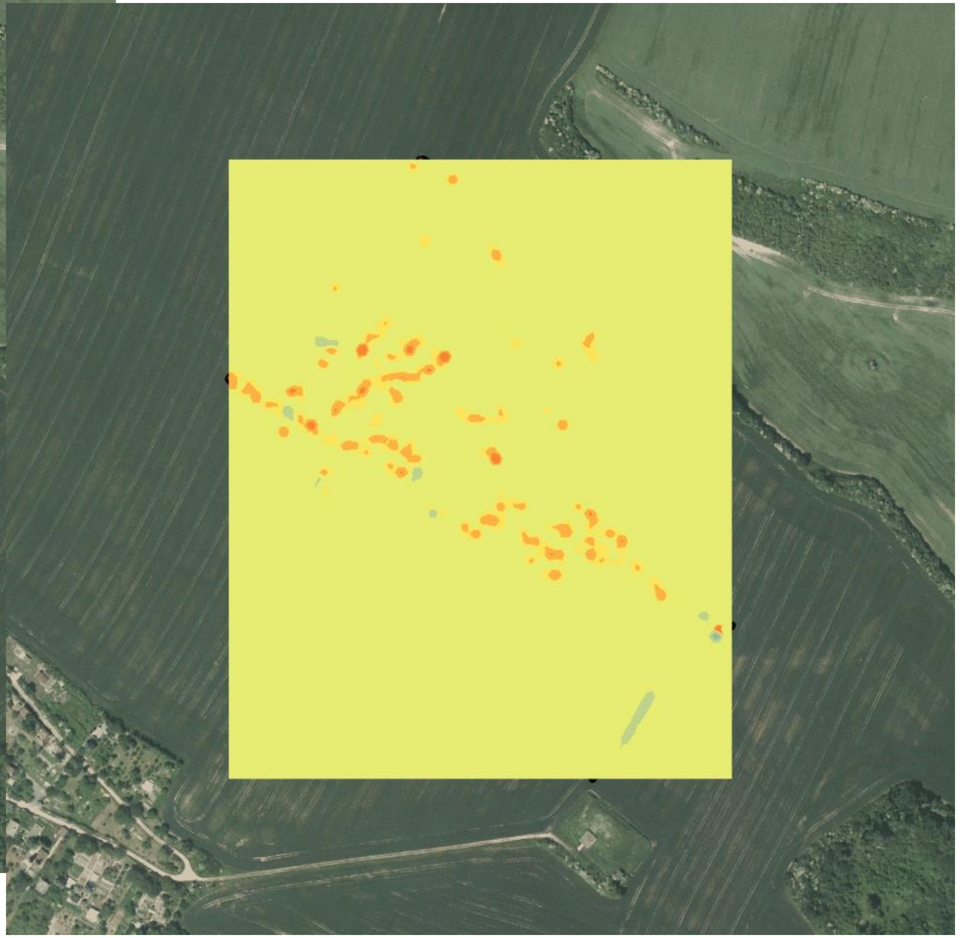
Ortofoto 2003

Magnetometrical measurement

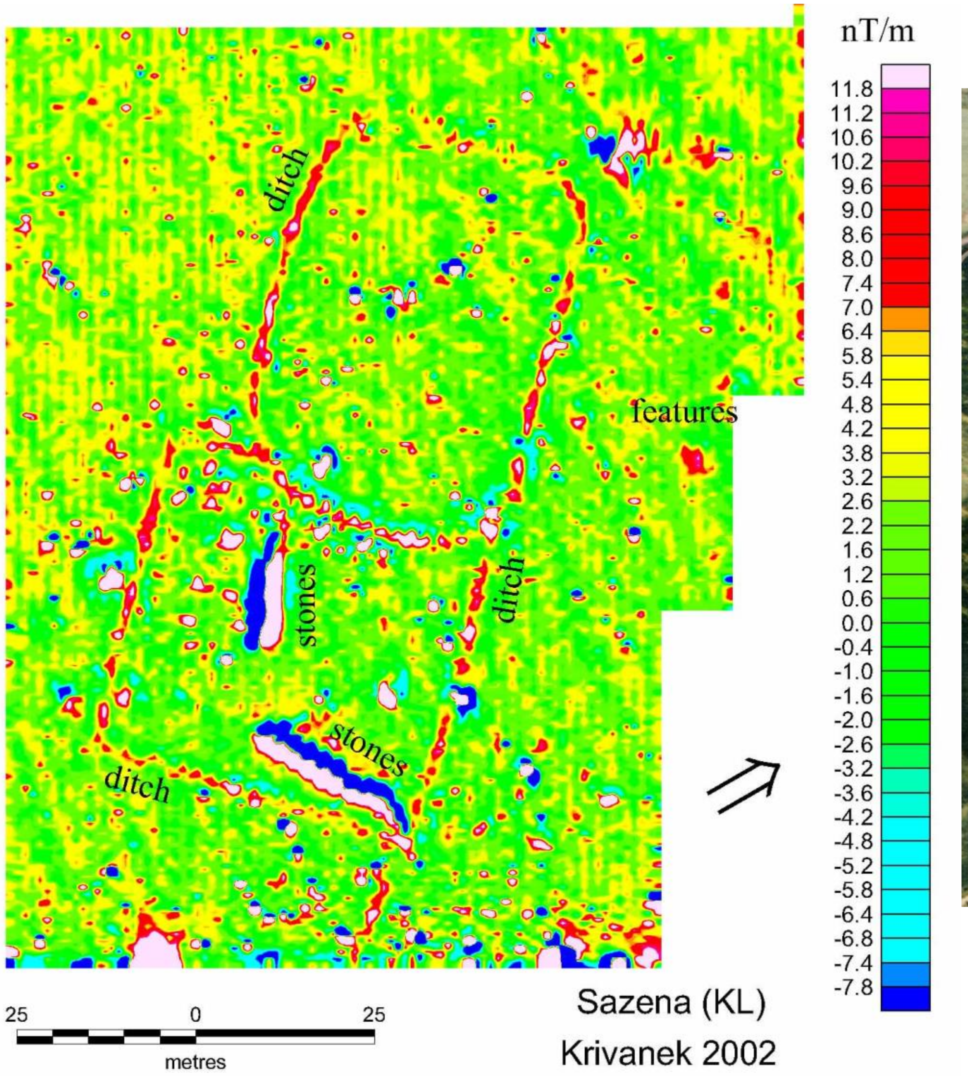
kriging nT



nT_m



Professional measurement (cesium magnetometer)



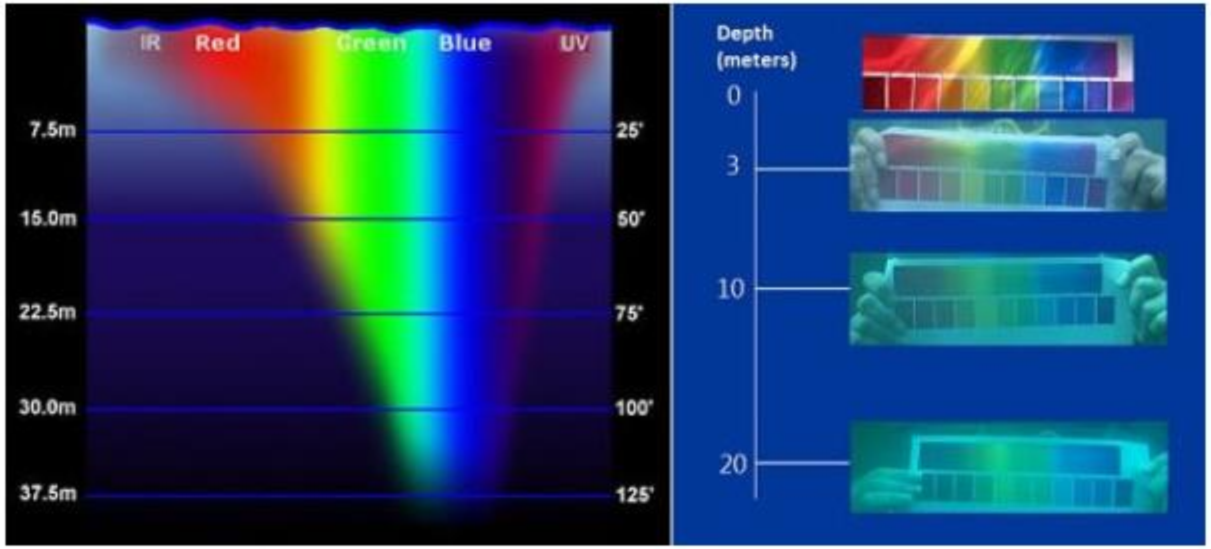
Archeologický ústav, Dr.Křivánek

Measurement under water

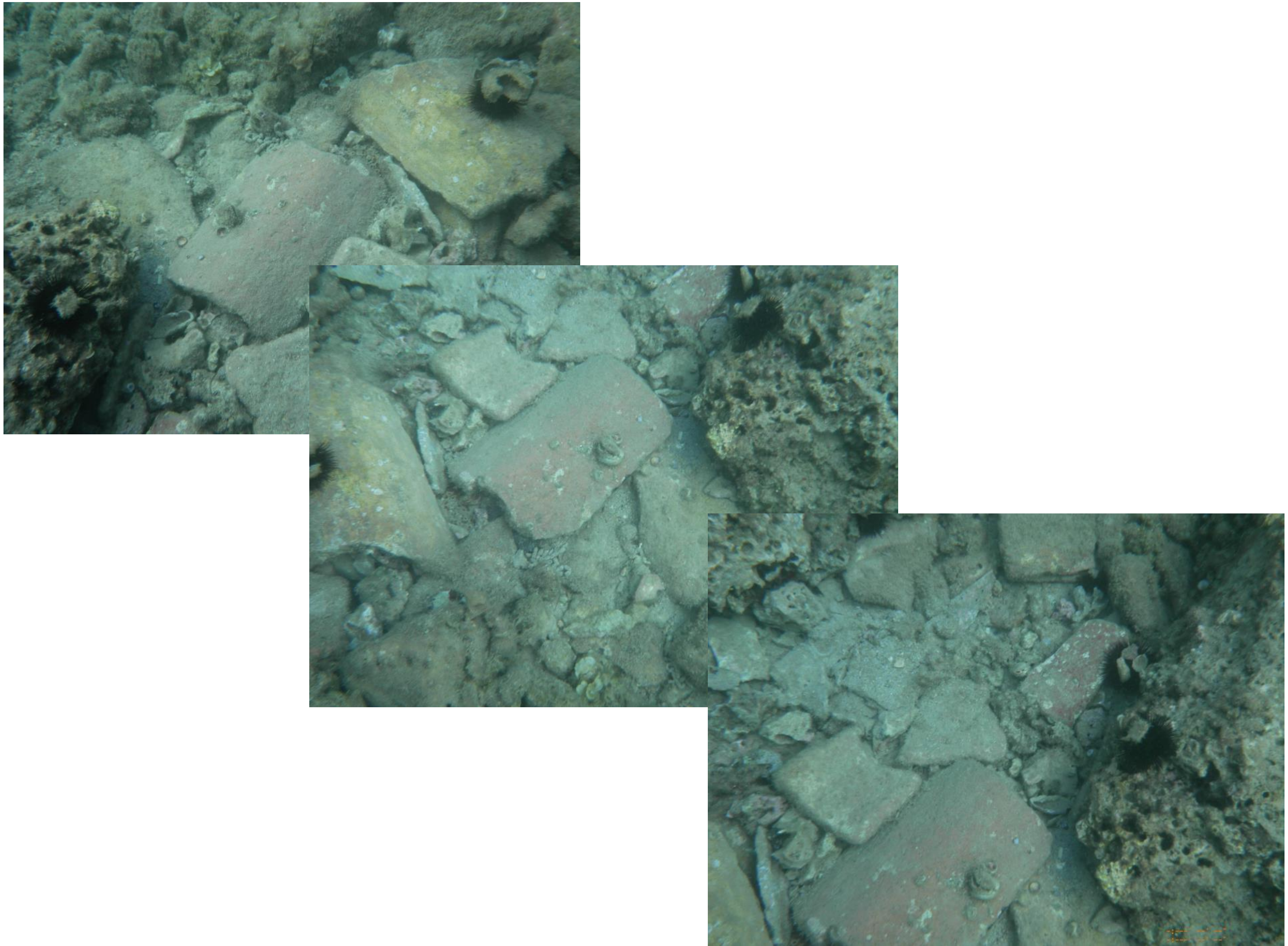
- -Sonar + GNSS-Underwater photogrammetry-(diver + waterproof camera (IBMR technology)-Underwater drone

Underwater Fotogrammetry?

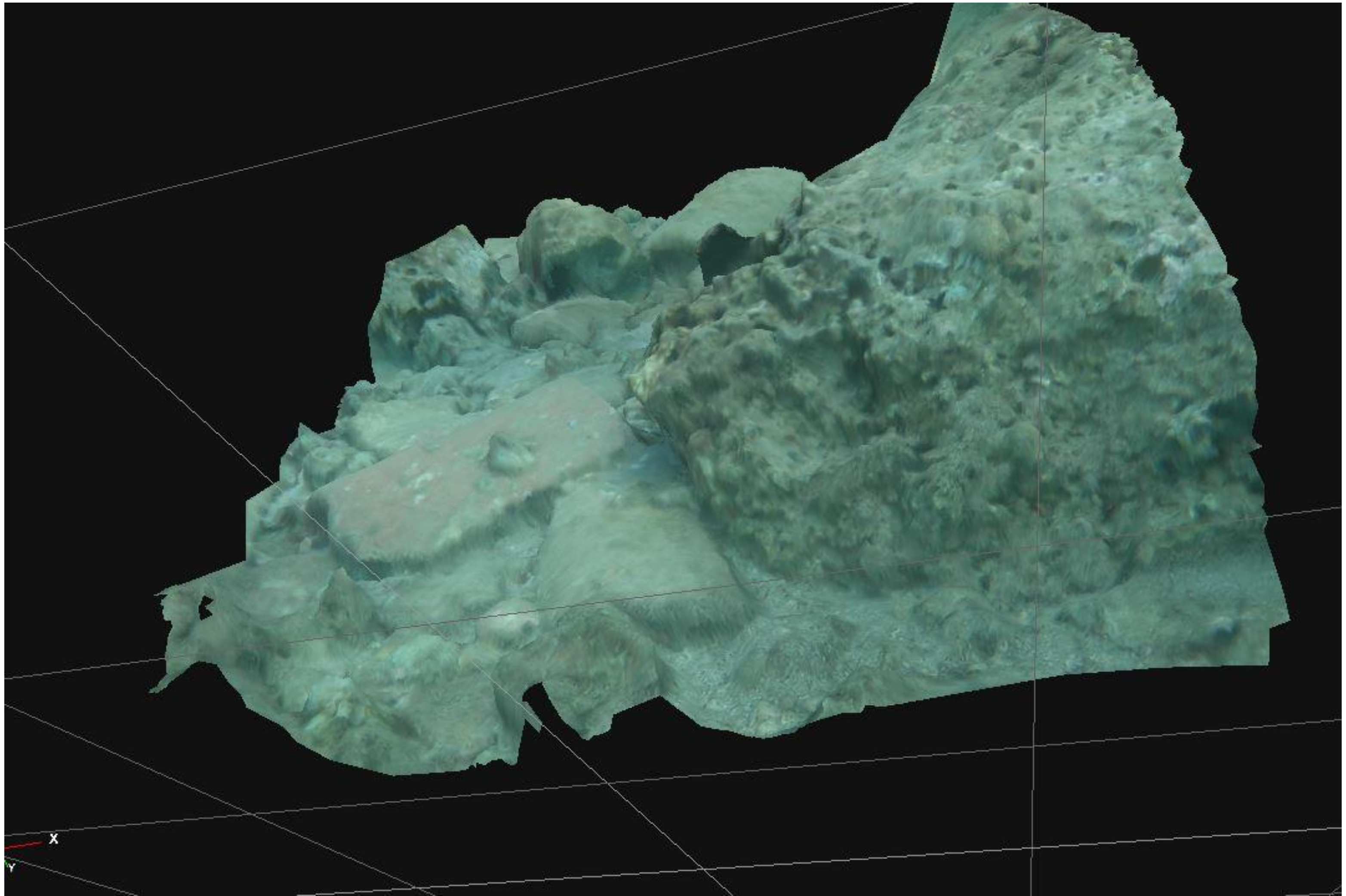
- -You can, but it must be borne in mind that:
- 1.water refracts light differently than air
- 2.variable environment (density, salinity, currents)
- 3.lighting - from 30-40m artificial lighting is necessary (in clear sea)
- 4.more difficult to photograph

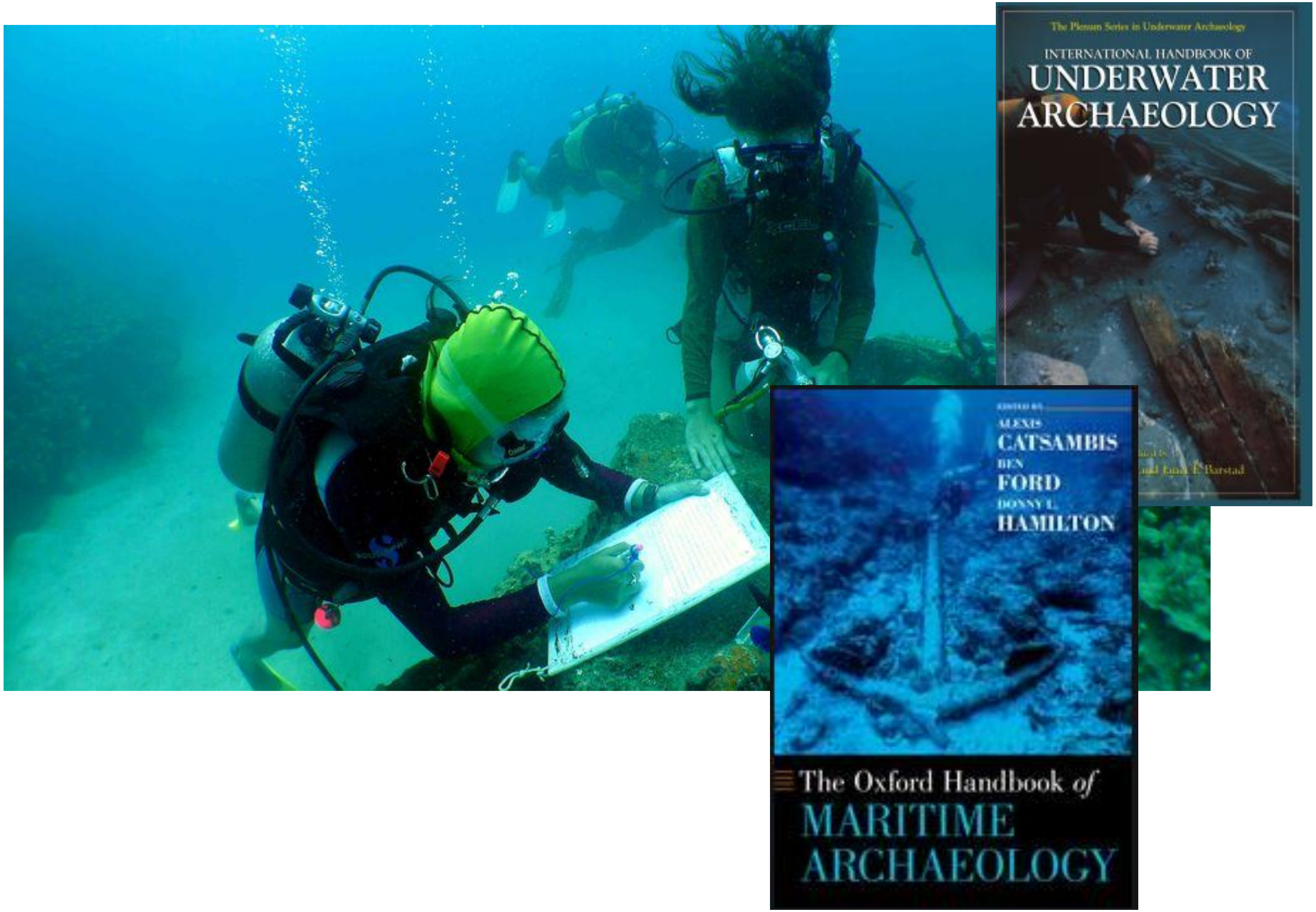


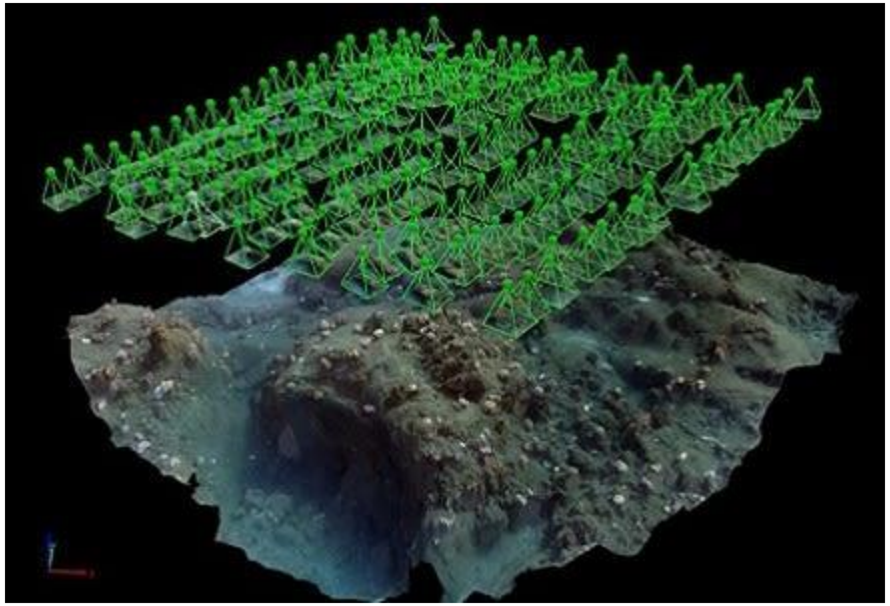
Every color is percieved differently underwater, based on its wavelength.

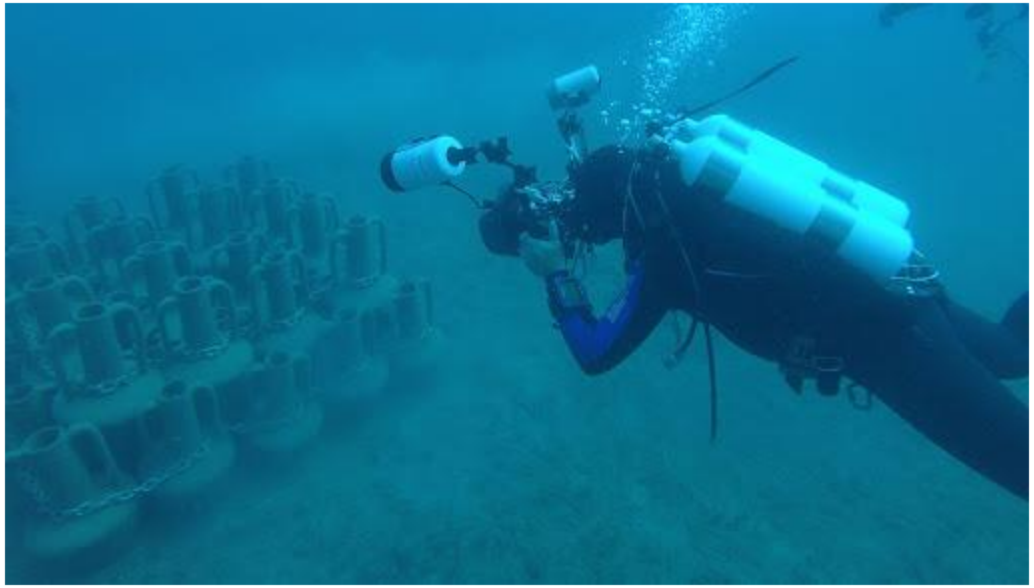


Processing: (SfM - IBMR) or other methods (intersection fm)




The Plenum Series in Underwater Archaeology
INTERNATIONAL HANDBOOK OF
UNDERWATER
ARCHAEOLOGY
ALEXIS
CATSAMBIS
BEN
FORD
DONNY L.
HAMILTON
The Oxford Handbook of
MARITIME
ARCHAEOLOGY



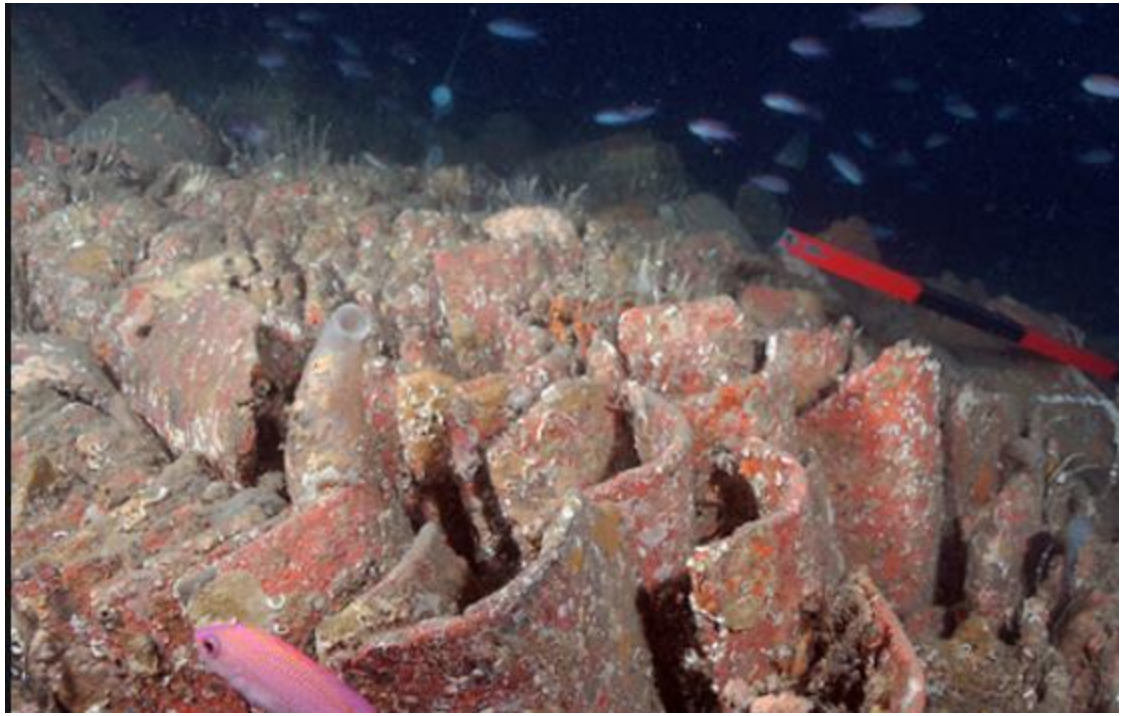


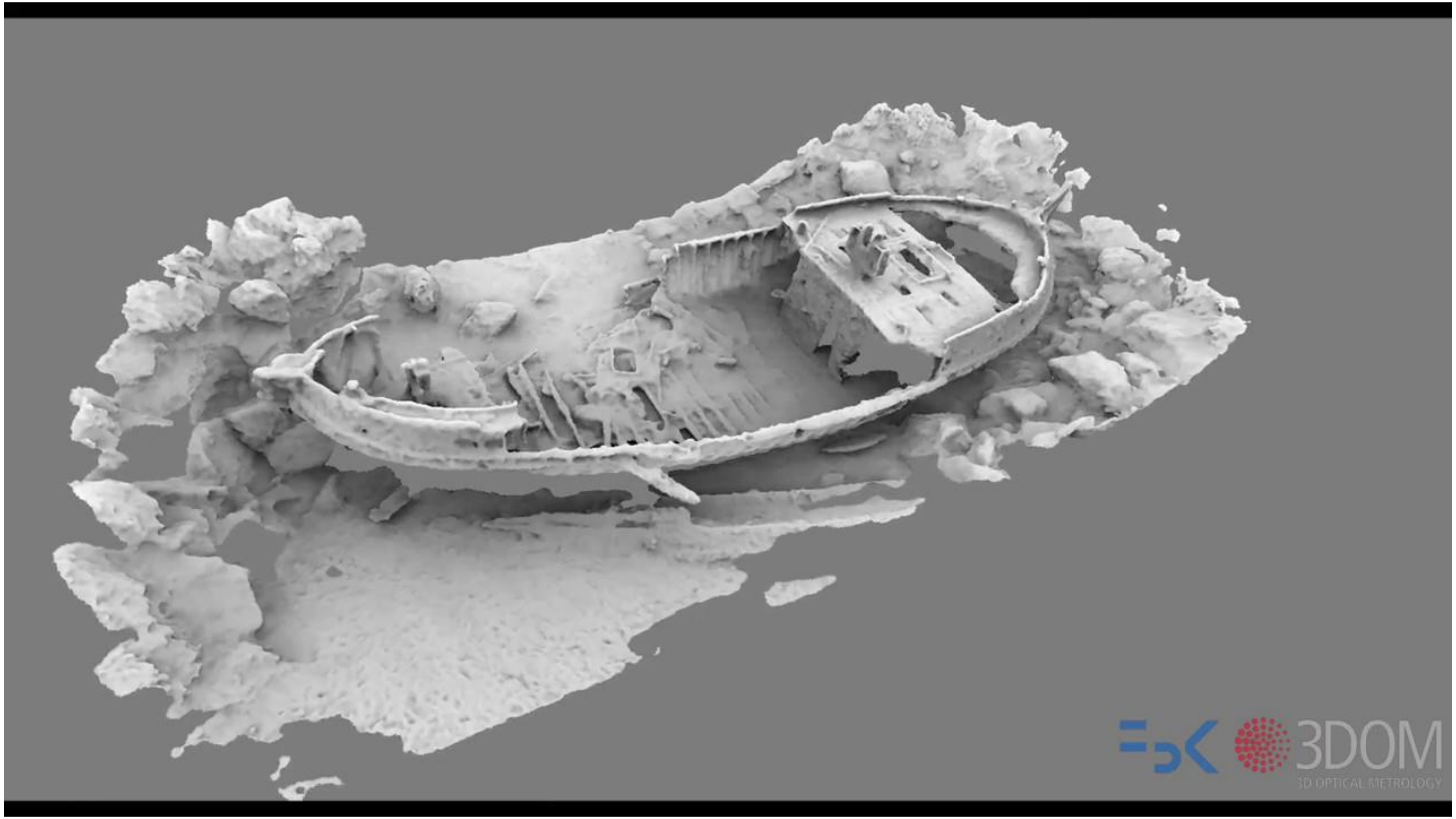
CIPA has its own working group on underwater photogrammetry

http://www.lsis.org/cipa-uwp/#

CIPA
Heritage
Documentation

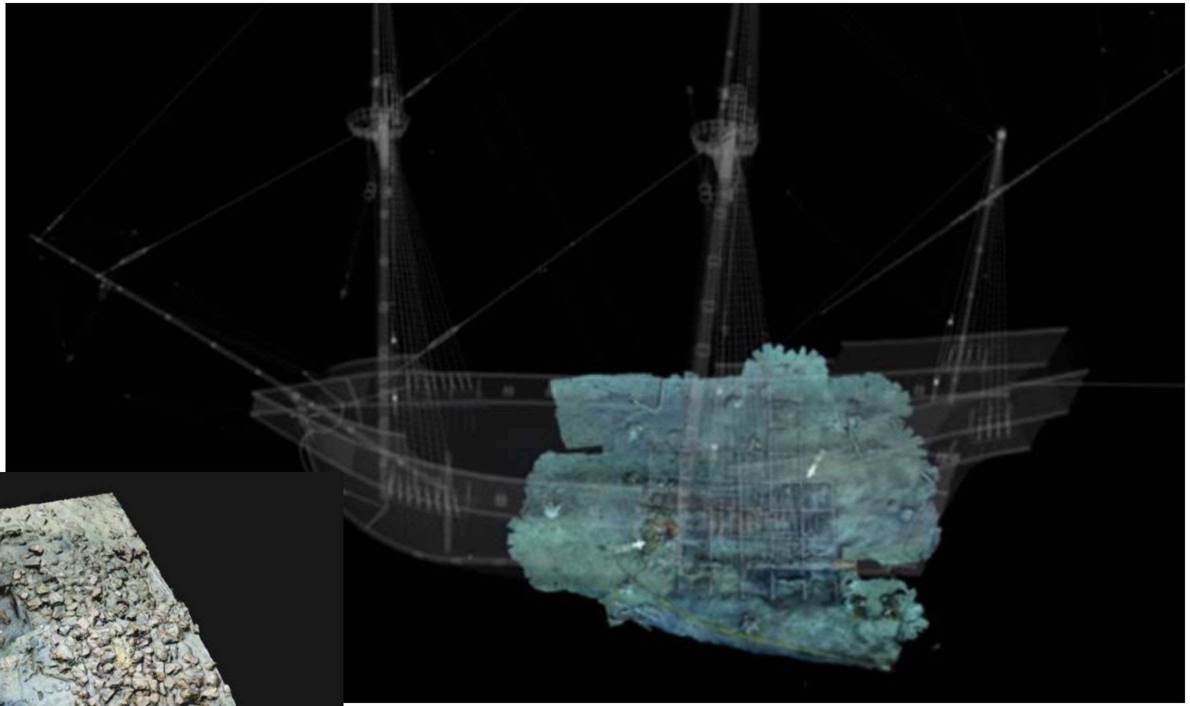
Underwater Photogrammetry
Task Group

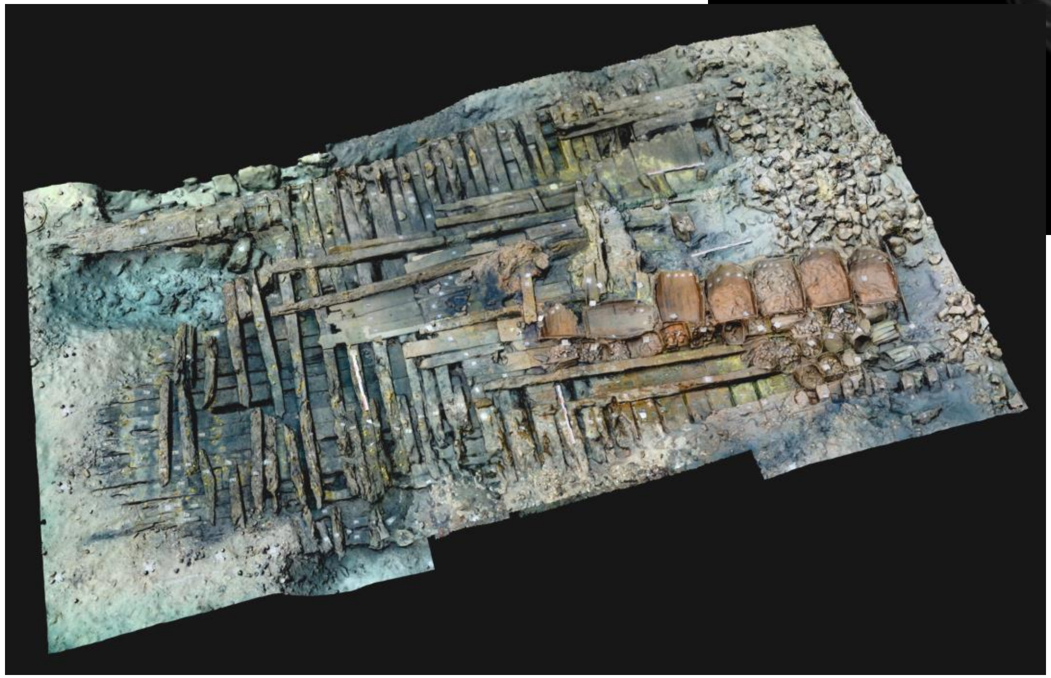



3DOM
3D OPTICAL METROLOGY

Gnalič (HR, Biograd na moru), 16th century wreck

- https://www.youtube.com/watch?v=s7ONnWlHmRg





E-mail: pavelka@fsv.cvut.cz