MUON TOMOGRAPHY
-LOUMU PROJECT-

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LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

UNIVERSIDADE
DE ÉVORA

Centro
Ciência Viva
do Lousal
Mina de Ciência

FCT Fundação
para a Ciência
e a Tecnologia

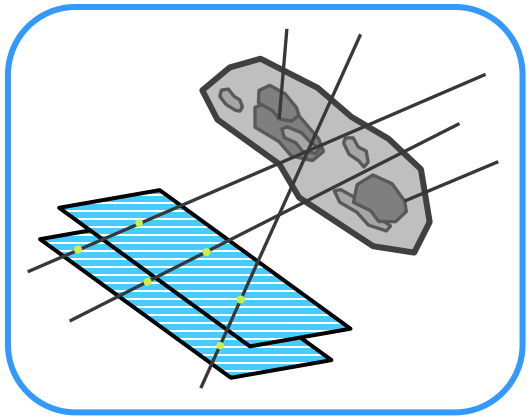
CERN/FIS-PAR/0031/2019

MUON TOMOGRAPHY

OVERVIEW

MUON TOMOGRAPHY

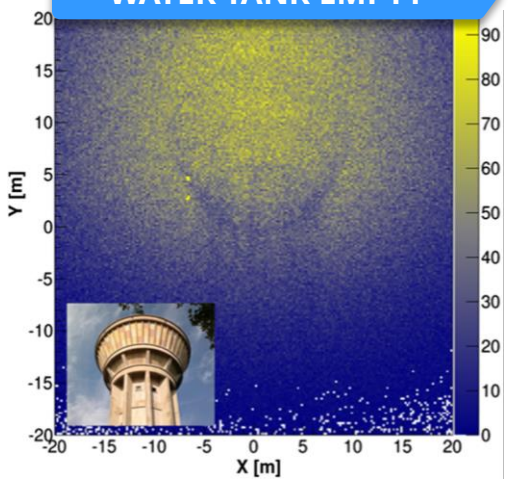
MUON TRANSMISSION



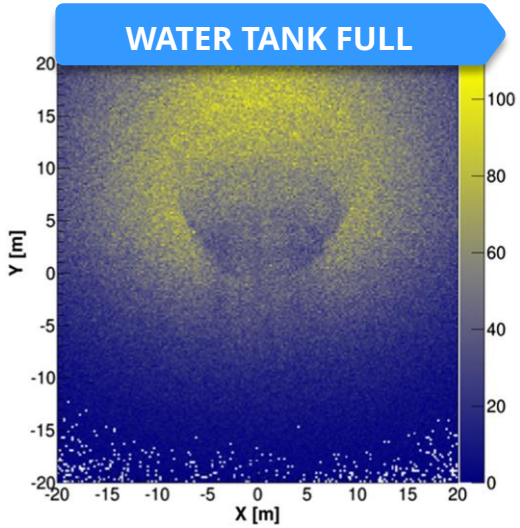
MUOGRAPHY OF A WATER TOWER (FRANCE)

- 4 days of exposure for each image
- density differences observed

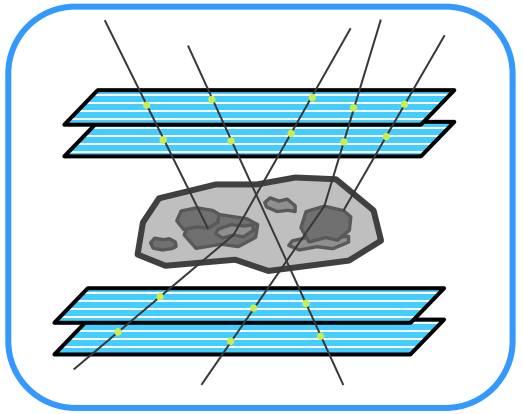
WATER TANK EMPTY



WATER TANK FULL

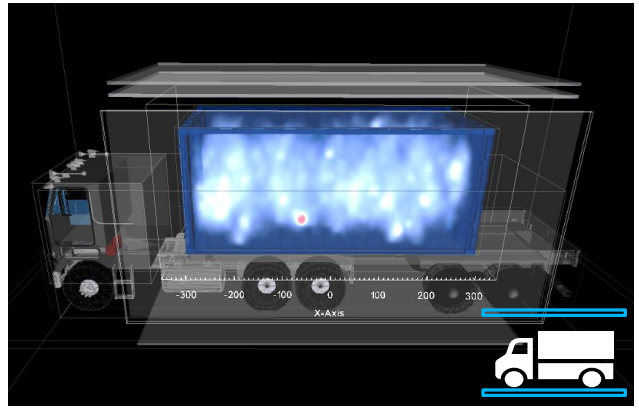


MUON SCATTERING



PORTAL SCANNER (BAHAMAS)

- trafficking surveillance of high dense materials (eg. radioactive)
- in this case, the inspection takes less than 5 min

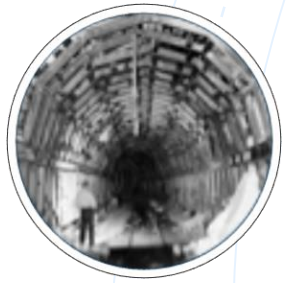


MUON TOMOGRAPHY

BRIEF TIMELINE

MUON TOMOGRAPHY - BRIEF TIMELINE

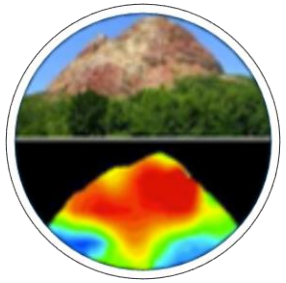
1955 — 1ST USE: AUSTRALIA TUNNEL



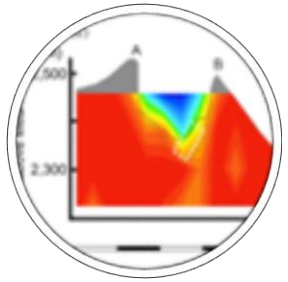
1969 — CHEPHREN PYRAMID

MUOGRAPHY BEGINS

2007 — AVERAGE DENSITY PROFILE OF MT. ASAMA



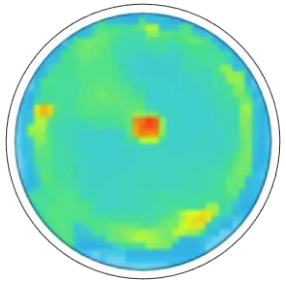
2009 — MUOGRAPHY AND GRAVIMETRY



JAPAN LEADS GEOPHYSICAL APPLICATIONS

2014 — BUILDING STABILITY MONITORIZATION

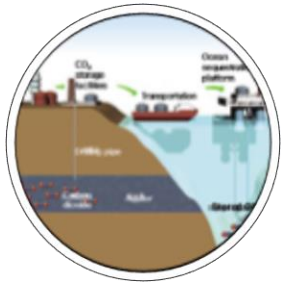
2014 — NUCLEAR WASTE CONTROL



MONITORING SYSTEMS

2017 — CHEOPS PYRAMID

APPLICATIONS IN STUDY



CO2 STORAGE SITES

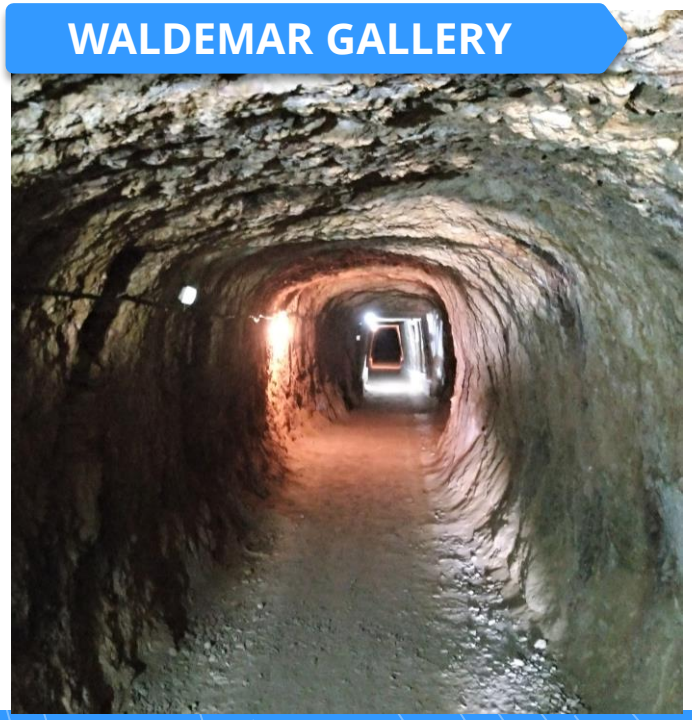
MUON TOMOGRAPHY IN MARS

MUON TOMOGRAPHY

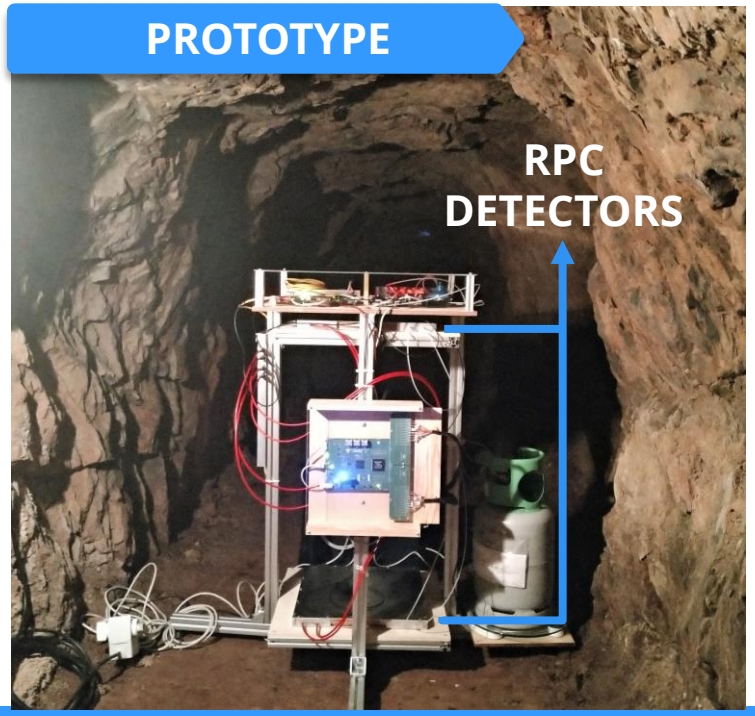
LOUMU PROJECT

LOUSAL MINE

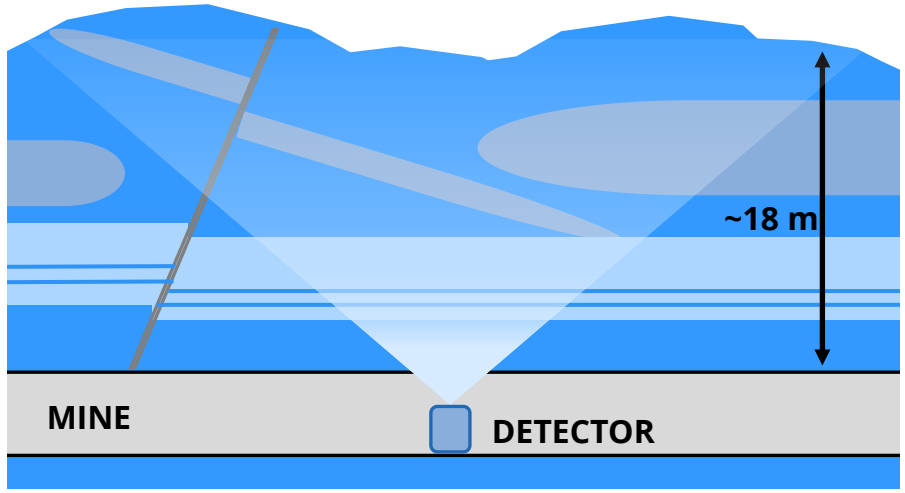
WALDEMAR GALLERY



PROTOTYPE



OBJECTIVE: to do a geological reconnaissance of the ground above the mine to test the performance and the sensitivity of the telescopes.

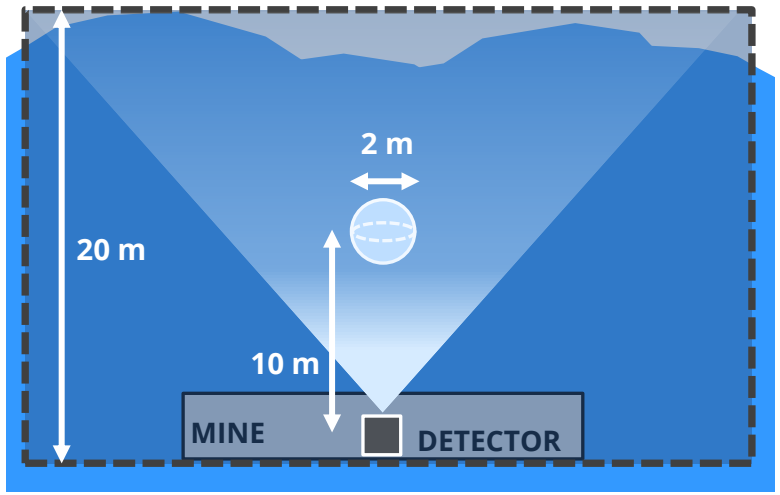


MUON TOMOGRAPHY

GEANT SIMULATIONS

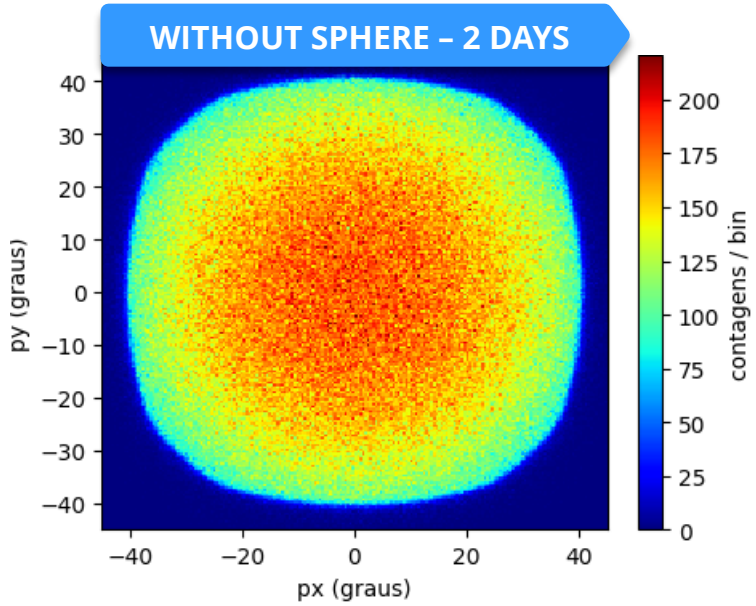
GEANT4 SIMULATIONS

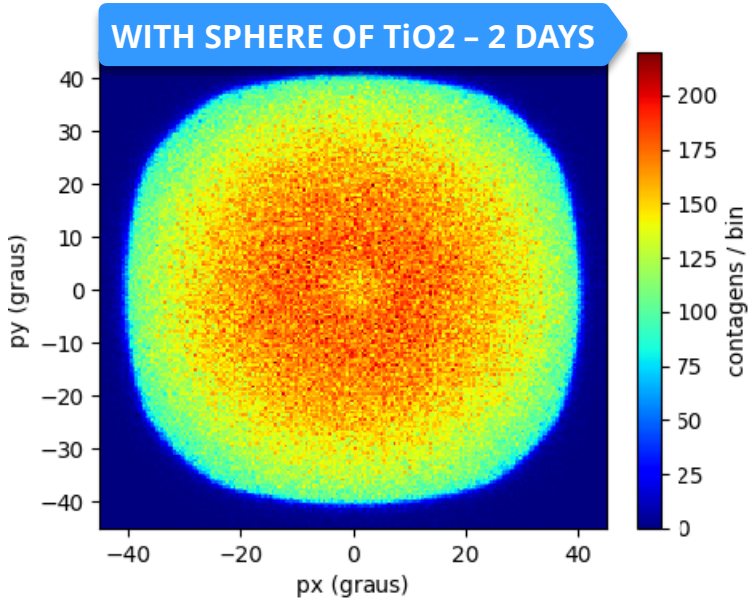
BUILDING A SIMPLE GEOMETRY



ANALYSING THE RESULTS

Materials	Density (g/cm3)		1 day	2 days	4 days	8days
Air	0,0012	-2,6	O	O	O	O
Water	1	-1,6	O	O	O	O
Bone	1,85	-0,75	X	X	V	O
Lithium Oxide (Li2O)	2,013	-0,59	X	X	?	?
Concrete	2,3	-0,3	X	X	X	?
Glass Plate	2,4	-0,2	x	x	x	?
Sodium Carbonate (Na2CO3)	2,54	-0,06	x	x	x	?
Shale (medium)	2,6	0	x	x	x	?
Silica (SiO2)	2,648	0,05	x	x	x	?
Aluminium (Al)	2,7	0,1	x	x	x	?
Magnesium Carbonate (MgCO3)	2,958	0,36	X	X	X	?
Calcium Oxide (CaO)	3,34	0,74	X	X	V	?
Aluminium Oxide (Al2O3)	3,987	1,39	X	V	O	O
Titanium Dioxide (TiO2)	4,23	1,63	O	O	O	O
Ferric Oxide (Fe2O3)	5,25	2,65	O	O	O	O
Silver Bromide (AgBr)	6,473	3,87	O	O	O	O
Lead Oxide (PbO)	9,53	6,93	O	O	O	O
Plutonium Dioxide (PuO2)	11,5	8,9	O	O	O	O
Gold (Au)	19,3	16,7	O	O	O	O



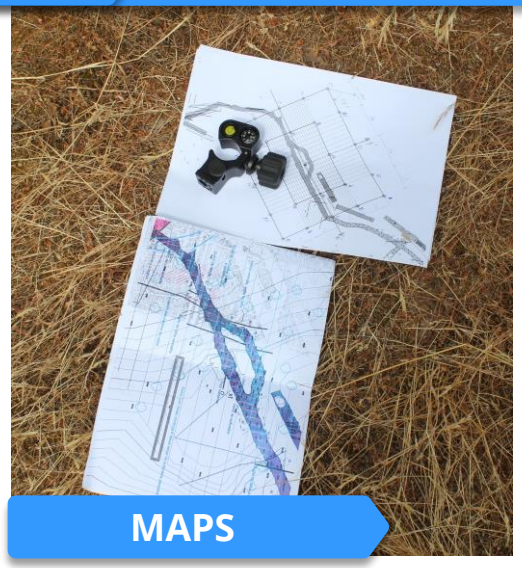


- Part of the work is about developing simulations in GEANT4, so we can have references when we analyse the muography data.

MUON TOMOGRAPHY

GEOPHYSICAL SURVEY

SITE PREPARATION



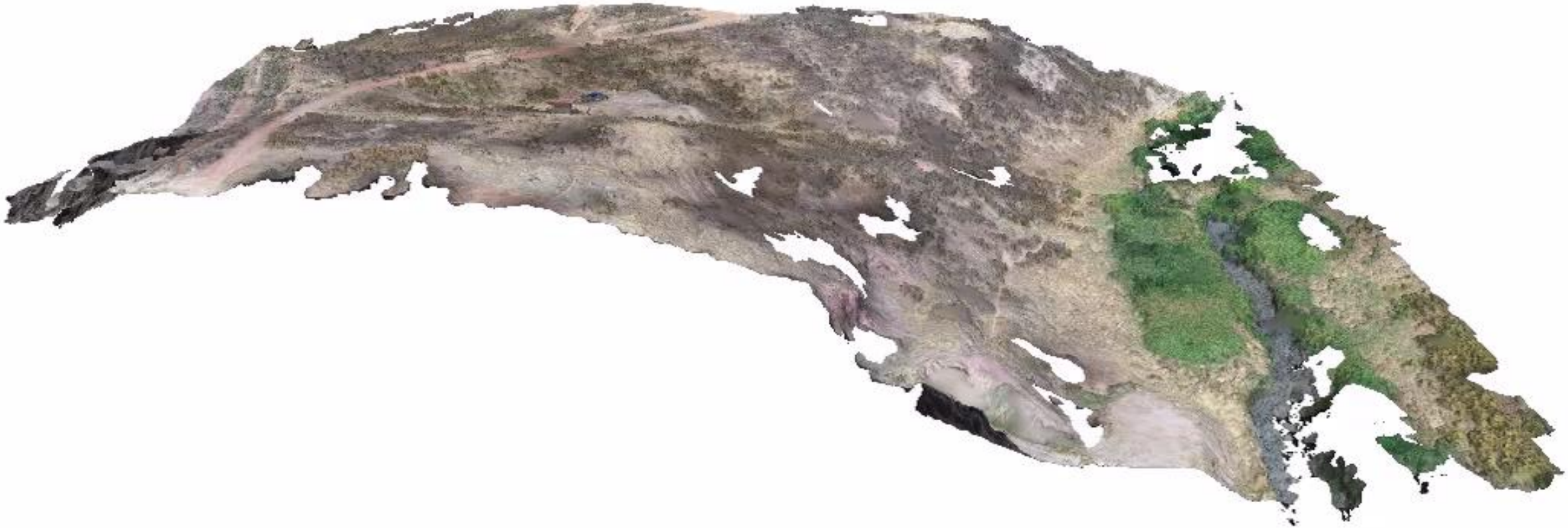
MAPS

GPS EQUIPMENT

PHOTOGRAMMETRY

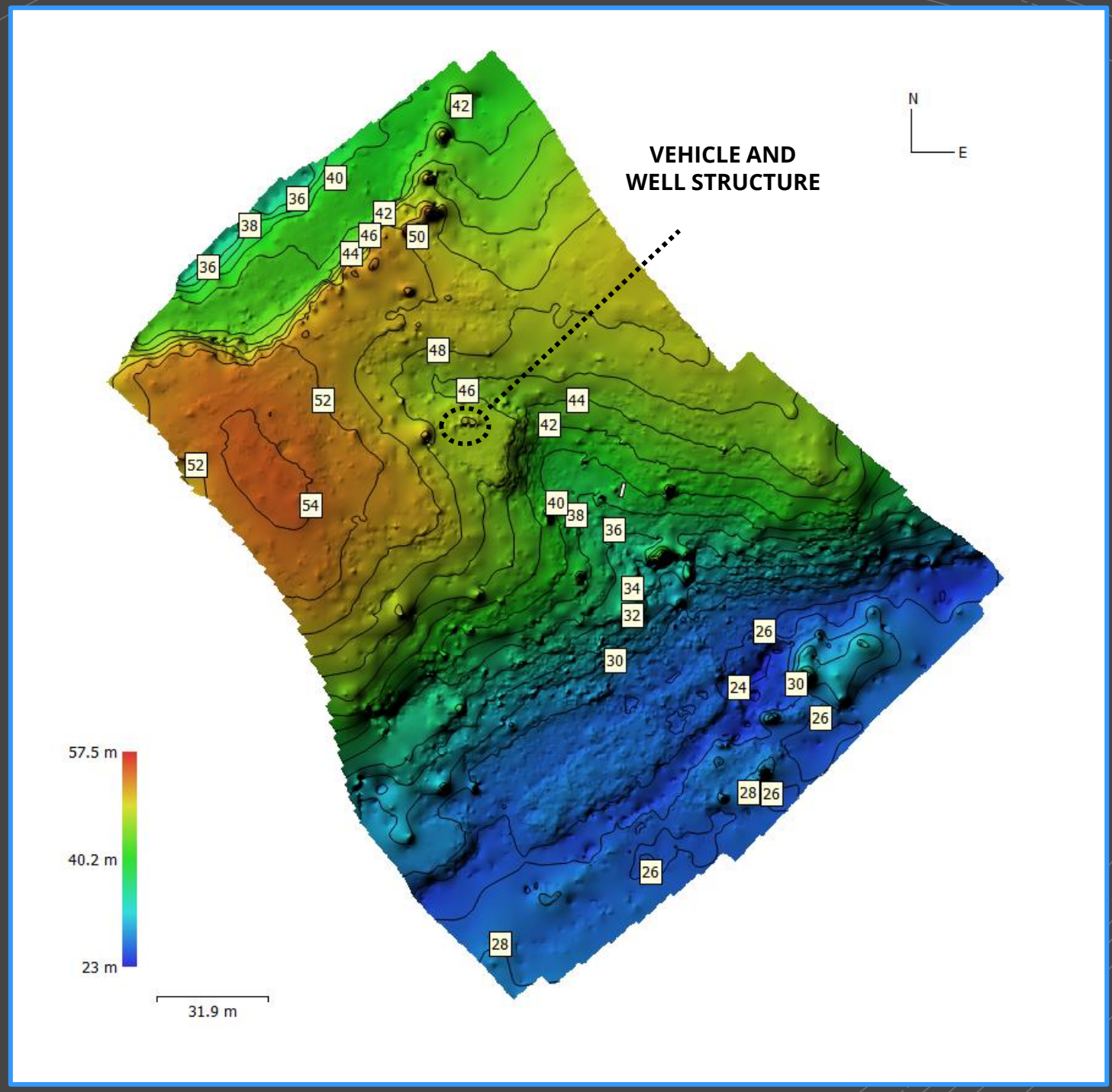
DRONE

DIGITAL MAP SURFACE (v.2)



DIGITAL ELEVATION MAP

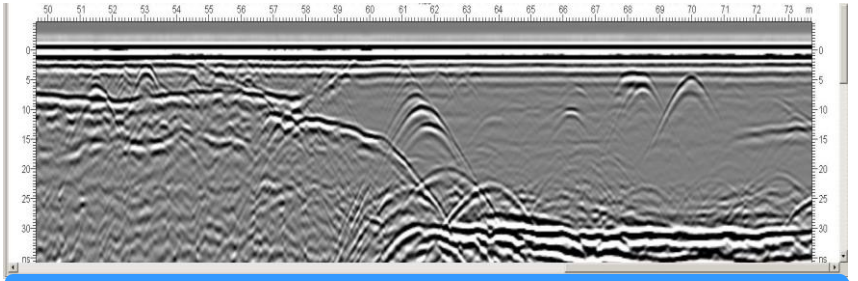
A detailed description of the topology is necessary to compare the observed information with the expected results.



GPR – GROUND PENETRATING RADAR

GPR ANTENNA

- It measures the electrical resistivity of the materials.



GPR PROFILE (EXAMPLE FROM OTHER WORK)

SEISMIC REFRACTION

SEISMIC SENSORS

- It measures the speed propagation of the seismic waves.

WELL OF THE MINE

WORK PROGRESSION

STANDARD TECHNIQUES

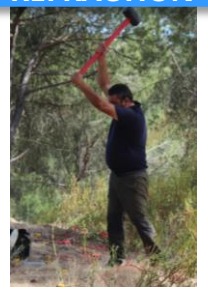
PHOTOGRAMMETRY

+

GPR

+

SEISMIC REFRACTION



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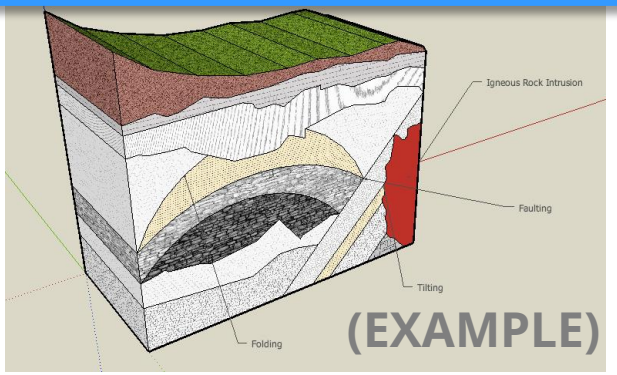
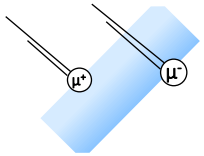
REFERENCE GEOLOGICAL PROFILE



(EXAMPLE)

FOCUS TECHNIQUE

MUOGRAPHY



$$\phi \propto \frac{1}{\rho}$$

$$g \propto \rho$$

JOINT INVERSION

MUOGRAPHY

obtains the density through the attenuation of the muon flux

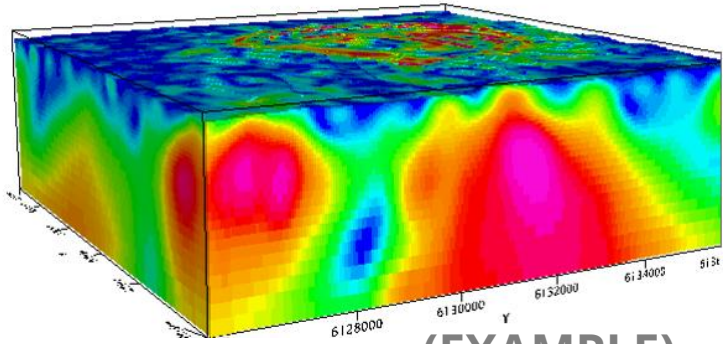
+

GRAVIMETRY

obtains the density through the strength of the gravitational field

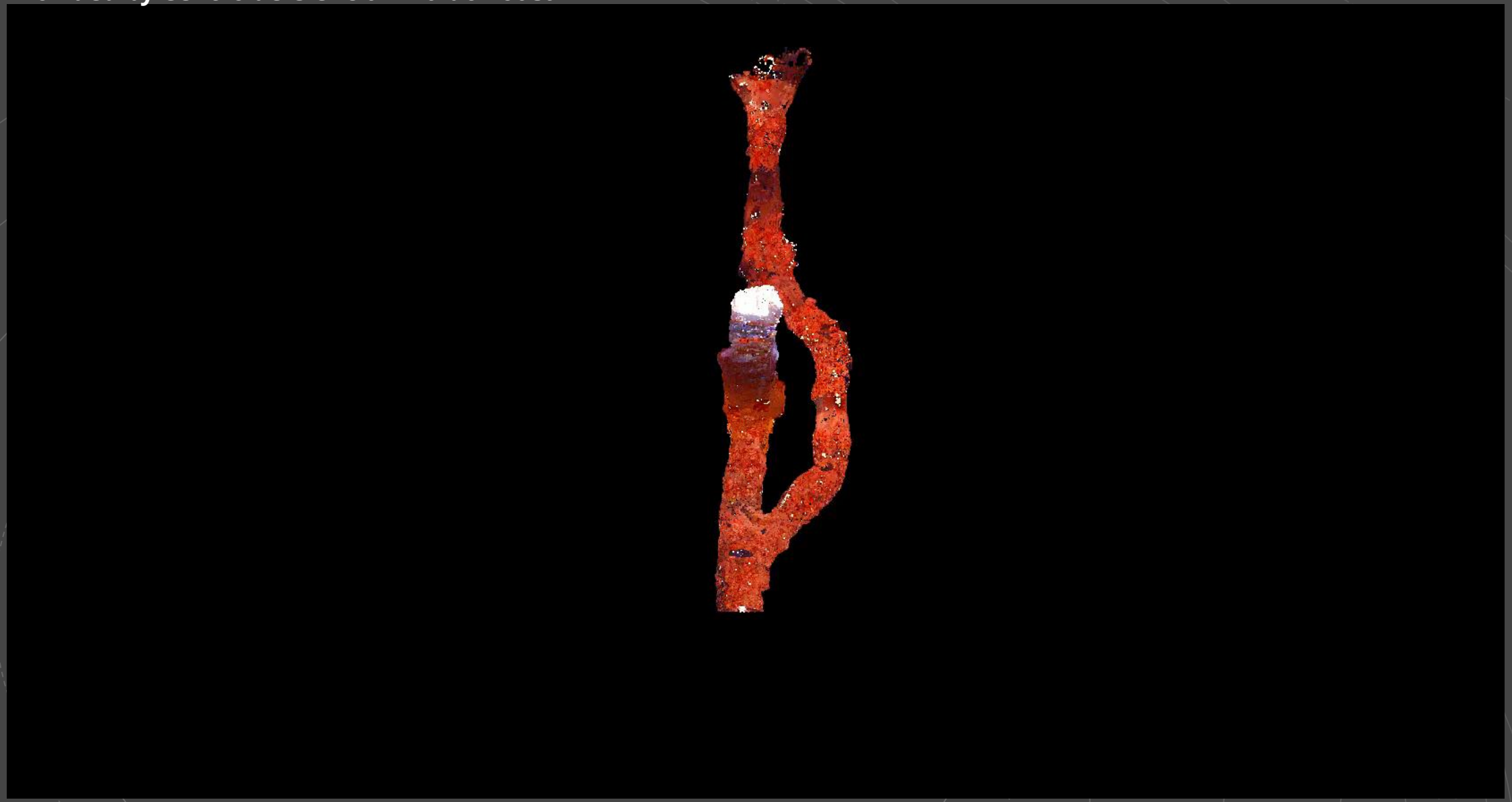
=

RECONSTRUCTED 3D DENSITY PROFILE



(EXAMPLE)

Provided by Centro de Ciência Viva do Lousal



THANK YOU!

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