MUOGRAPHY FOR UNDERGROUND GEOLOGICAL SURVEYS

ONGOIG APPLICATION AT THE LOUSAL MINE (PORTUGAL)

PEDRO TEIXEIRA

IN COLLABORATION WITH LOUMU TEAM

ICT Instituto de Ciências da Terra Institute of Earth Sciences

UNIVERSIDADE DE ÉVORA

LIP LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS partículas e tecnologia

Centro Ciência Viva do Lousal Mina de Ciência

LNEG

FCT Fundação para a Ciência e a Tecnologia

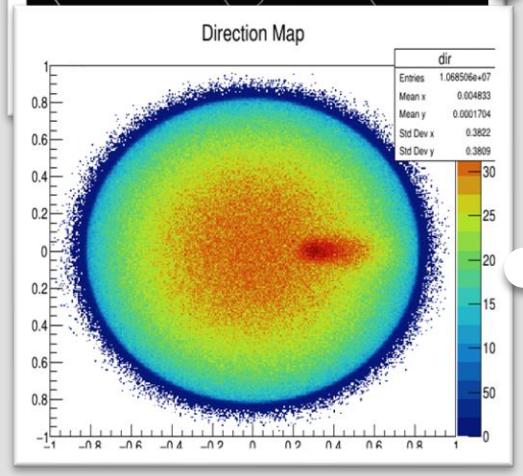
REPÚBLICA PORTUGUESA

THE LOUMU PROJECT AND THE LOUSAL MINE

LOUMU PROJECT

LouMu
SCIENCE WITH COSMIC MUONS AT THE LOUSAL MINE

SIMULATIONS AND ANALYSIS TOOLS



LIP
LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

Laboratory of Instrumentation and Experimental Particle Physics (LIP)

PURPOSE: to develop and make muography available in Portugal for applications in geophysics

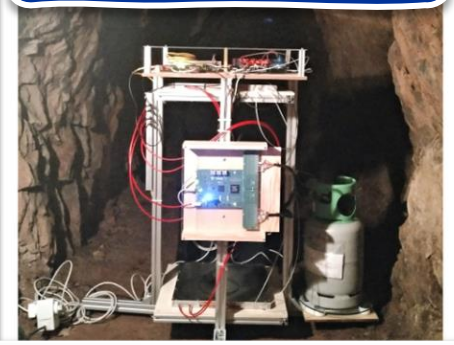
ICT
Instituto de Ciências da Terra
Institute of Earth Sciences
UNIVERSIDADE DE ÉVORA

Institute of Earth Sciences of the University of Évora

Centro Ciência Viva do Lousal
Mina de Ciência

Lousal Living Science Center

MUOGRAPHY AND TELESCOPES

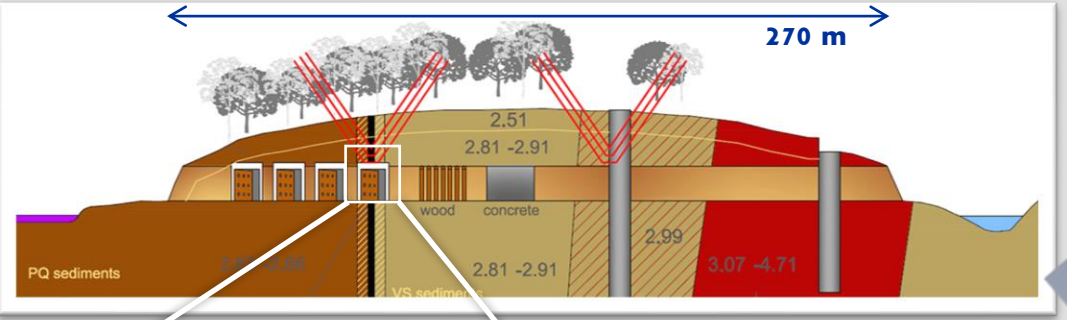


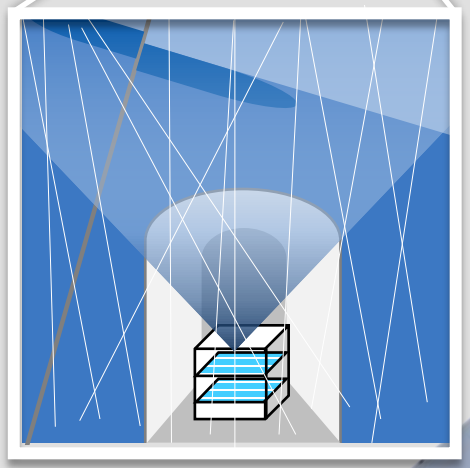
GEOPHYSICAL WORK

OUTREACH ACTIVITIES

LOUSAL MINE

GOAL: to do a geological survey of the terrain between the telescope and the surface with muography and improve the existing information with new data while evaluating the performance of the telescope and the muography analysis tools .





PROTOTYPE - 2019

COREPIX - 2022

WALDEMAR GALLERY

MINE ENTRANCE

MUON TELESCOPE / COREPIX

IN COIMBRA

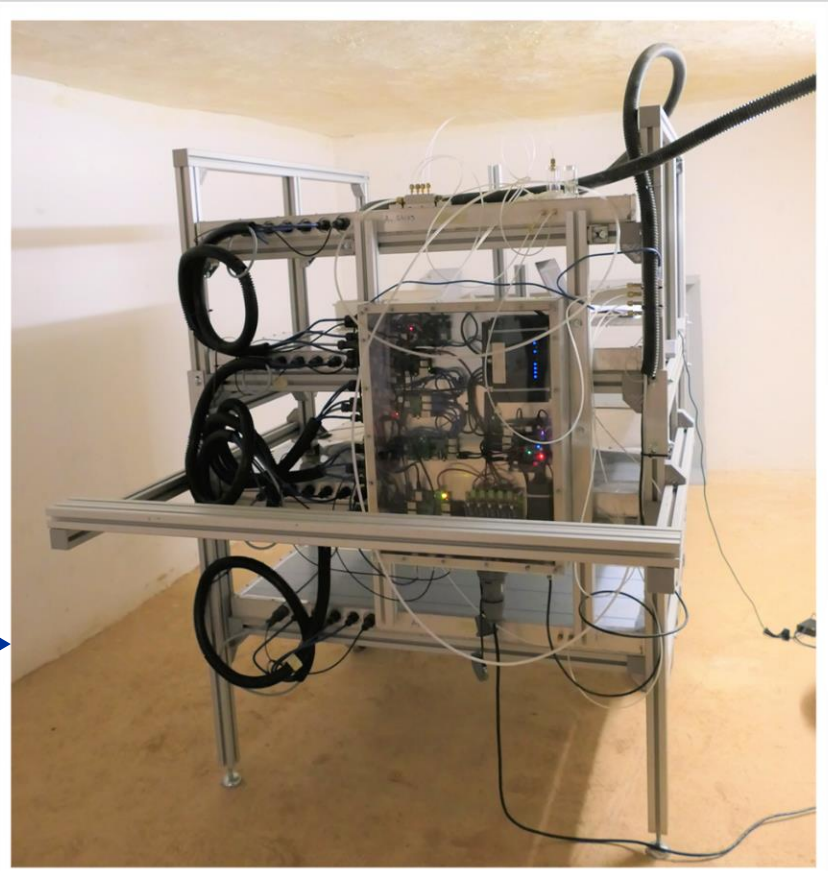
- CorePix telescope was developed in the LIP detectors laboratory, in Coimbra, where it stayed for several months collecting data for calibration purposes.

- It was moved to the Lousal Mine on April 26th 2022, and placed in one of the storage rooms of the mine gallery. The muography data acquisition started on the week after.

COREPIX

- 4 RPC detectors
- Size 1 m x 1 m square shaped
- Current location: gallery storage room nº 4 (Paiol 4)

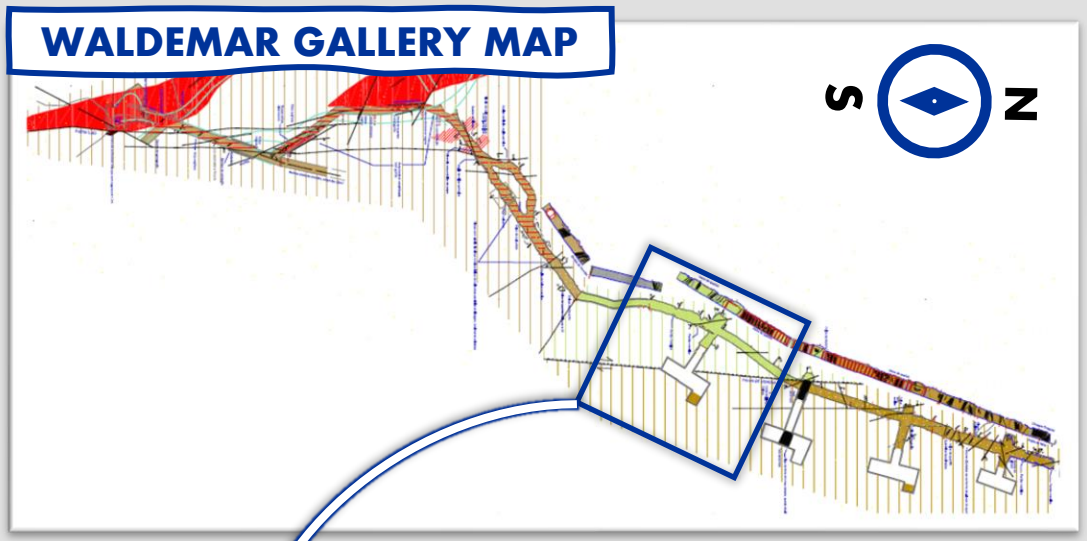
IN LOUSAL MINE

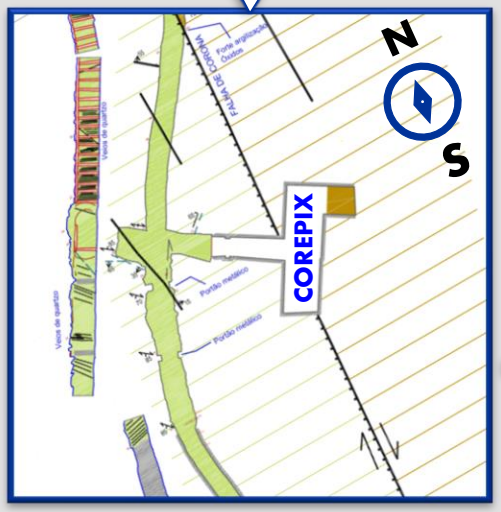


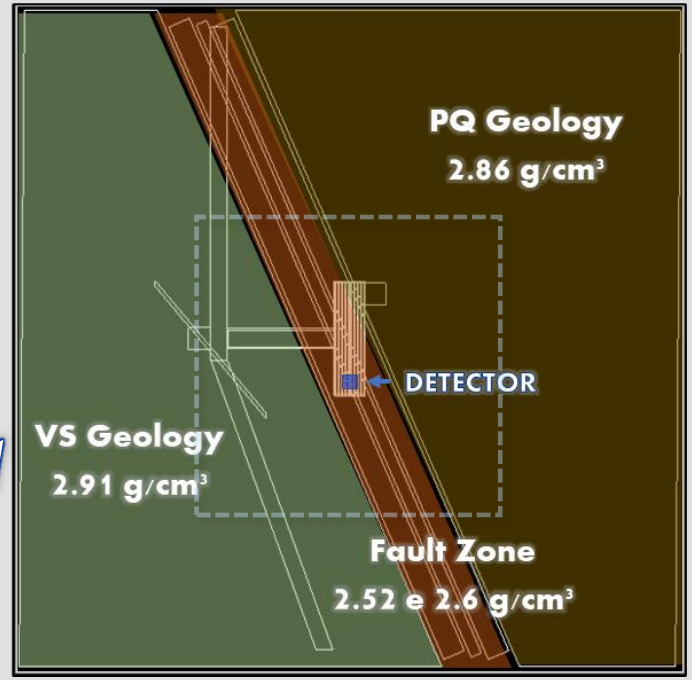
SIMULATIONS AND ANALISYS

COREPIX MINE LOCATION SIMULATION

WALDEMAR GALLERY MAP

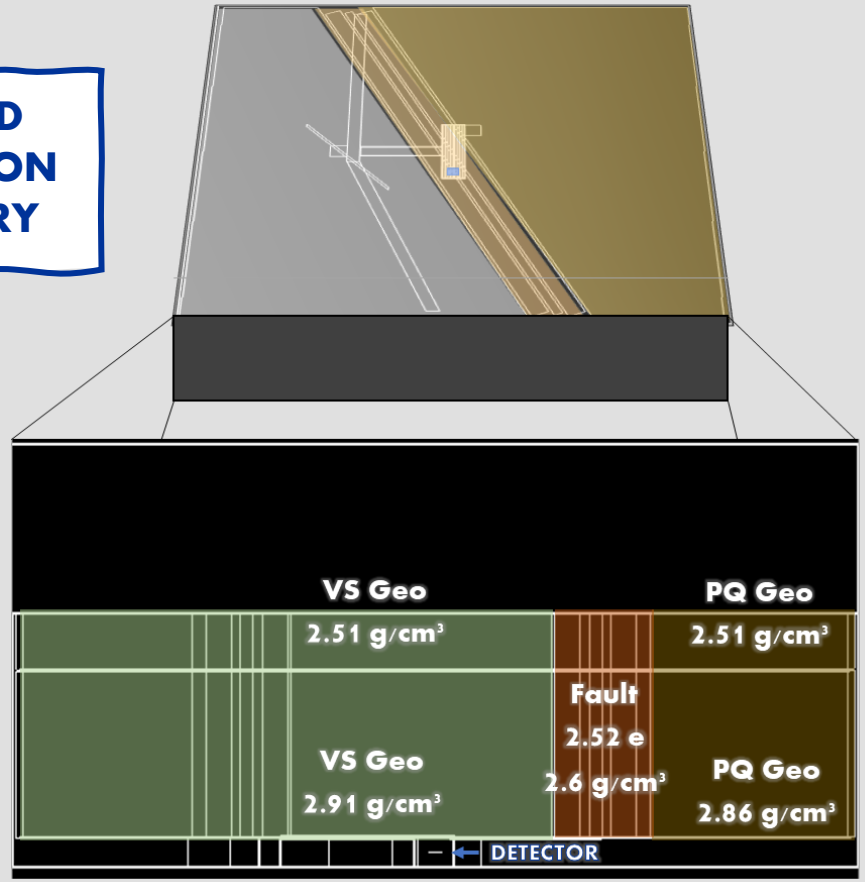






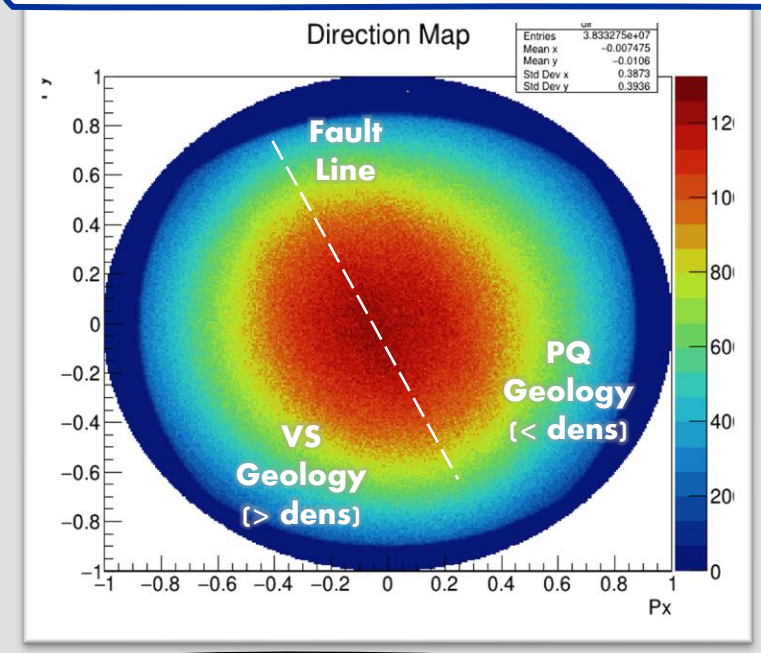
- Simulations are done in Geant and the latest approach uses a geometry based on the current location of the muon telescope inside the storage room nº 4.
- A regional fault (Corona Fault) crosses the location and on each side the geology has a different composition and density (both higher than the fault zone.

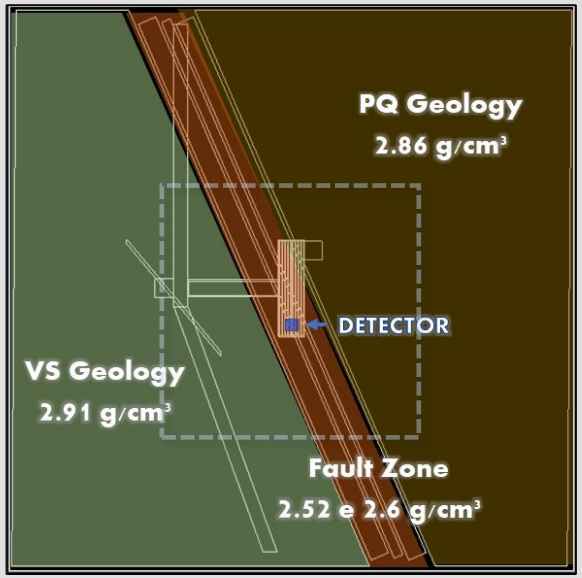
COLORED SIMULATION GEOMETRY

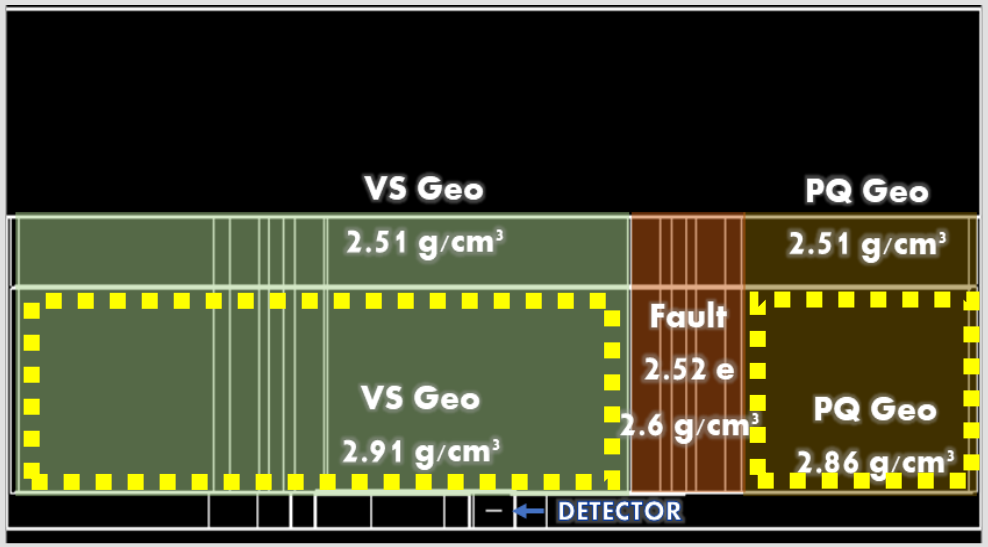


SIMULATION ANALYSIS

SIMULATION MUON COUNTS MAP

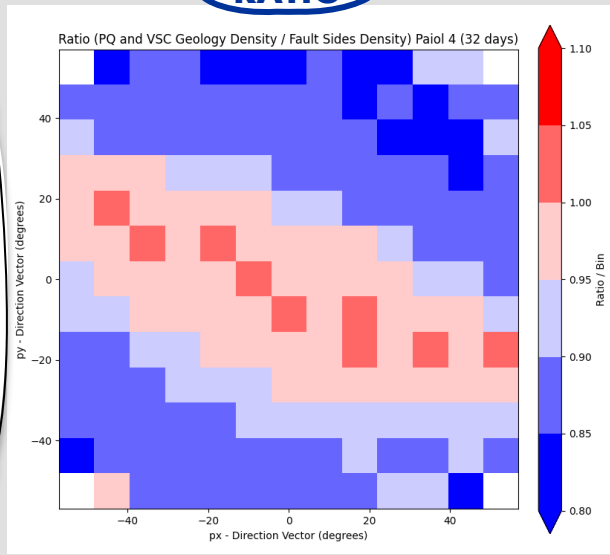




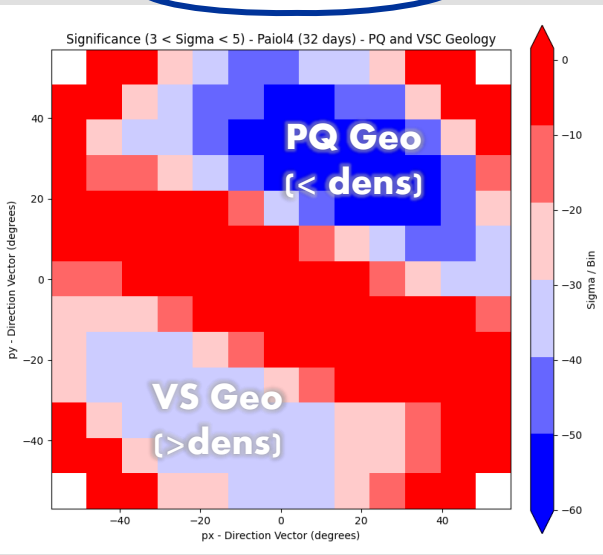


- In this example, the geology volumes marked yellow were used in the simulation with the densities indicated and with their density reduced by 10%. Simulation data were obtained for both situations. The overall difference in the muon counts between the two cases was 6%.
- The Ratio and the Significance parameters were calculated using both datasets and show only the influence of the change of the density of those two volumes in the muons detected. The ratio map show that a 10% density difference can make a 10 to 15% difference in the muon detection in some parts of the area.

RATIO

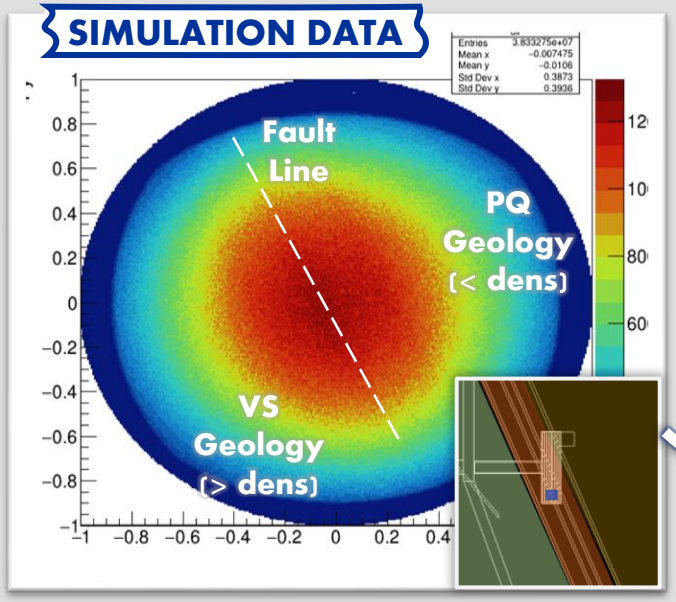


SIGNIFICANCE



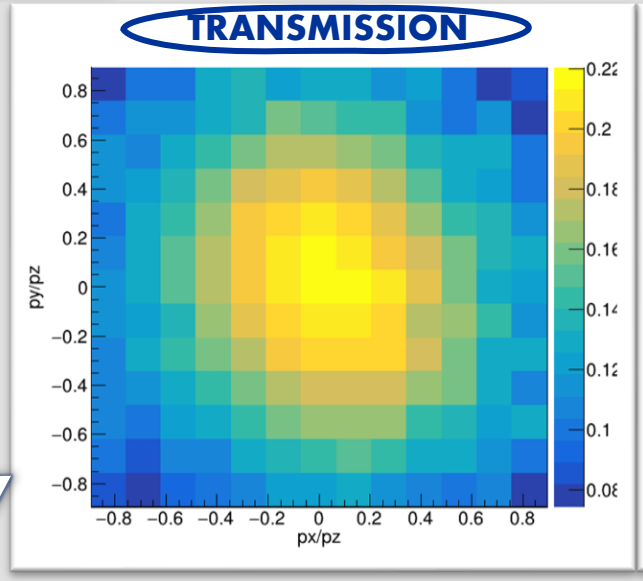
DETECTION ANALYSIS

SIMULATION DATA

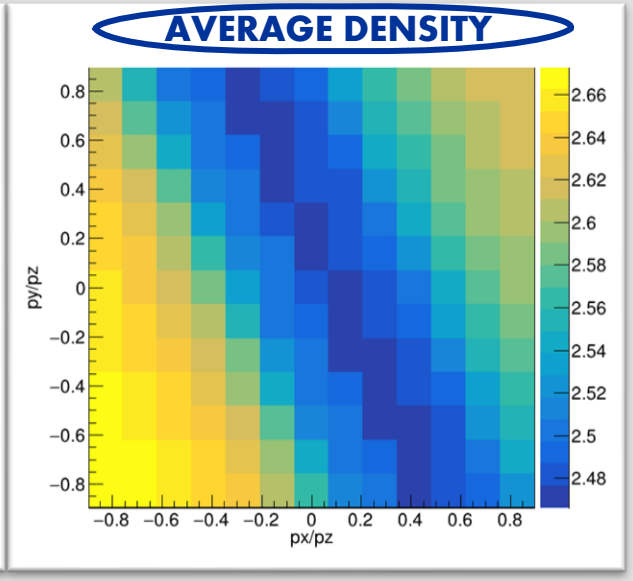


With the same Geant simulation data, **Isabel Alexandre** analysis focus on seeing the data as the telescope sees it, to compare it with the CorePix real data.

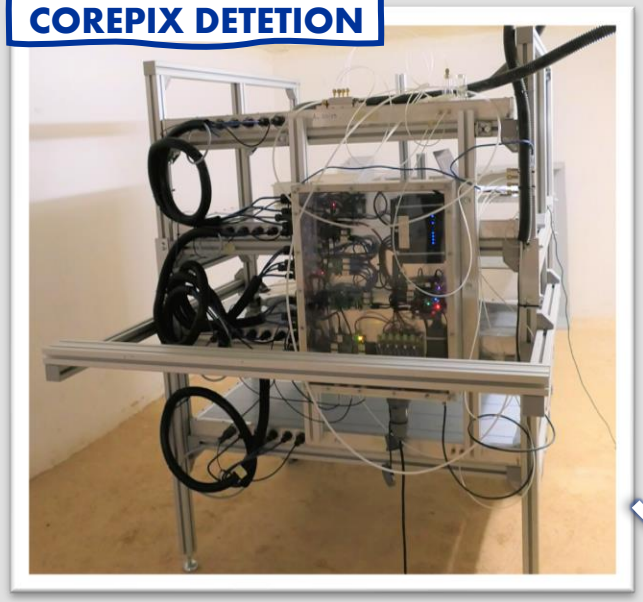
TRANSMISSION



AVERAGE DENSITY



COREPIX DETETION

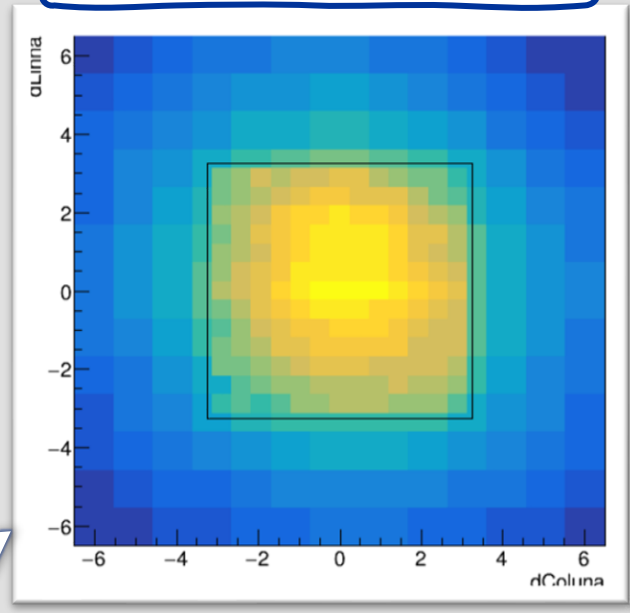


CorePix has now 2 months of collected data.

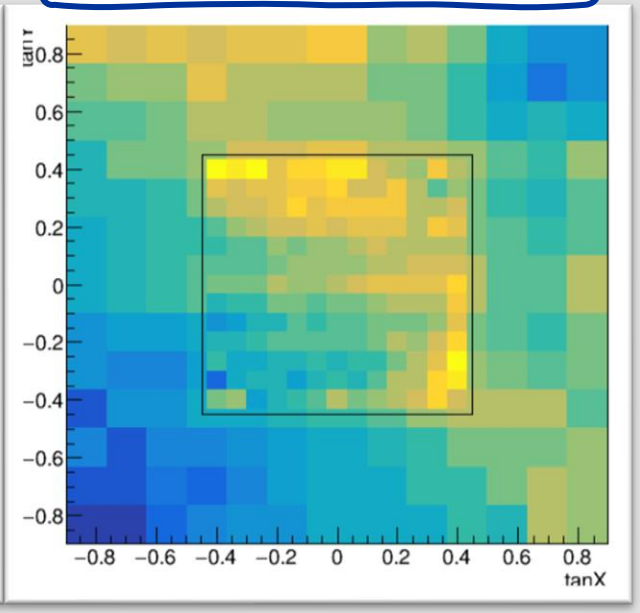
Dividing the transmission map by the open-air muon flux map, the observation muography is obtained.

The division created by the fault in the land geology is already visible

COREPIX TRANSMISSION



COREPIX MUOGRAPHY

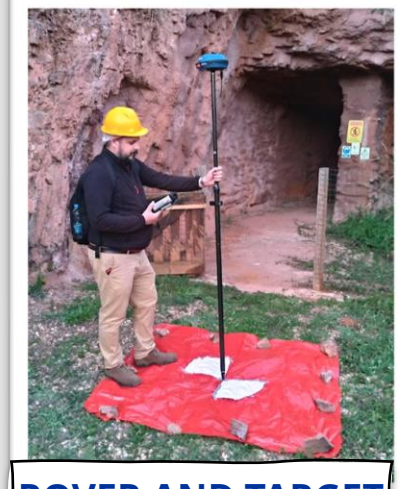


GEOLOGICAL AND GEOPHYSICAL WORK

GROUND SURVEY

DIFFERENTIAL GPS

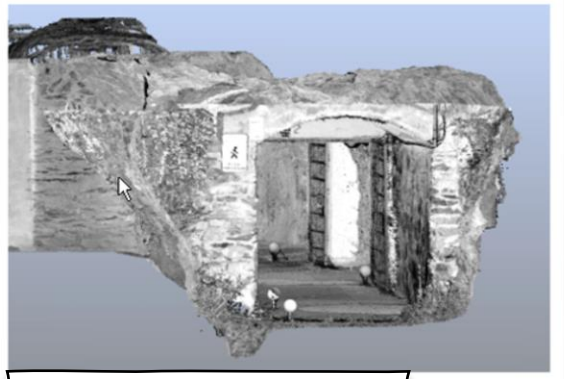
BASE



ROVER AND TARGET

- A detailed characterization of the terrain is required to compare the muographic information from the observation with the expected results, so that the attenuation caused by topographical differences can be normalized.

GROUND LIDAR



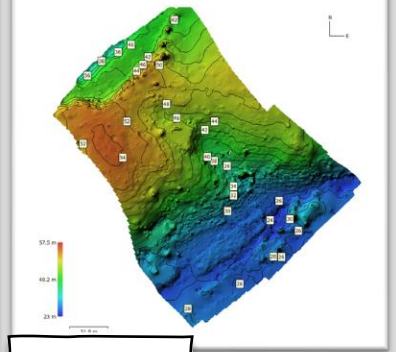
3D REPRESENTATION

LIDAR

PHOTOGRAMMETRY

DRONE

CONTROL COMMAND

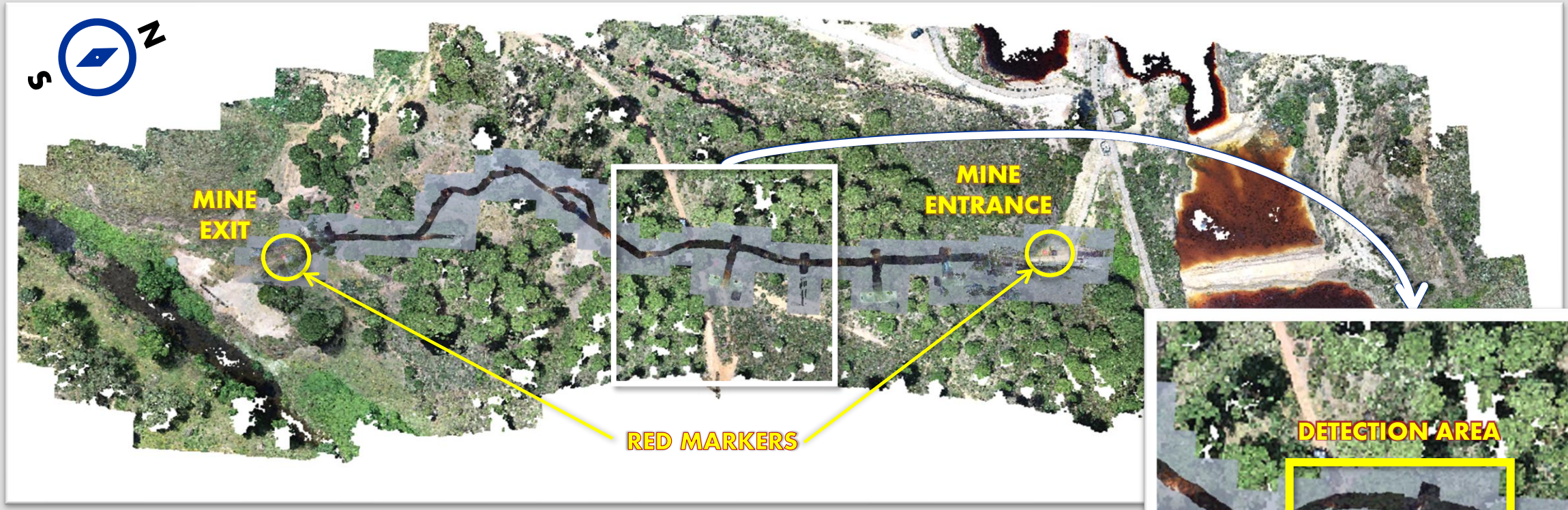


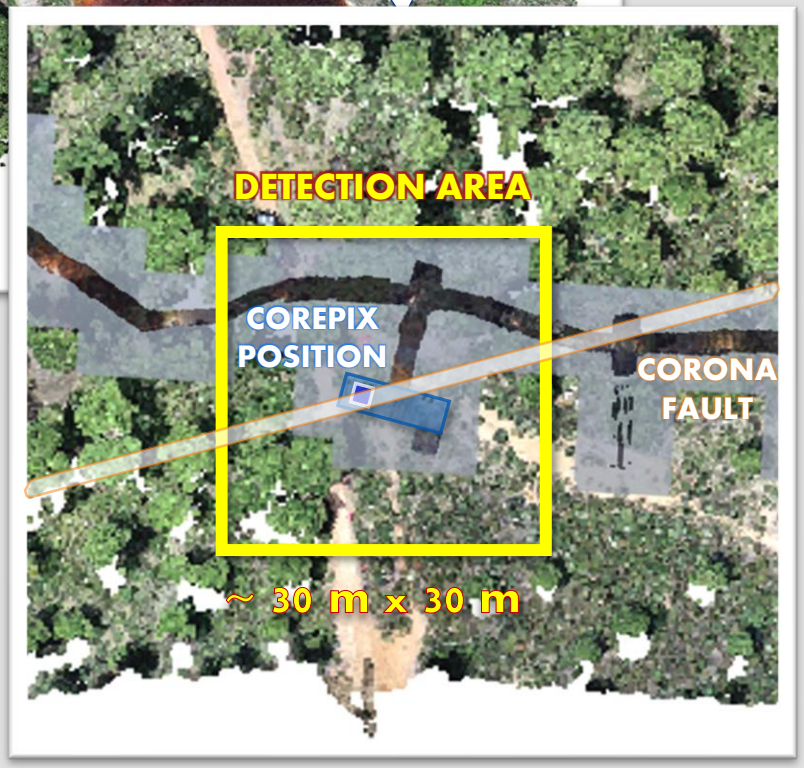
DEM

ROCK SAMPLES

SAMPLES FROM THE GALLERY

PRELIMINARY PROJECTION





- Preliminary 2D projection of the gallery cloud projected on the surface model.
- The two red markers at the entrance and exit of the mine were used as reference points, and the two images were adjusted to match the markers without distorting their shape. It fits with what is known in the location.
- The later combination of both clouds into a 3D digital model will give the exact geopositioning of the muon telescope inside the gallery and other features of interest.

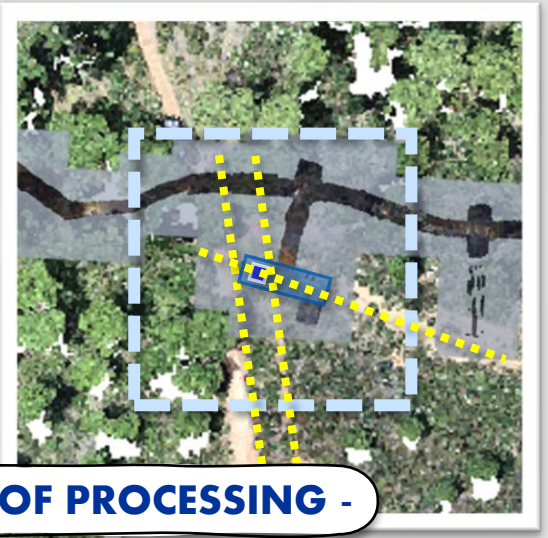
GROUND PENETRATING RADAR

GPR ANTENNA

- The GPR antenna emits electromagnetic pulses through the ground and measures the dielectric constant of the materials.

GPR PROFILES

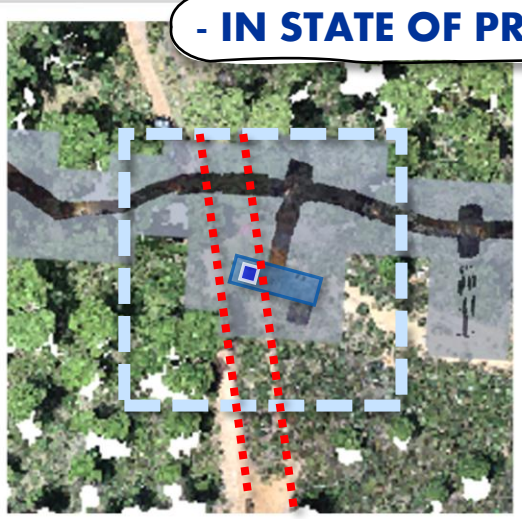
4 profiles measured in 3 locations in the proximity of the terrain above the muon telescope, the length is around 50 m each



SEISMIC REFRACTION

GEOPHONES

- IN STATE OF PROCESSING -



SEISMIC PROFILES

2 seismic profiles obtained in parallel positions, 8 m apart from one another, and with a length of 48 m each

- The geophones detect the vibration waves induced on the ground with hammer strokes and measure the propagation speed of these waves through the ground.

GEOPHYSICAL AND MUOGRAPHY WORK

STANDARD TECHNIQUES

DIFFERENTIAL GPS

PHOTOGRAMMETRY

GROUND LIDAR

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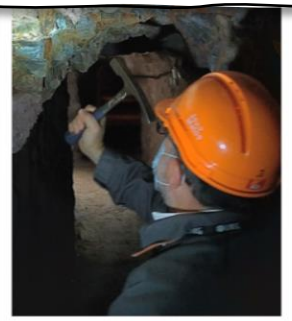
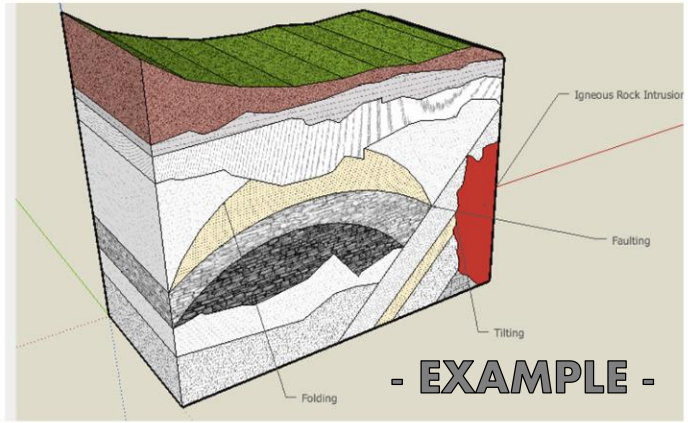
ROCK SAMPLES



GPR

SEISMIC REFRACTION

REFERENCE GEOLOGICAL MODEL



TARGET TECHNIQUE

MUOGRAPHY

SIMULATIONS

ANALYSIS TOOLS

TELESCOPE

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GEOLOGICAL MODEL

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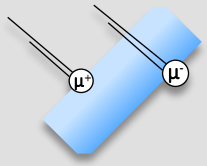
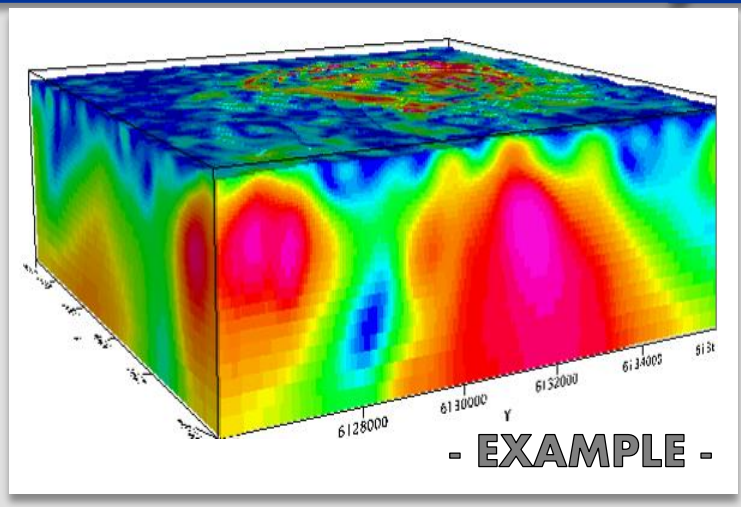


$$\phi \propto \frac{1}{\rho}$$

RECONSTRUCTED 3D DENSITY MODEL



THANK YOU!

EMAIL

mutom-info@lip.pt

WEBPAGE

https://pages.lip.pt/loumu/en/

PARTNERS

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REPÚBLICA PORTUGUESA

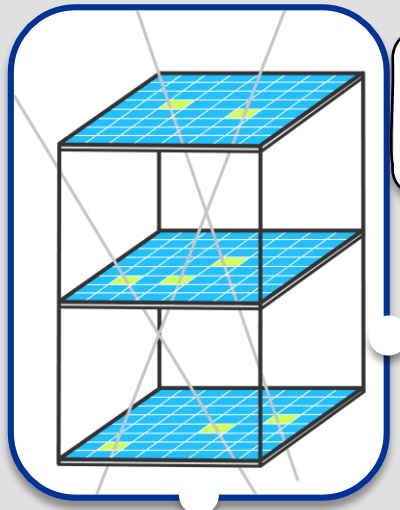
IDPASC-FCT: PD/BD/150490/2019
I&D: EXPL/FIS-OUT/1185/2021

LOUSAL MINE

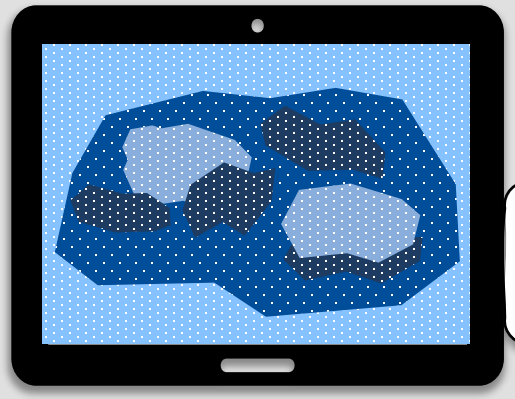
EXTRA SLIDES

NOT INCLUDED IN THE PRESENTATION

MUOGRAPHY OVERVIEW



Muon detectors assembled in a structure called a **MUON TELESCOPE**



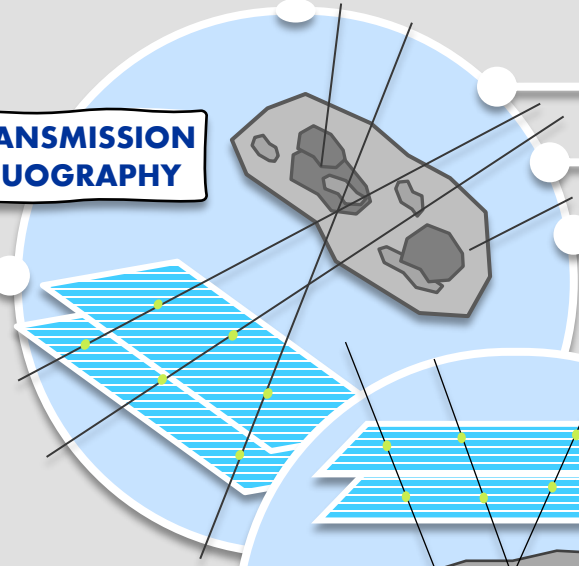
The observation produces images called **MUOGRAPHS**

COSMIC RAYS

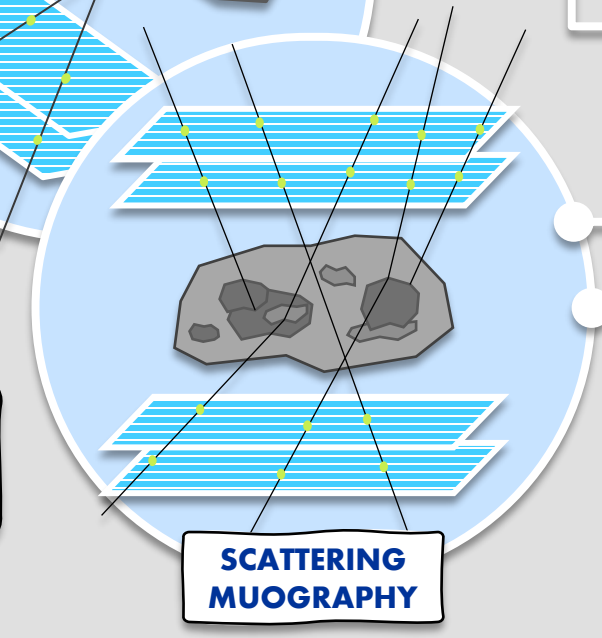
PARTICLE SHOWERS

ATMOSPHERIC MUONS

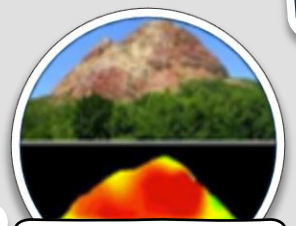
TRANSMISSION MUOGRAPHY



SCATTERING MUOGRAPHY



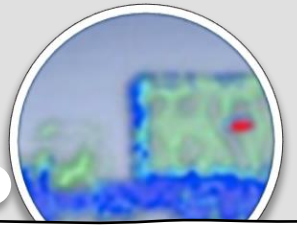
APPLICATIONS IN DIFFERENT FIELDS



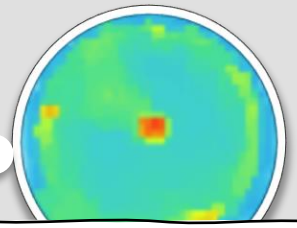
GEOSCIENCES

ARCHAEOLOGY

CIVIL ENGINEERING



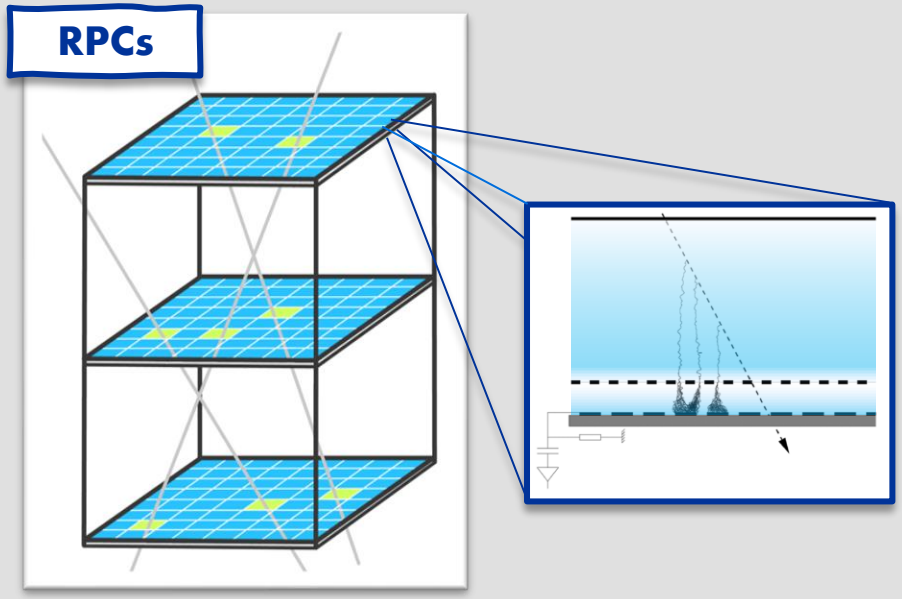
CARGO SURVEILLANCE



NUCLEAR REACTOR AND WASTE CONTROL

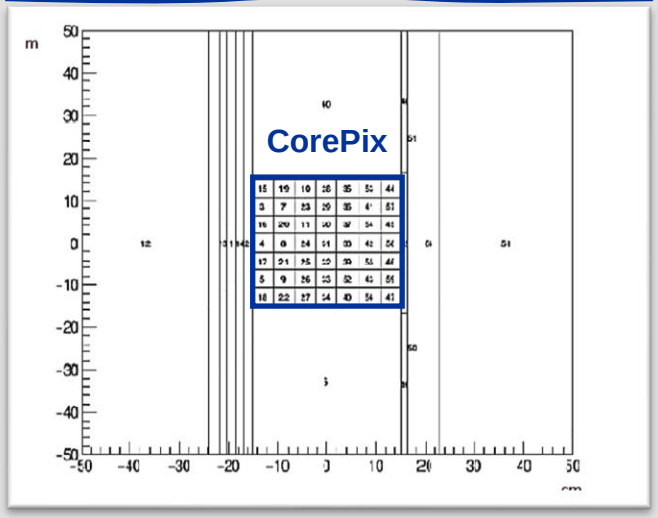
MUON DETECTORS / RPCs

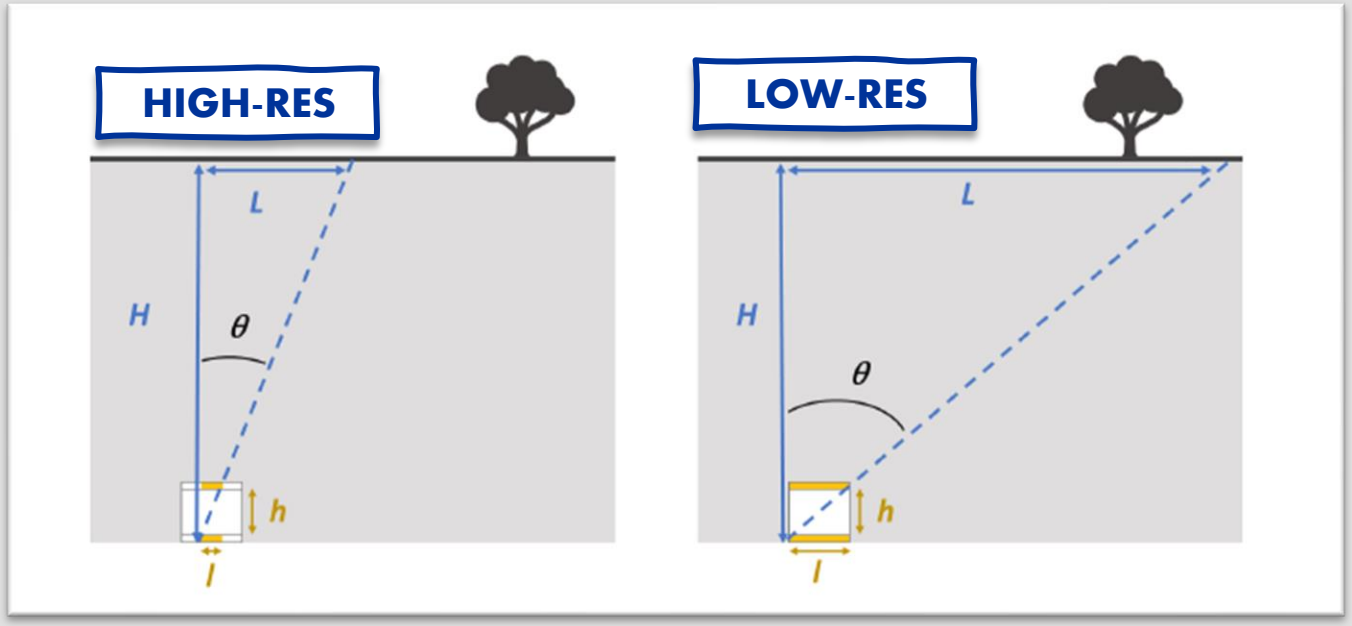
RPCs



- RPCs (Resistive Plate Chambers) are particle detectors that contain a mixture of an ionizing gas.
- The passage of muons ionize the gas and causes an avalanche of electrons, which produce an electrical signal.
- The gas is sent to the RPCs and collected with a low flux, from a container outside the mine, without leakage to the environment.
- The detection pads are configured in different shapes and the RPC center pads (CorePix) offer a higher resolution observation in a narrow angle.

RPC MAIN CONFIGURATION

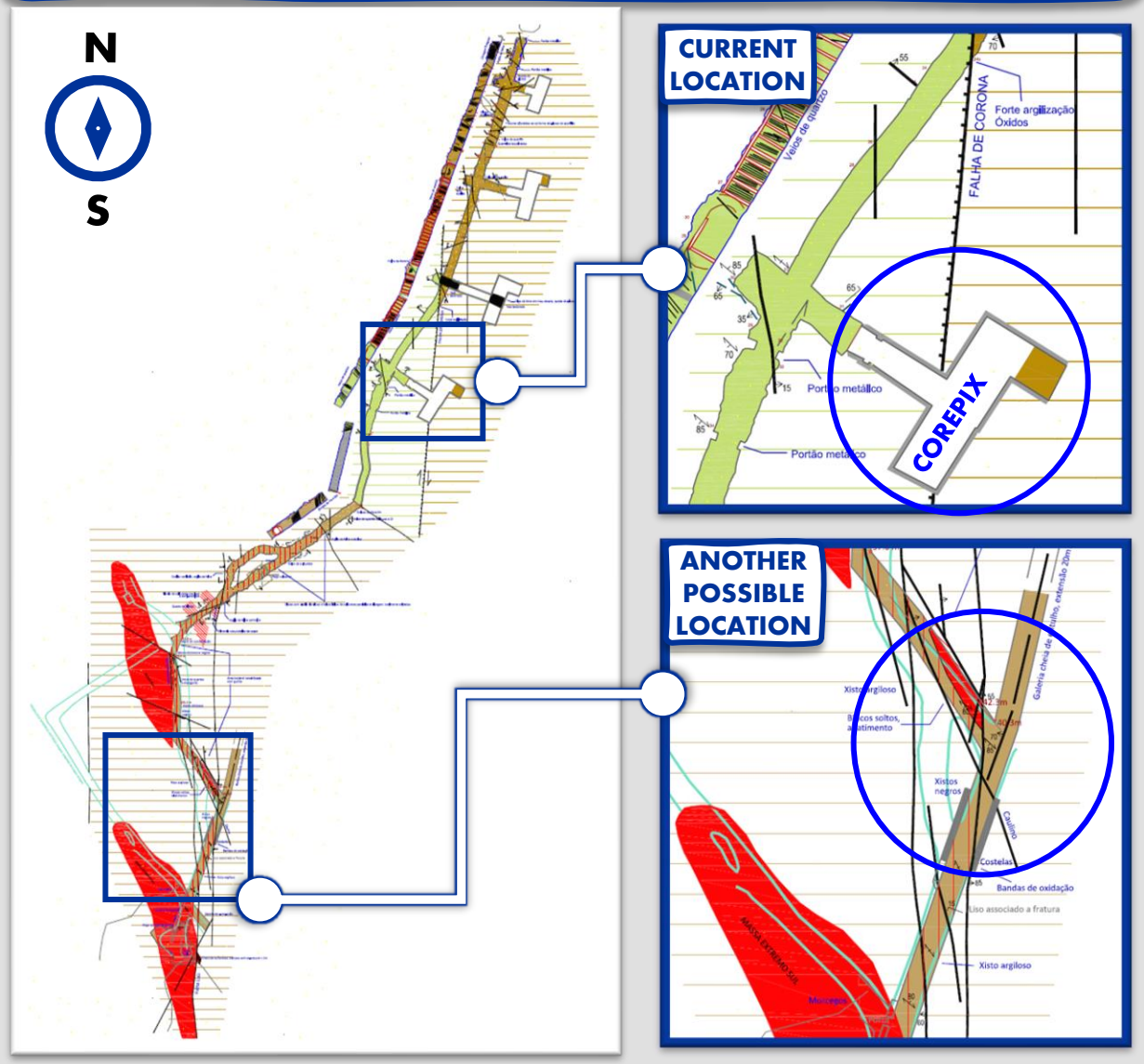




OBSERVATION MAIN TARGETS

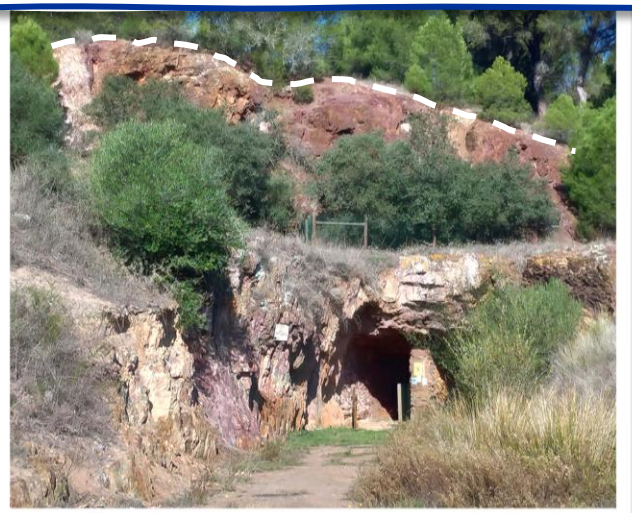
We expect these targets to offer density contrasts that make them able to be identified with muography.

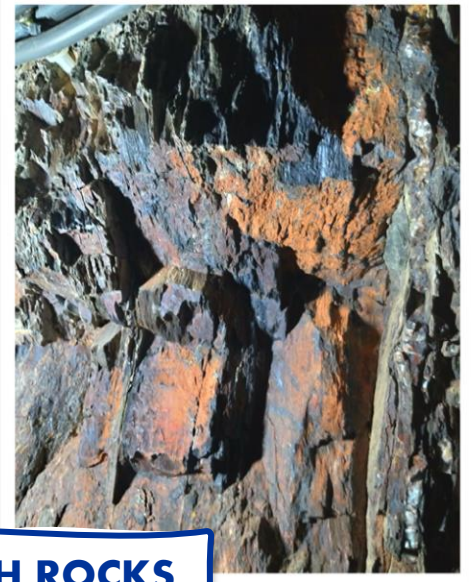
WALDEMAR GALLERY MAP – OBSERVATION LOCATIONS



CORONA FAULT

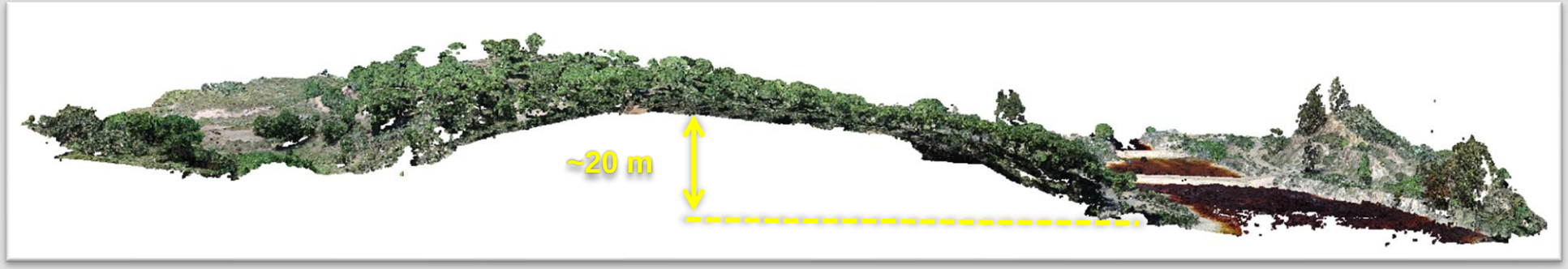
IRON CAPROCK ABOVE GALLERY



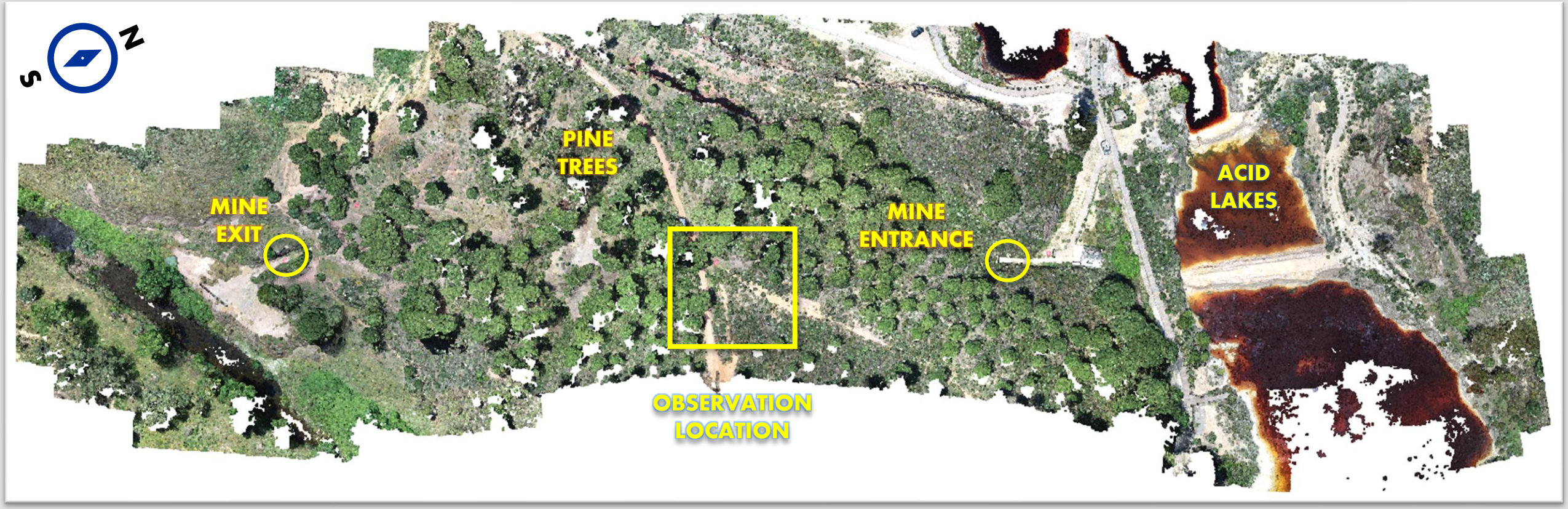


IRON-RICH ROCKS

DIGITAL SURFACE MODEL

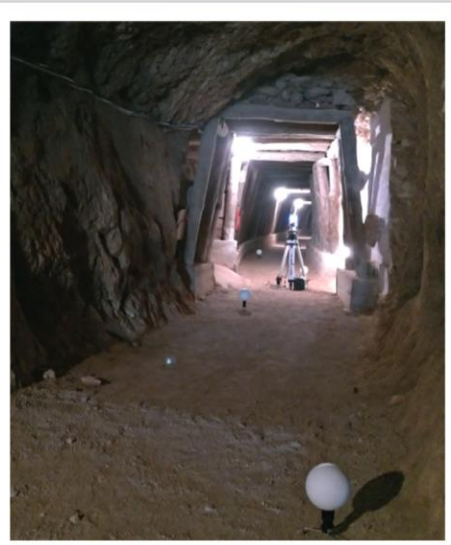


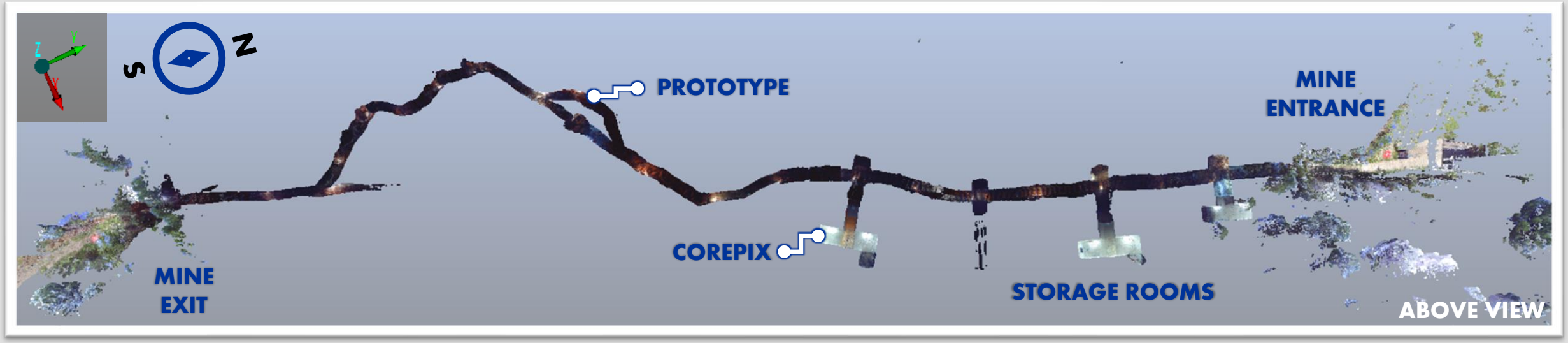
- The photos obtained with the drone were processed in a photogrammetry software to create the digital surface.
- Gives the geomorphology and the altitude of the terrain above the observation location.



WALDEMAR GALLERY LIDAR SCAN

- The Waldemar Gallery is 270 meters long, walking from the entrance to the exit.
- The dense cloud of the entire gallery was obtained by progressively scanning it with a ground Lidar.
- In combination with the surface cloud, can be used to georeference interesting points and locations underground, at the mine level, where GPS coordinates can't be obtained.





PROJECT OUTPUTS

LouMu is a local project where the muography technique is being developed independently for geophysical applications. It's planned to:

- To add geological information about Lousal to the national heritage.
- To make available functional and stand-alone telescopes for the geophysical community and generalized muography methods to apply in other scenarios.
- A trained multidisciplinary team with comprehensive knowledge and able share the muography with other communities.