

# UNEXMIN

AN AUTONOMOUS UNDERWATER EXPLORER FOR FLOODED MINES

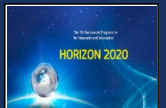
CORNISH INSTITUTE OF ENGINEERS

9 APRIL 2020

**ROBOT SUBMERSIBLES INVESTIGATE GEOLOGY AND  
INDUSTRIAL ARCHAEOLOGY IN ECTON MINE,  
STAFFORDSHIRE**

STEPHEN HENLEY ( [STEVE@VMINE.NET](mailto:STEVE@VMINE.NET) )

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690008.



# EUROPEAN-FUNDED PROJECTS

- **UNEXMIN**

- Horizon2020 **R&I**
- 45 months 2016-2019



- **UNEXUP**

- EIT-Raw Materials **upscaling**
- 36 months 2020-2022

- **ROBOMINERS**

- Horizon2020 **R&I**
- 48 months 2019-2023



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# THE UNEXMIN CONSORTIUM: 12 MEMBERS, 7 COUNTRIES

- University of Miskolc
  - Tampere University of Technology, Department of Mechanical Engineering Systems
  - Universidad Politécnica de Madrid, Centre for Robotics and Automation
  - INESC Tec – Instituto de Engenharia de Sistemas e Computadores, Tecnologia e Ciência
  - Resources Computing International Ltd
- 
- La Palma Research Centre for Future Studies
  - Geological Survey of Slovenia
  - European Federation of Geologists
  - Geo-Montan Kft
- 
- Empresa de Desenvolvimento Mineiro
  - Ecton Mine Educational Trust
  - Center za Upravljanje z Dediscino Zivega Srebra Idrija

TECHNOLOGY  
DEVELOPMENT

TECHNOLOGY  
EXPLOITATION

STAKEHOLDERS



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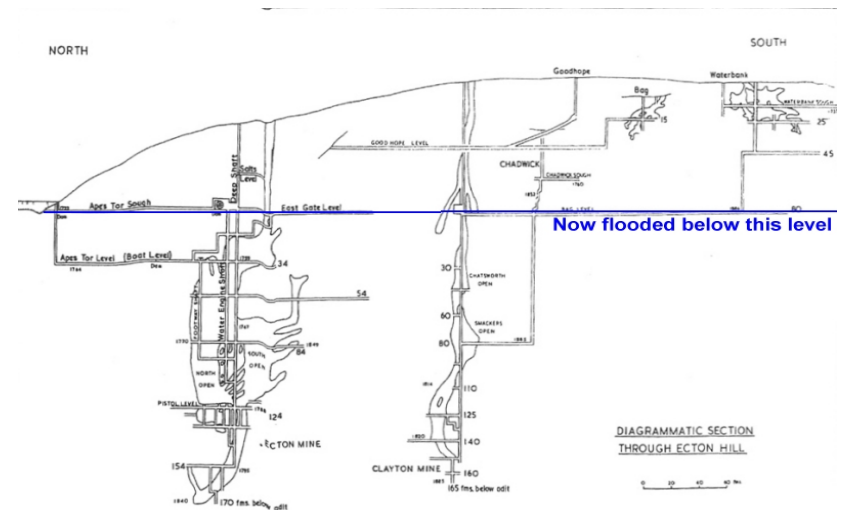
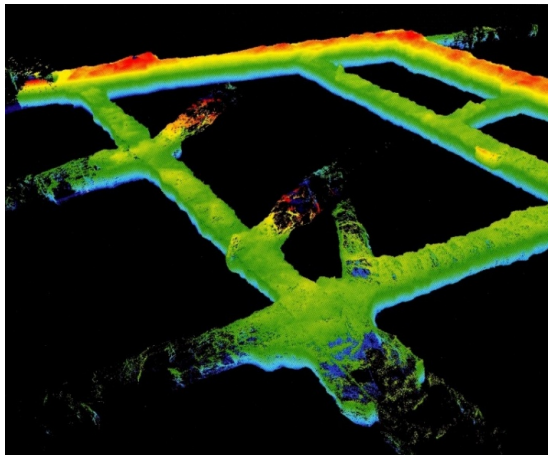
This  
Union's H



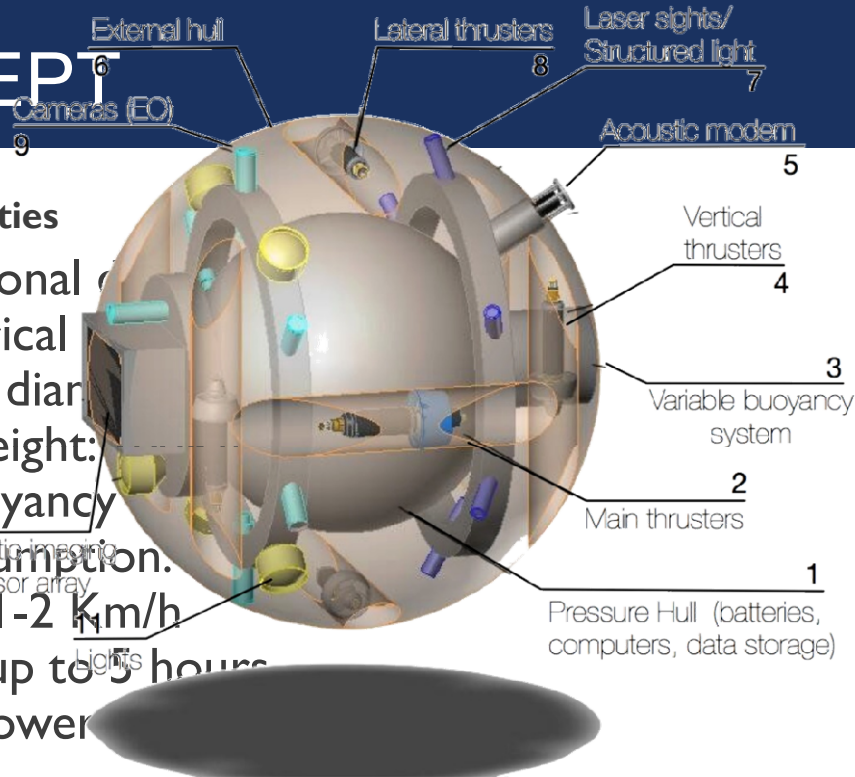
# CONCEPT

- There are of the order of 30,000 closed mine sites in Europe and many of them potentially contain considerable amounts of valuable mineral raw materials, **At least 8,000 of these are underground mines**
- The closure of a mine is usually more related to economics and technological challenges than to the actual depletion of mineral resources
- often minerals which were disregarded during the operational life of the mine (such as fluorite in lead/zinc mines)
- Many of these mines are now flooded and the last information of their status and layout is decades or hundreds of years old.

UNEXMIN



# CONCEPT



## Physical Properties

- Max operational depth: 1000m
- Shape: spherical
- Size: ~ 0.5m diameter
- Expected weight: 100kg
- Neutral Buoyancy
- Power consumption: 100W
- Max speed: 1-2 Km/h
- Autonomy: up to 5 hours
- Thrusters power: 100W

## Propulsion:

- Thrusters, oil ballast, pendulum

# INSTRUMENTATION

1. **pH measuring unit**
2. **Electrical conductivity measuring unit**
3. **Water sampler unit**
4. **Multispectral unit**
5. **UV fluorescence imaging unit**
6. **Magnetic field measuring unit (3 axes flux-gate sensors)**
7. **Sub-bottom sonar**
8. **Natural gamma ray activity measuring unit**



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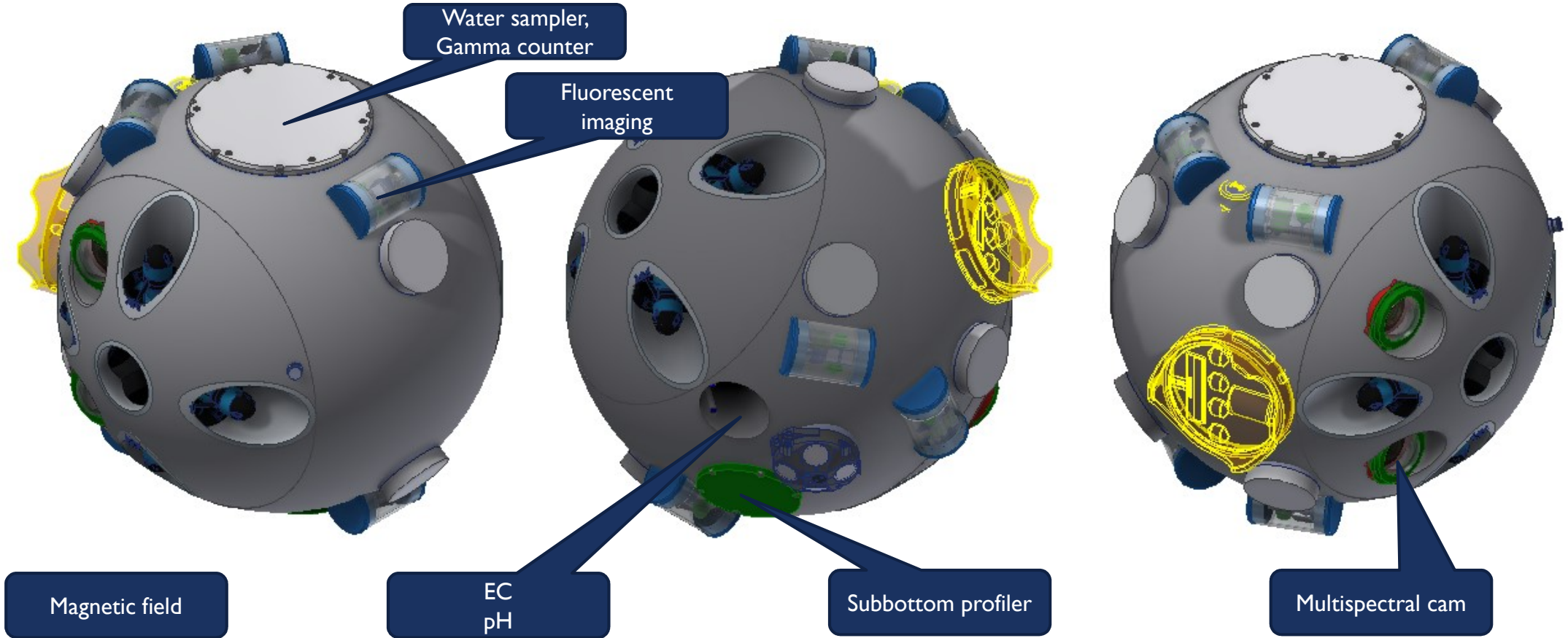


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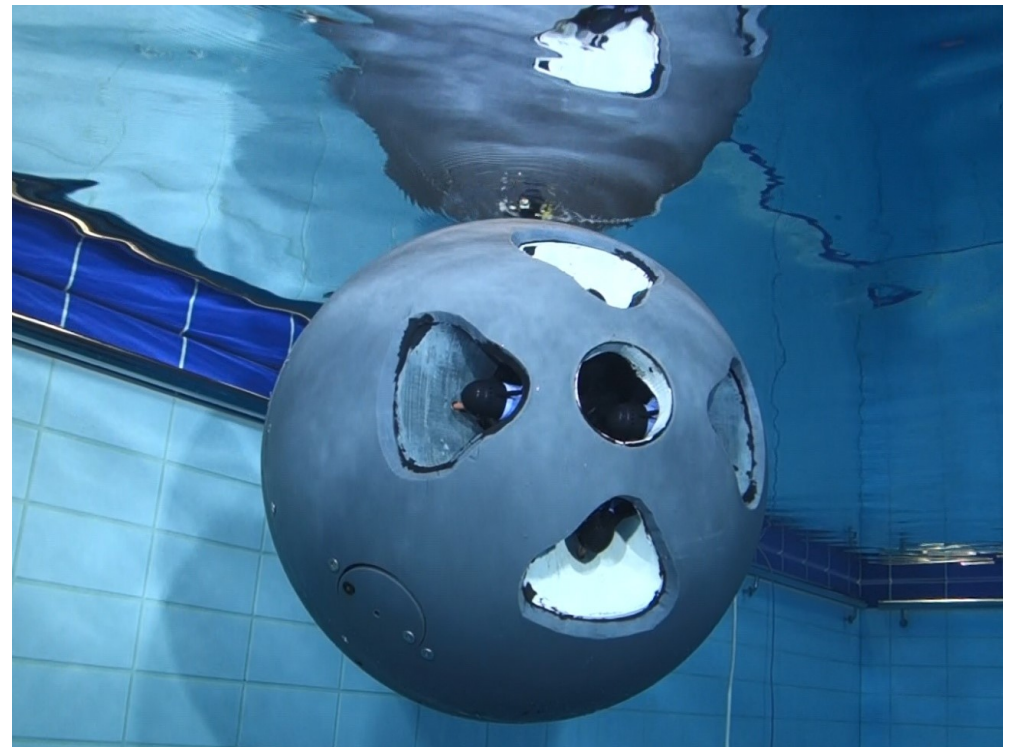
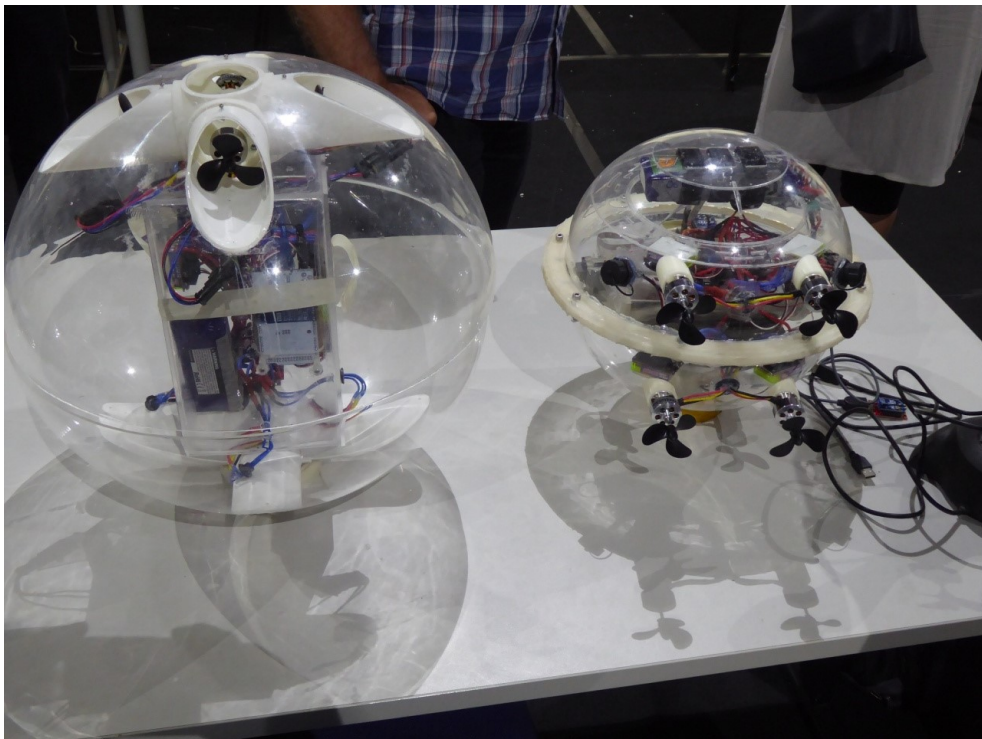


**MISKOLCI**  
EGYETEM  
UNIVERSITY OF MISKOLC

# INSTRUMENTATION - POSITIONING



# SCALE MODELS AND POOL TESTS – 2016-2017





# TEST AND DEMONSTRATION SITES 2018-2019

- |                                     |                           |
|-------------------------------------|---------------------------|
| 1. Kaatiala, Finland                | basic functionality       |
| 2. Idrija Mercury Mine, Slovenia    | instrumentation, autonomy |
| 3. Urgeirica Uranium Mine, Portugal | navigation                |
| 4. Ecton Mine, UK                   | live tests; exploration   |
| 5. Molnar Janos Cave, Hungary       | navigation; surveying     |



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# KAATIALA PILOT – JUNE 2018



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# IDRIJA PILOT – SEPTEMBER 2018



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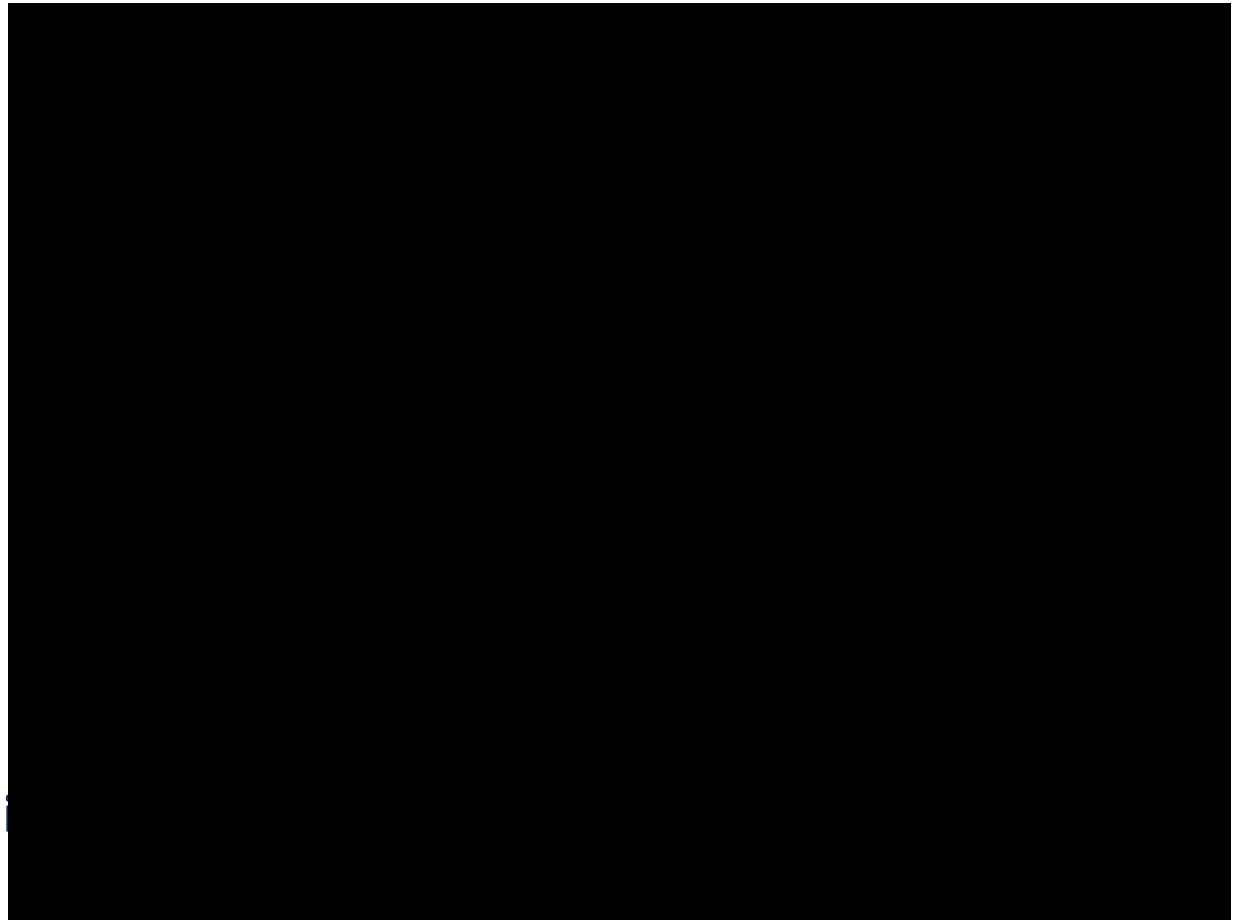
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# URGEIRIÇA PILOT – MARCH-APRIL 2019



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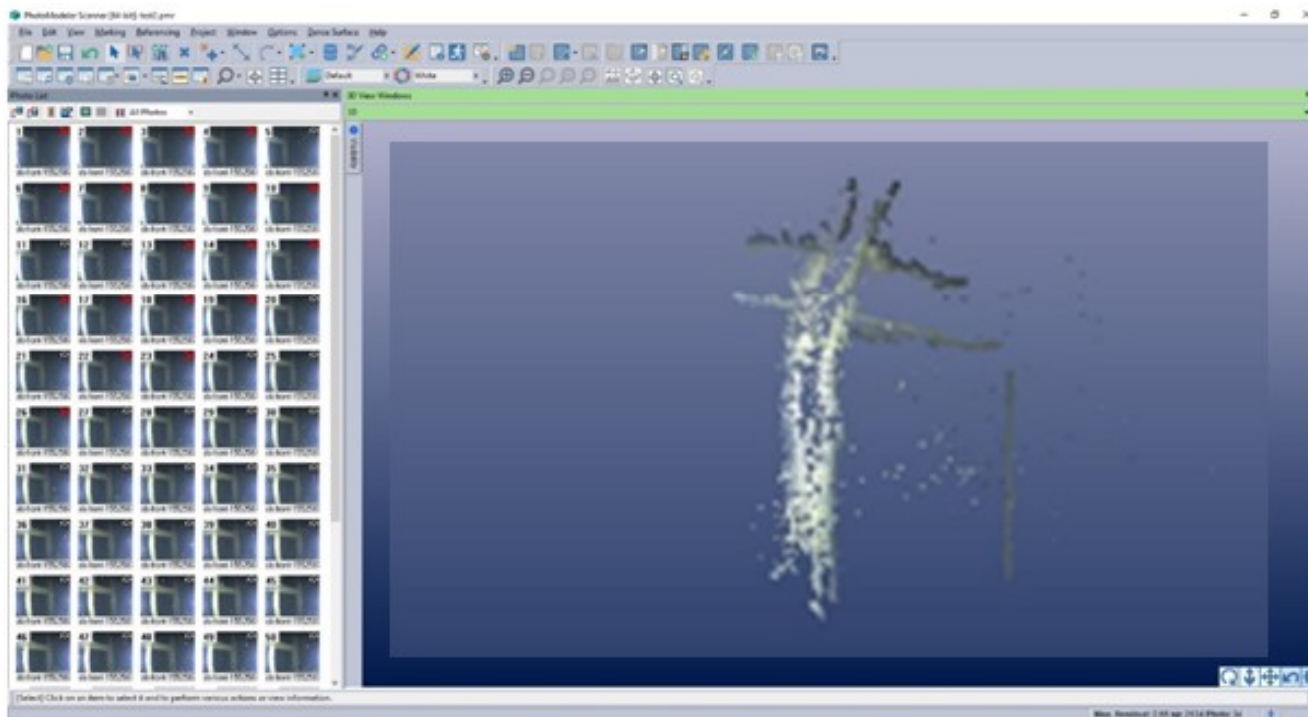


# IMAGE PROCESSING SOFTWARE (PHOTODEMON, VIRTUALDUB)

Fish-eye distortion correction, one image at a time



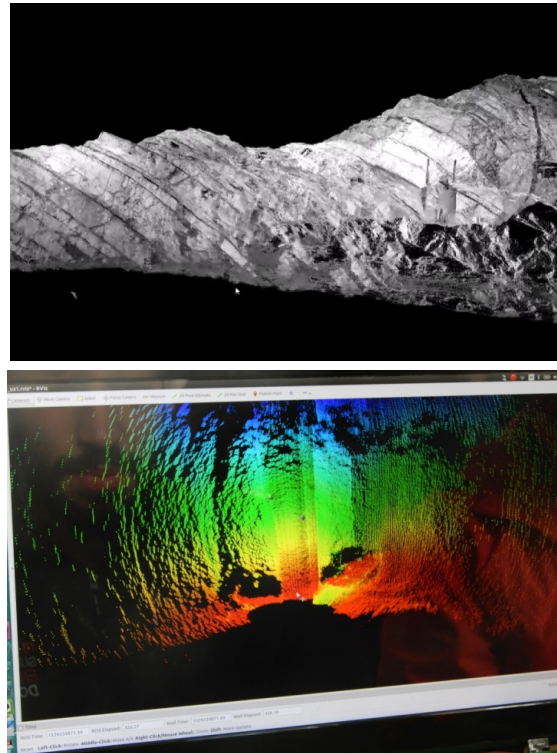
# PHOTOGRAMMETRY



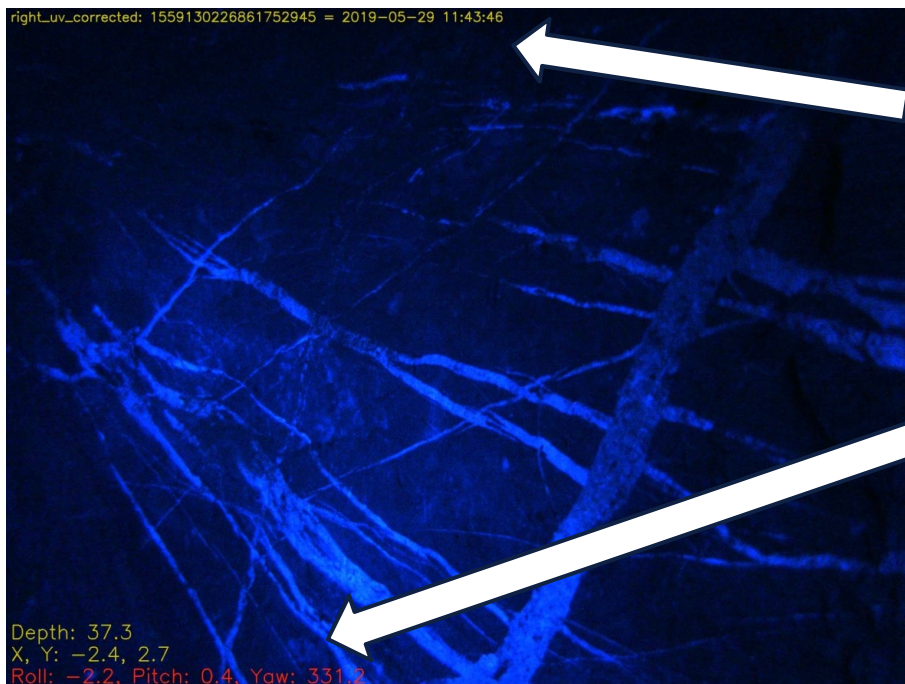
Data from Urgeirica pilot.  
Requires 'straight-line' dive missions specifically for photogrammetry  
Also needs correction for navigation drift

# POST-PROCESSING DATA ANALYSIS

- Data conversion: extensive enhancements to methods for rapid extraction of data from robots
- Multi-spectral analysis: development of a calcite detection application
- Tests of photogrammetric options for generation of 3D point clouds from image data
- Development of data processing solutions to correct for 'drift' in navigation data and for misalignment of data sets from multiple dives
- Point-cloud modelling and visualisation coding extended and applied to very large data sets from pilots at Urgeirica, Ecton, and Molnar Janos



# FAST PYTHON SCRIPTS FOR RAPID EXTRACTION OF DISTORTION-CORRECTED IMAGES & VIDEOS



Time caption

right\_uv\_corrected: 1559130226861752945 = 2019-05-29 11:43:46

Location caption

Depth: 37.3  
X, Y: -2.4, 2.7  
Roll: -2.2, Pitch: 0.4, Yaw: 331.2



# VIRTUAL REALITY

Demonstrated at  
the workshop in  
Bled, Slovenia, in  
January 2018

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# SAFETY WORKS OCTOBER 2018

VIDEO



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# ECTON MINE – 3 LAUNCH SITES

PUMPING SHAFT

WINDING SHAFT

PIPE WORKINGS



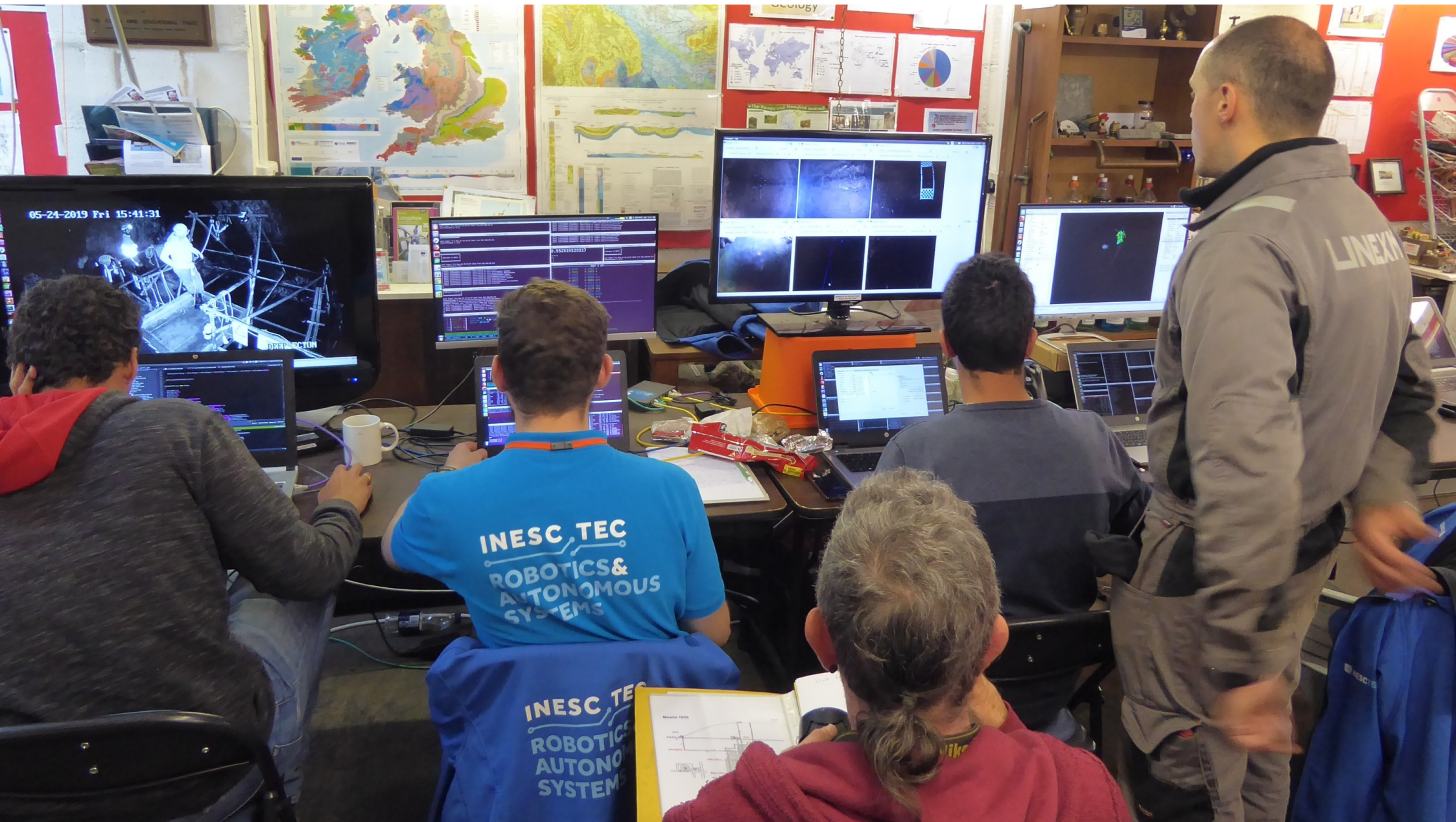
**UNEXMIN**

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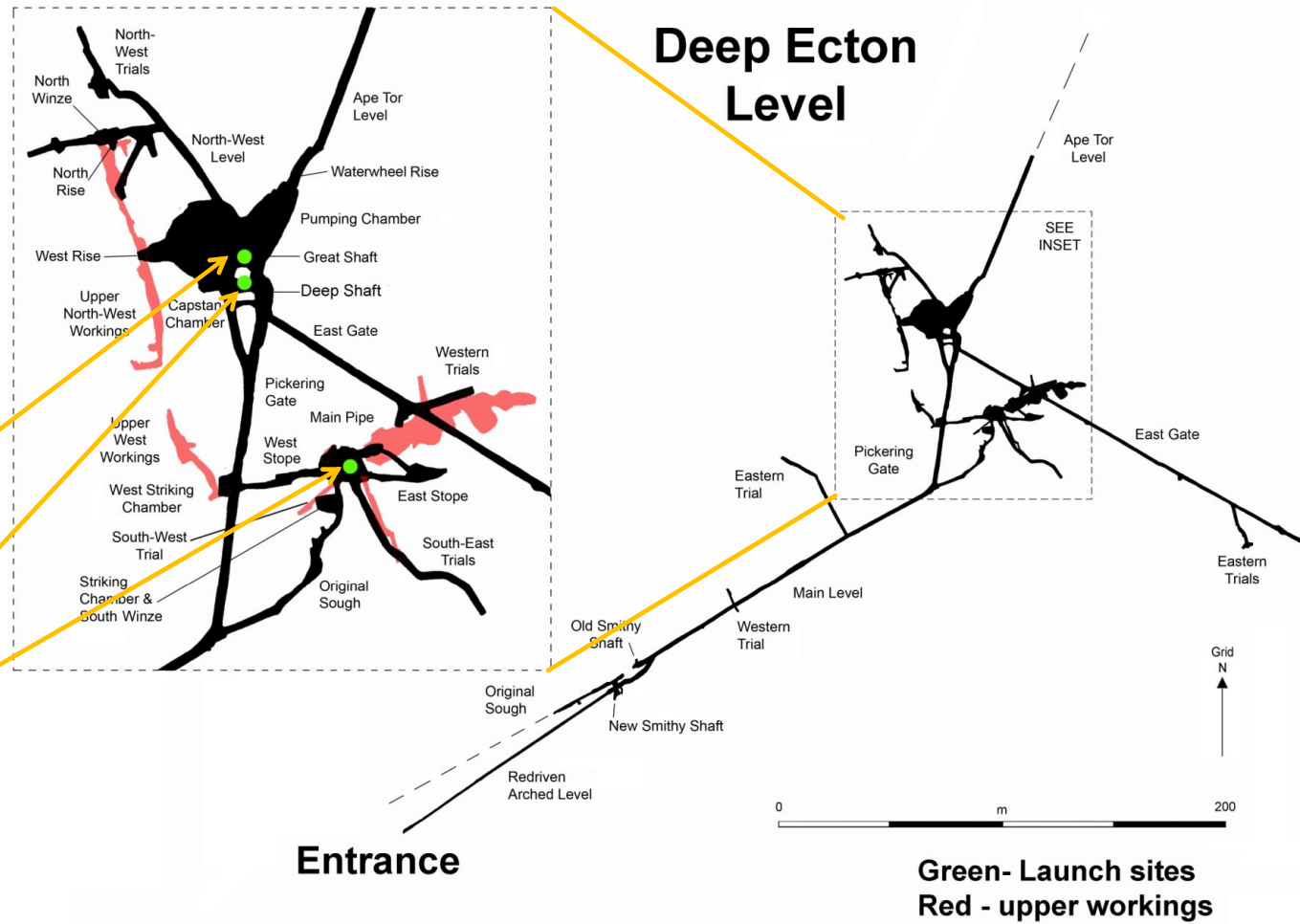


**MISSION  
CONTROL**

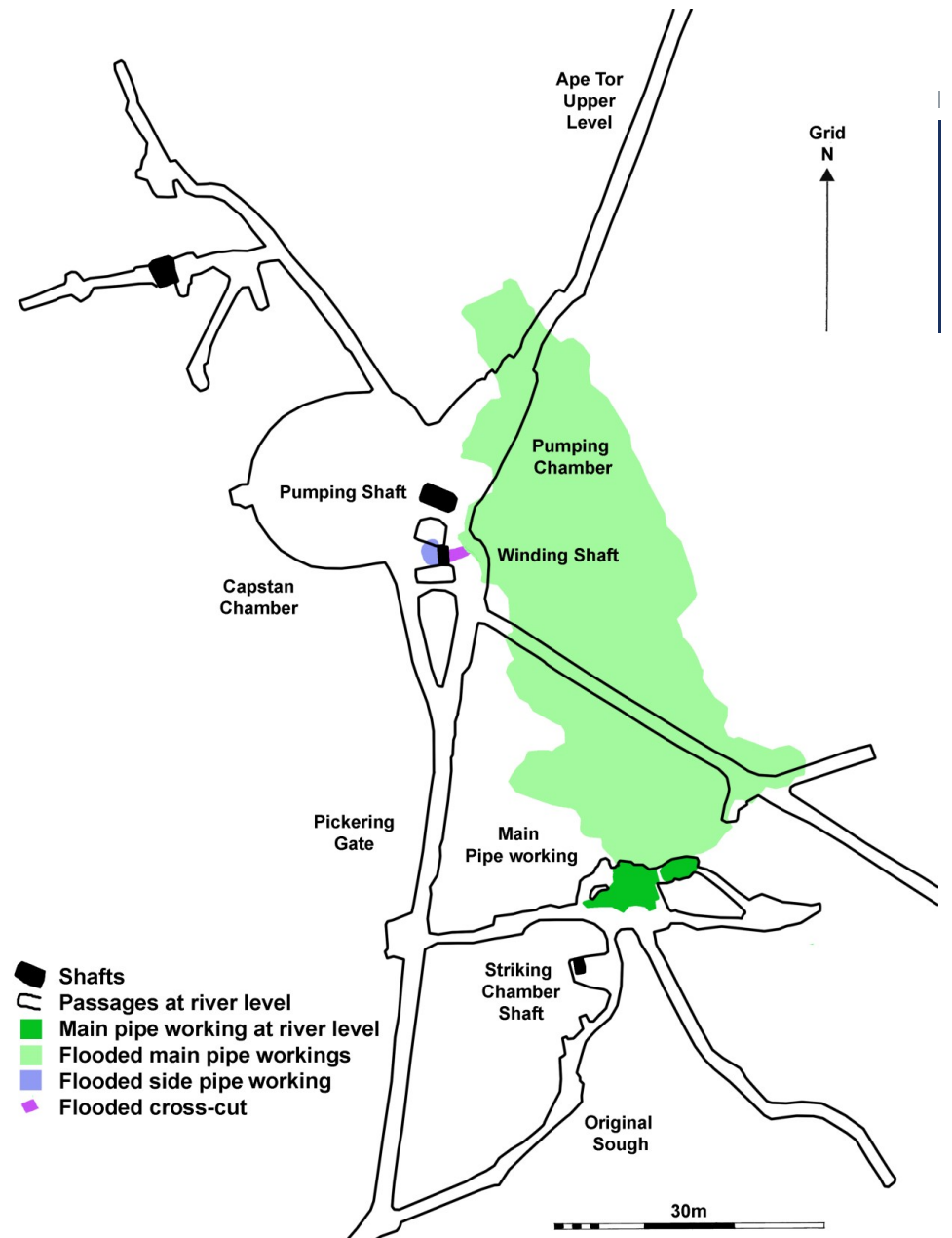
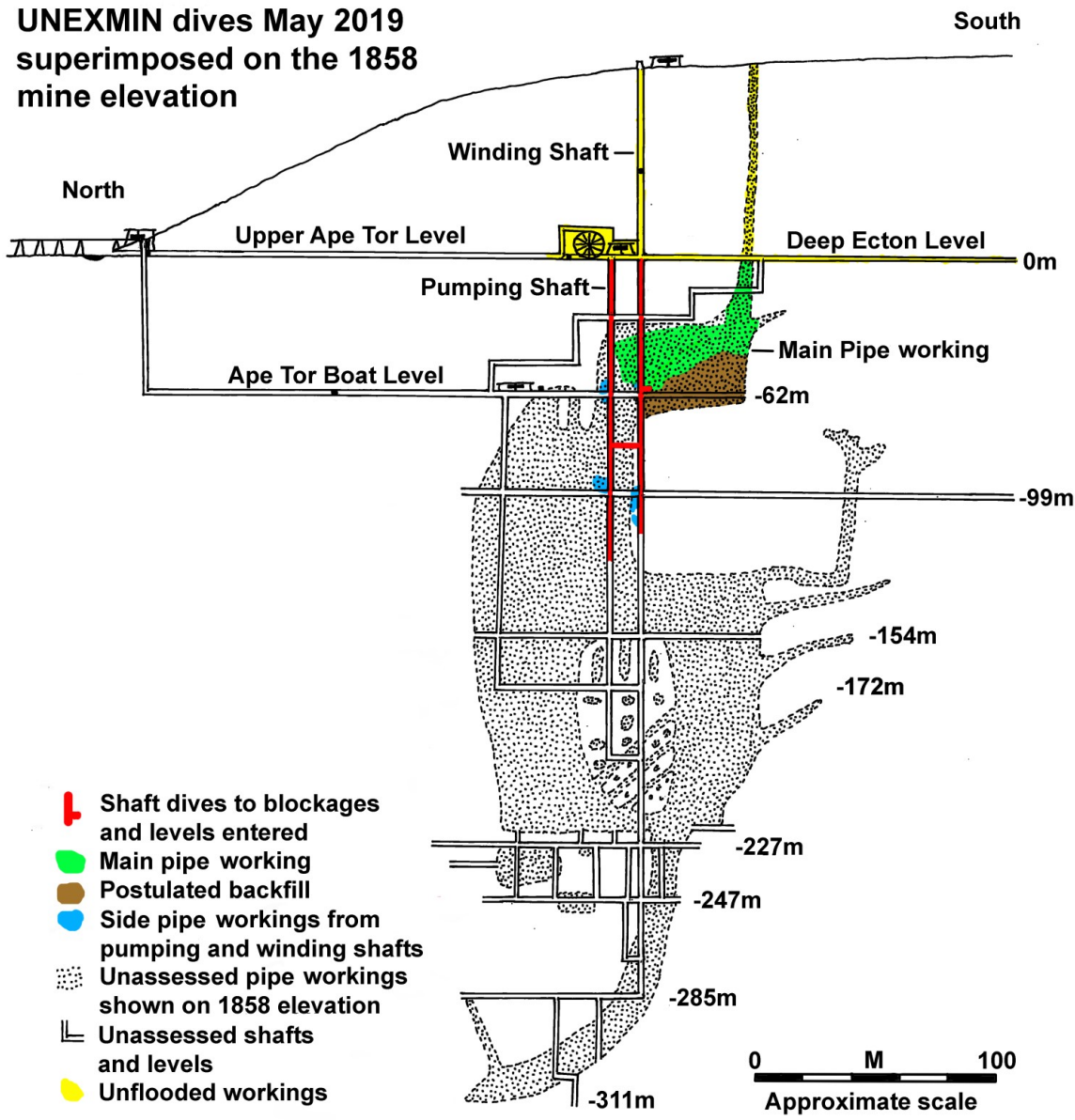


# ECTON 10 DIVES – MAY 2019

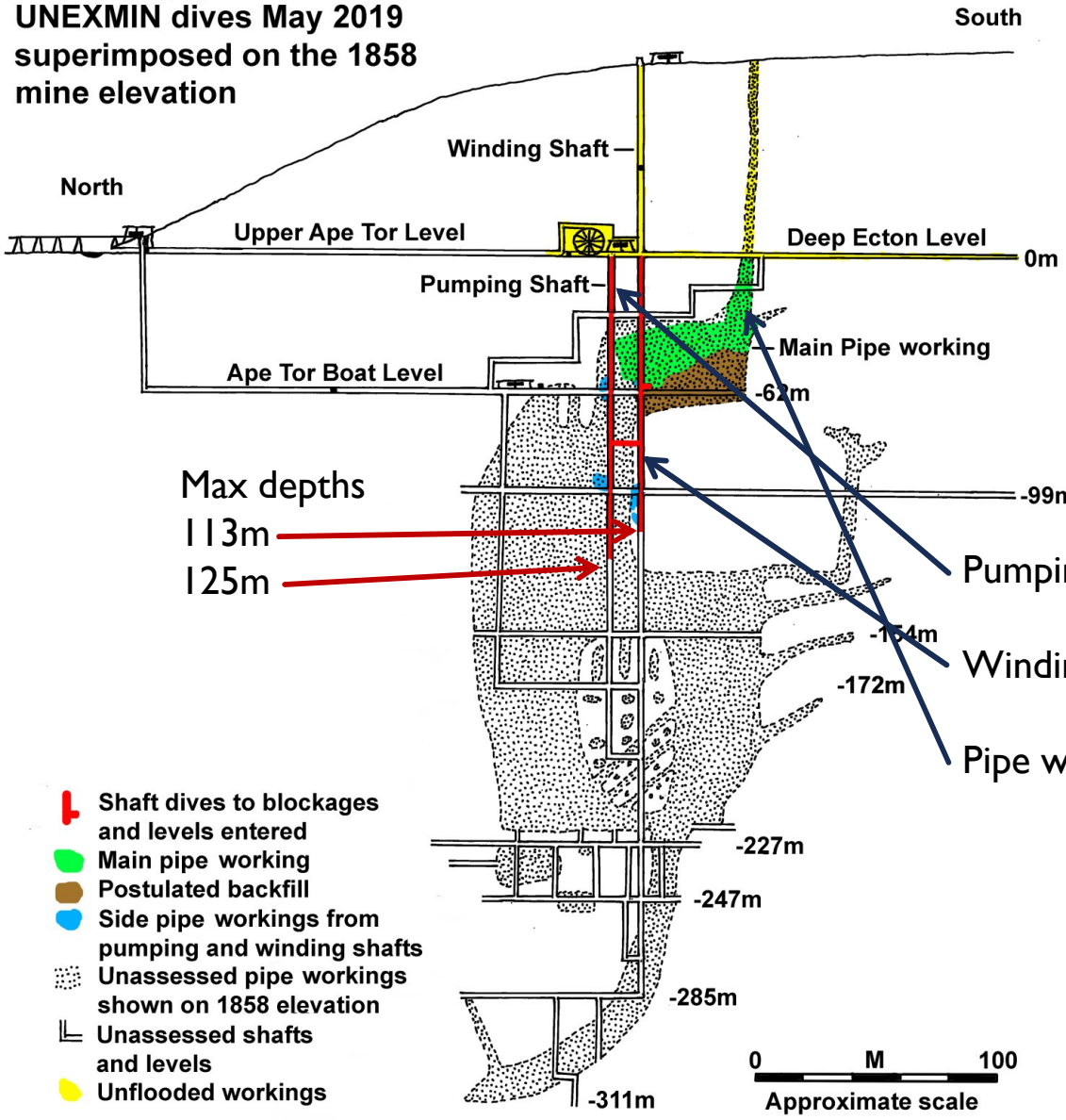
7 in Pumping shaft  
1 in Winding shaft  
2 in Pipe workings



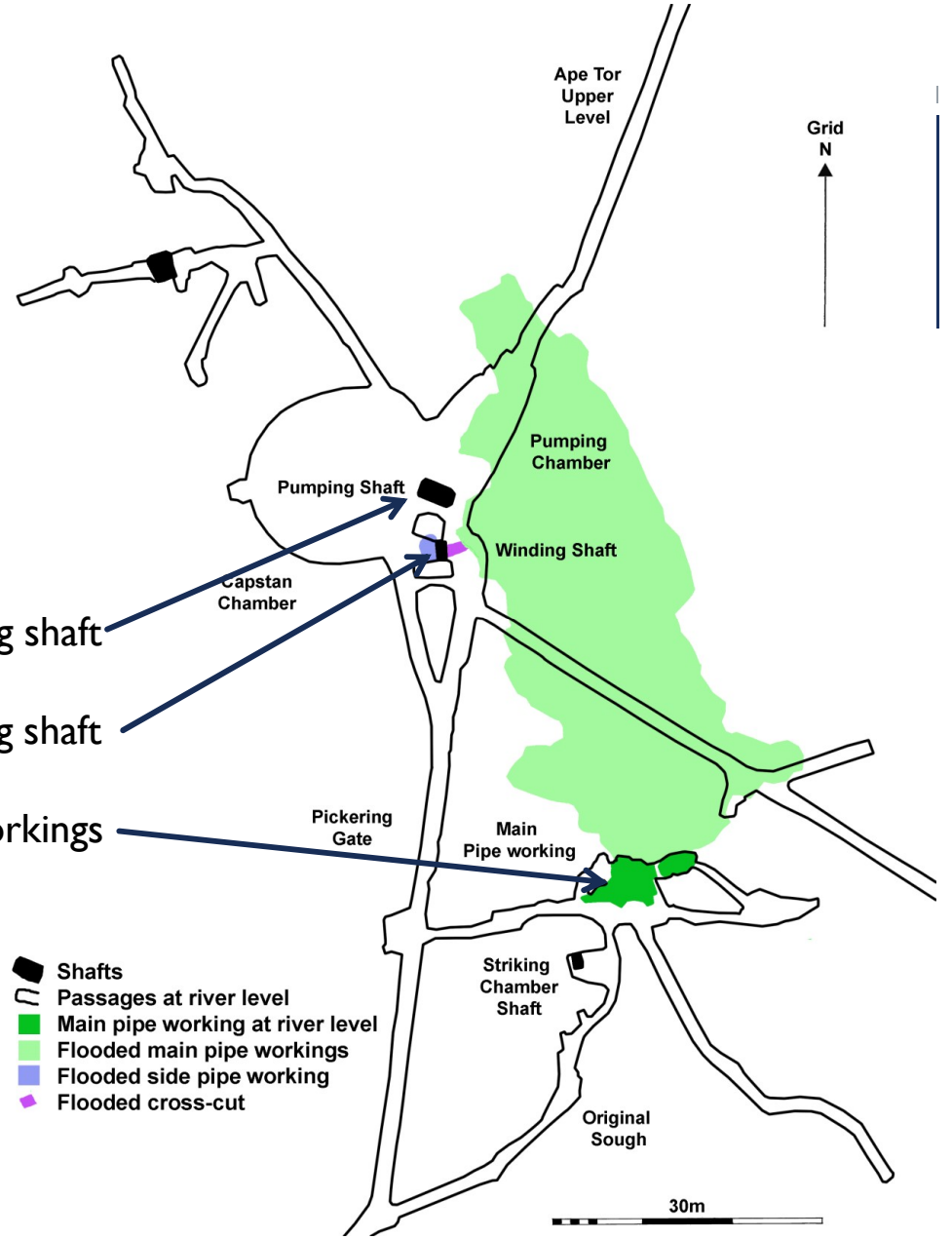
**UNEXMIN dives May 2019  
superimposed on the 1858  
mine elevation**



**UNEXMIN dives May 2019  
superimposed on the 1858  
mine elevation**



- Shaft dives to blockages and levels entered
- Main pipe working
- Postulated backfill
- Side pipe workings from pumping and winding shafts
- Unassessed pipe workings shown on 1858 elevation
- Unassessed shafts and levels
- Unflooded workings

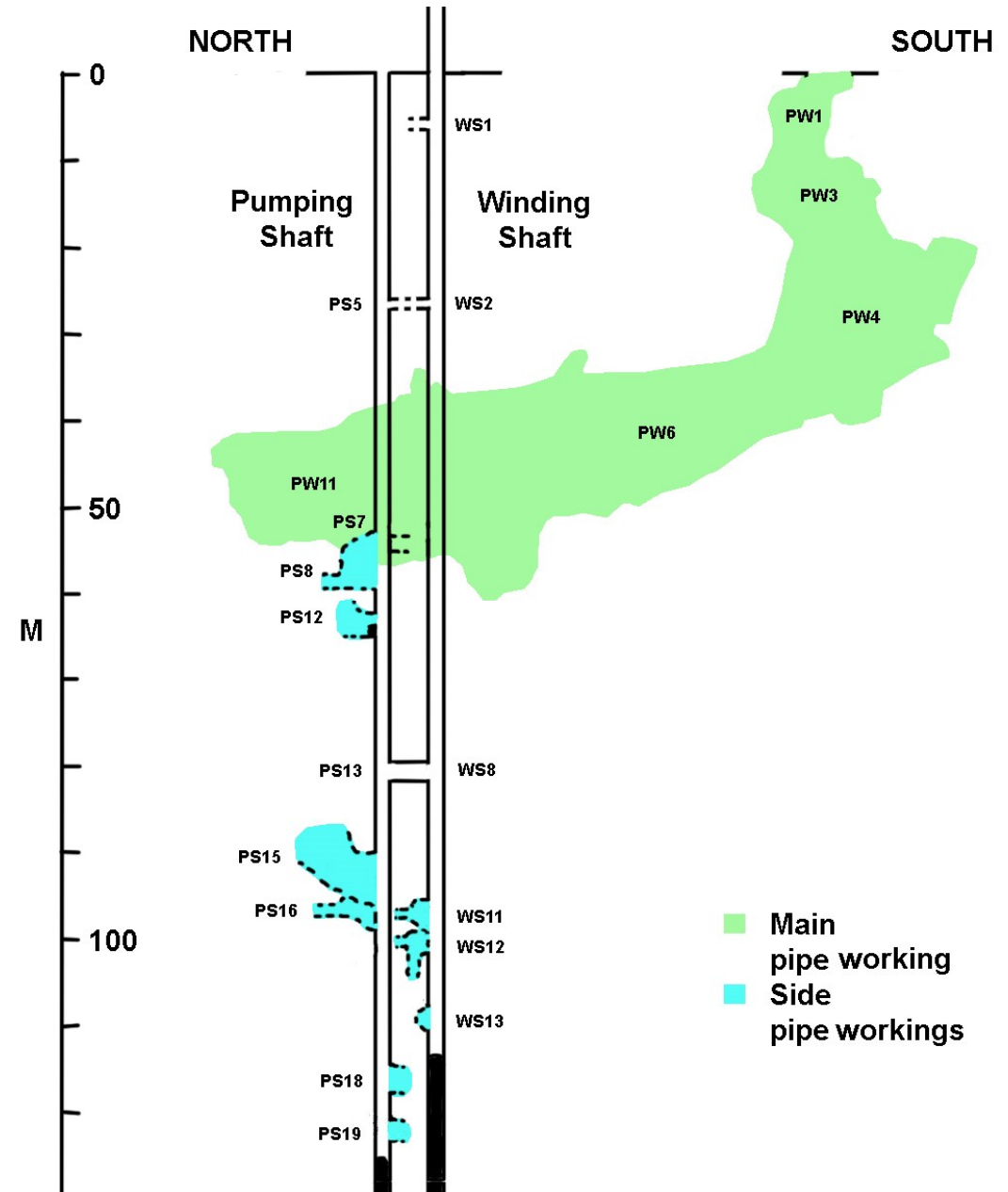


- Shafts
- Passages at river level
- Main pipe working at river level
- Flooded main pipe workings
- Flooded side pipe working
- Flooded cross-cut



# INTERSECTIONS WITH PIPE WORKINGS

- Green – upper pipe working directly accessible from launch site
- Blue – substantial openings into deeper pipe workings



## UPPER PIPE WORKINGS

Complex honeycomb of passages from adit level down to 20m depth – “Swiss Cheese”

front\_led\_corrected: 1558974276881437701 = 2019-05-27 16:24:36

Depth: 7.6  
X, Y: 3.0, -0.8  
Roll: -4.8, Pitch: 1.1, Yaw: 344.1



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# UPPER PIPE WORKINGS

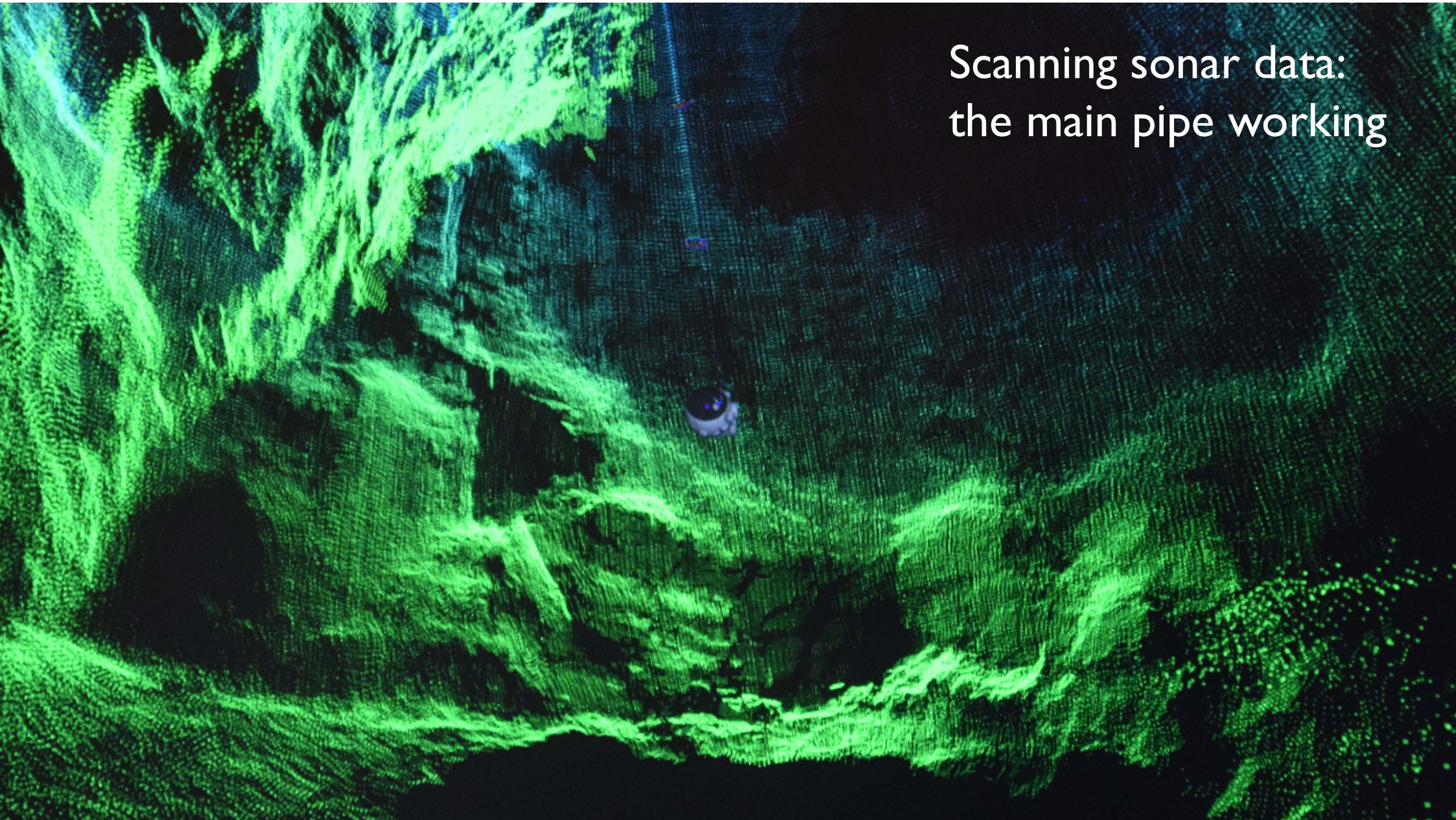


Upper pipe working: 16m depth within complex “Swiss Cheese” workings



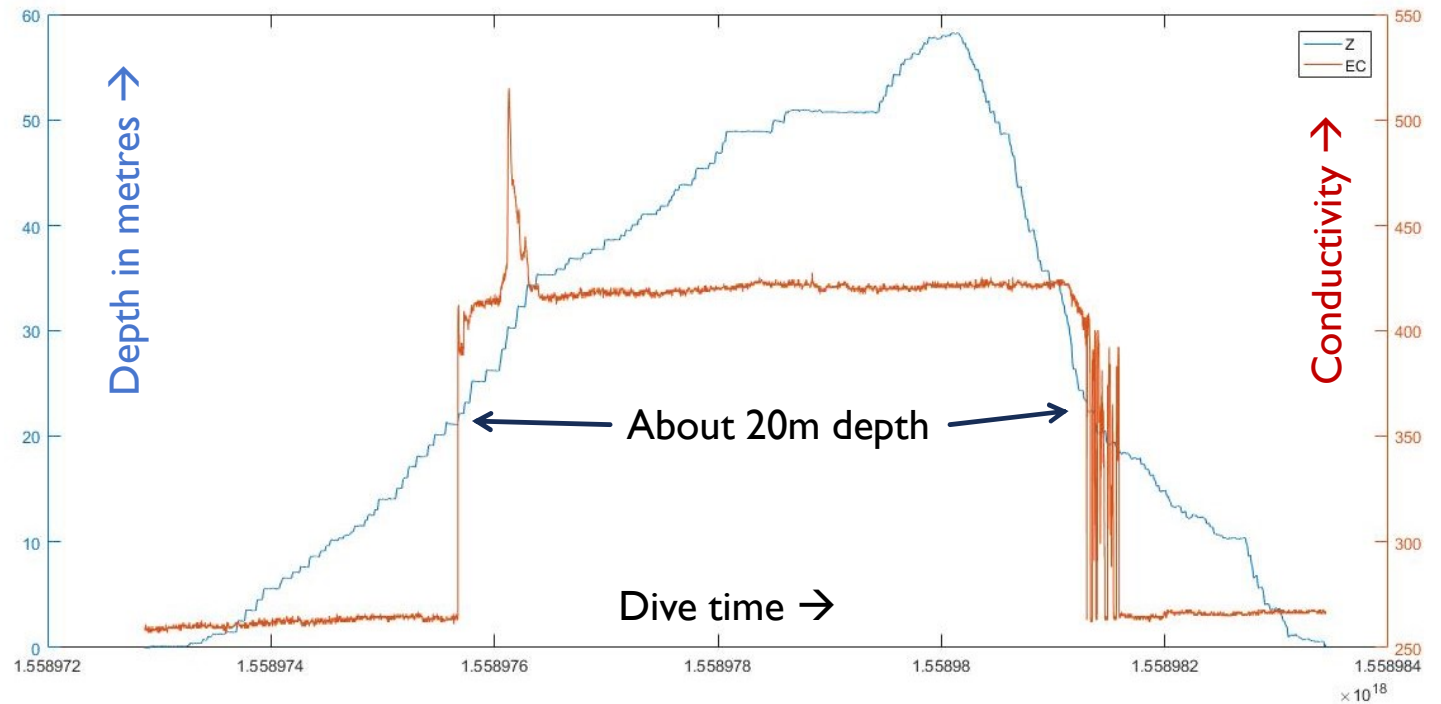
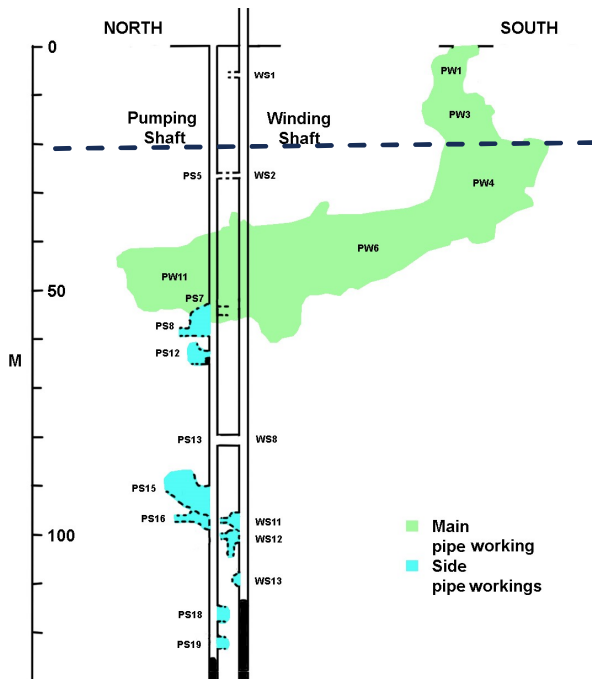
“Window” from pipe working into winding shaft at 53m depth, possibly accidental

Scanning sonar data:  
the main pipe working



# PIPE WORKINGS ELECTRICAL CONDUCTIVITY

- Blue = depth
- Red = EC



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## PUMPING SHAFT, 57M

- Pipe working on left, deep alcove or unexplored level below, right

front\_uv\_corrected: 1558373110079460234 = 2019-05-20 17:25:10

Depth: 57.7  
X, Y: -6.9, 0.9  
Roll: 3.6, Pitch: -0.1, Yaw: 111.0

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# GEOLOGY – ECTON PIPE WORKINGS

right\_led\_corrected: 1558981534985556849 = 2019-05-27 18:25:34



Anticline at  
19m depth

Depth: 19.2  
X, Y: 7.2, -24.4  
Roll: -2.7, Pitch: 3.1, Yaw: 144.9

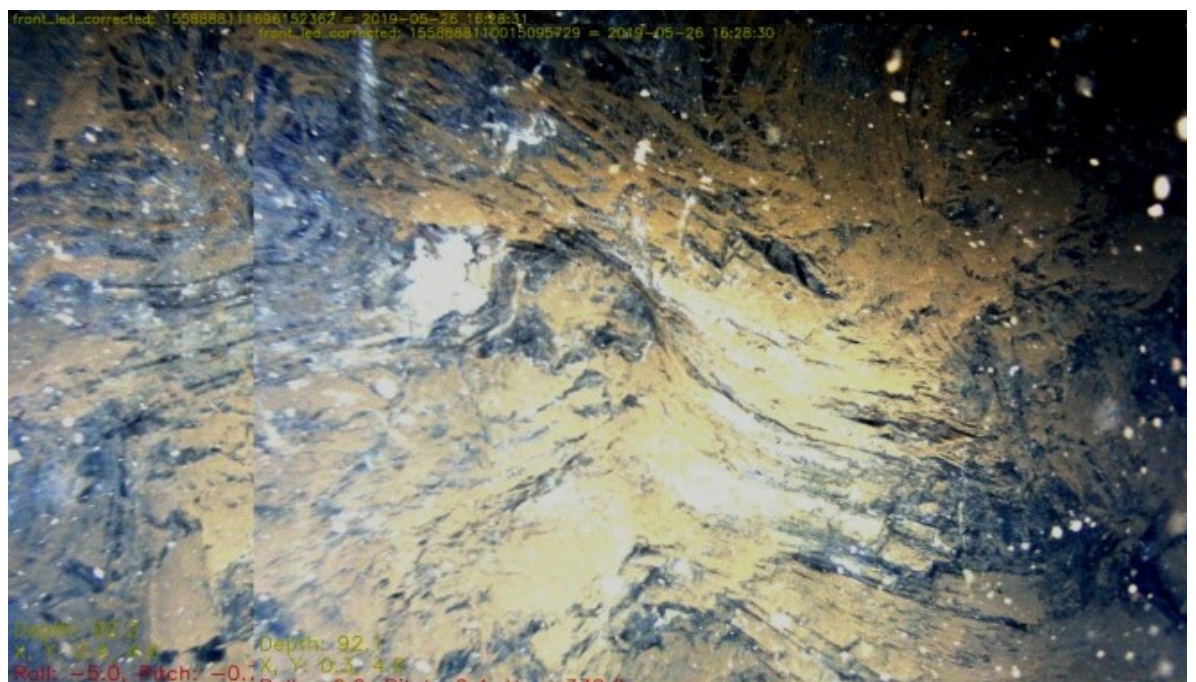
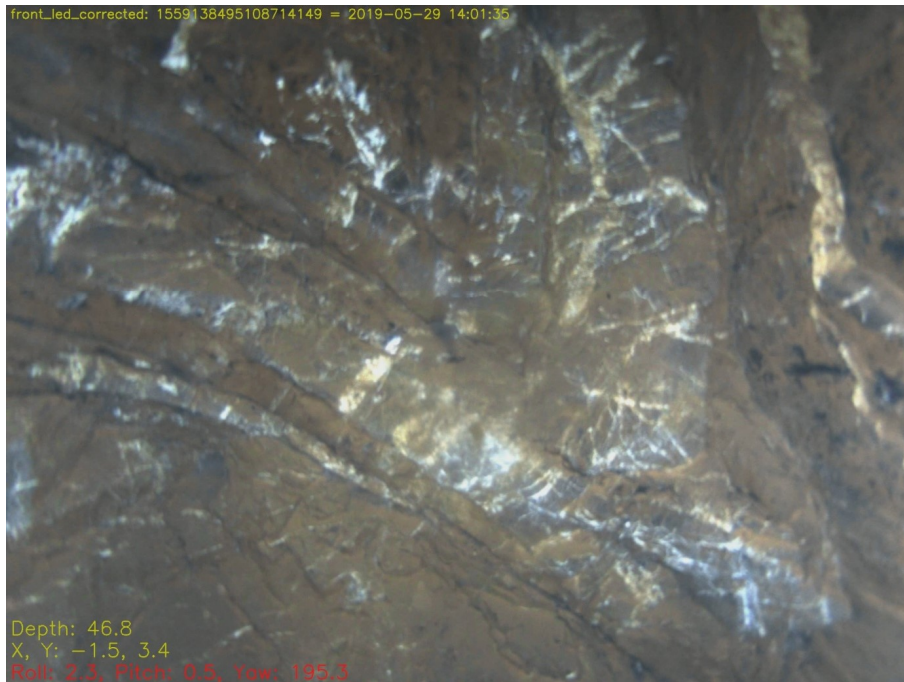
front\_led\_corrected: 1558976504403817289 = 2019-05-27 17:01:44



Syncline in roof  
at 35m depth

Depth: 35.2  
X, Y: 10.8, -0.5  
Roll: -3.0, Pitch: 0.8, Yaw: 5.3

# CONTRASTING FOLD STYLES



Syncline in thick-bedded limestone (46m depth)

Crumpled thin-bedded limestone (92m depth)



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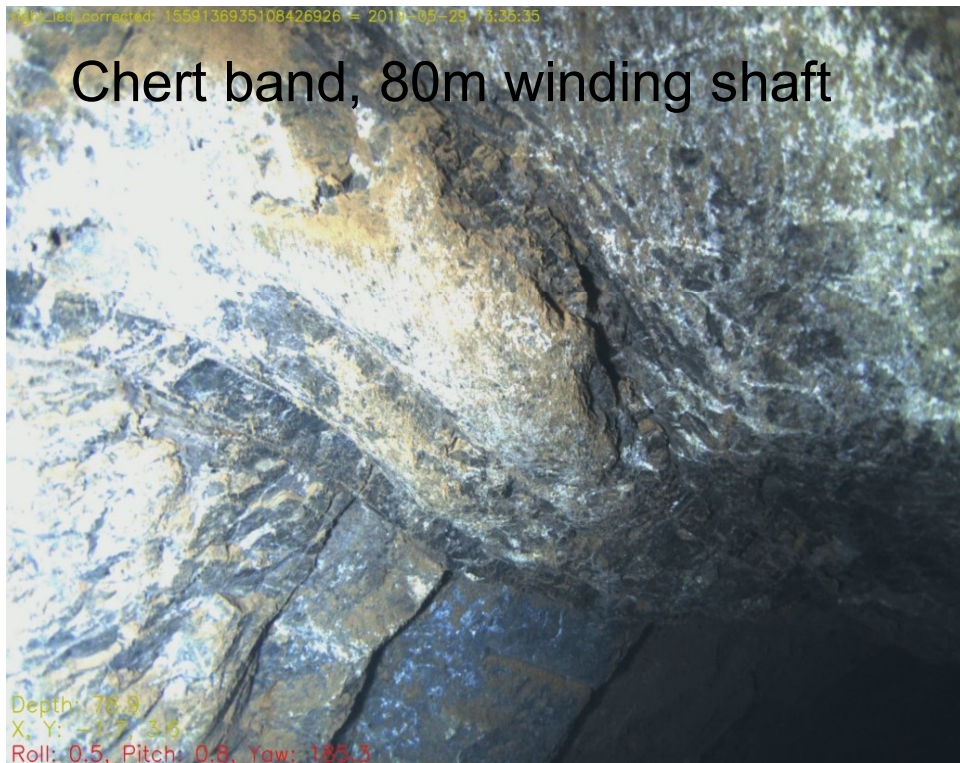




# GEOLOGY

front\_led\_corrected: 1559136935108426926 = 2019-05-29 13:35:35

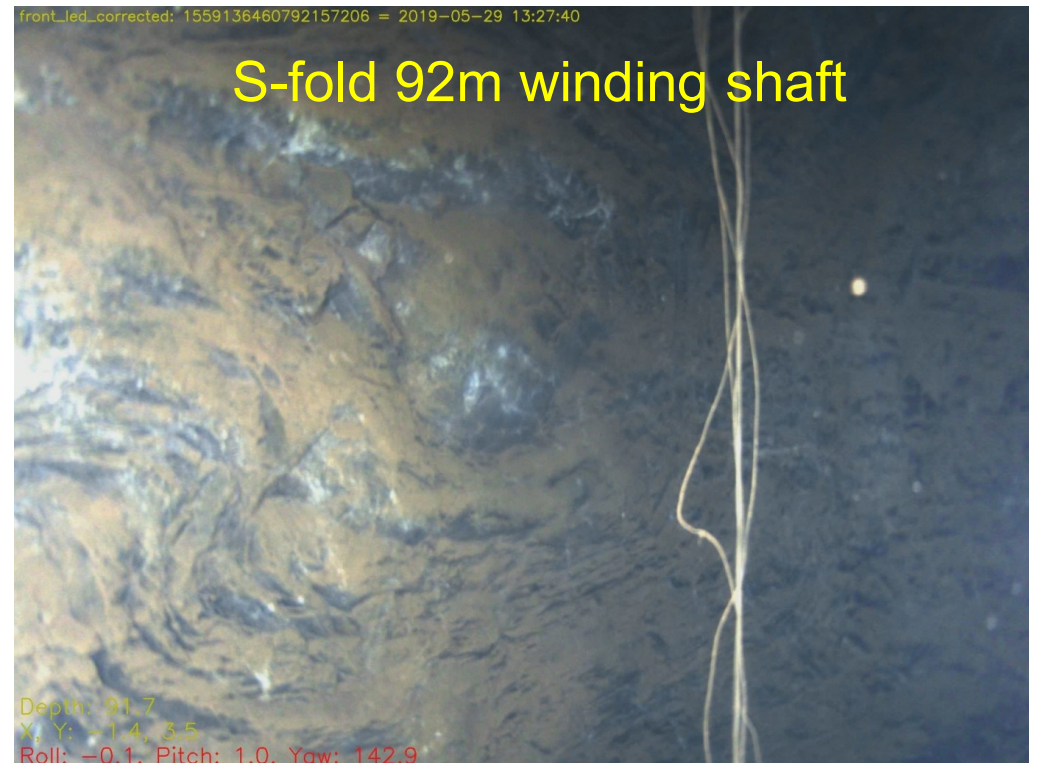
## Chert band, 80m winding shaft



Depth: 78.9  
X, Y: -1.7, 3.5  
Roll: 0.5, Pitch: 0.6, Yaw: 185.3

front\_led\_corrected: 1559136460792157206 = 2019-05-29 13:27:40

## S-fold 92m winding shaft



Depth: 91.7  
X, Y: -1.4, 3.5  
Roll: -0.1, Pitch: 1.0, Yaw: 142.9



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# FAULTING

front\_led\_corrected: 1559130549256325636 = 2019-05-29 11:49:09

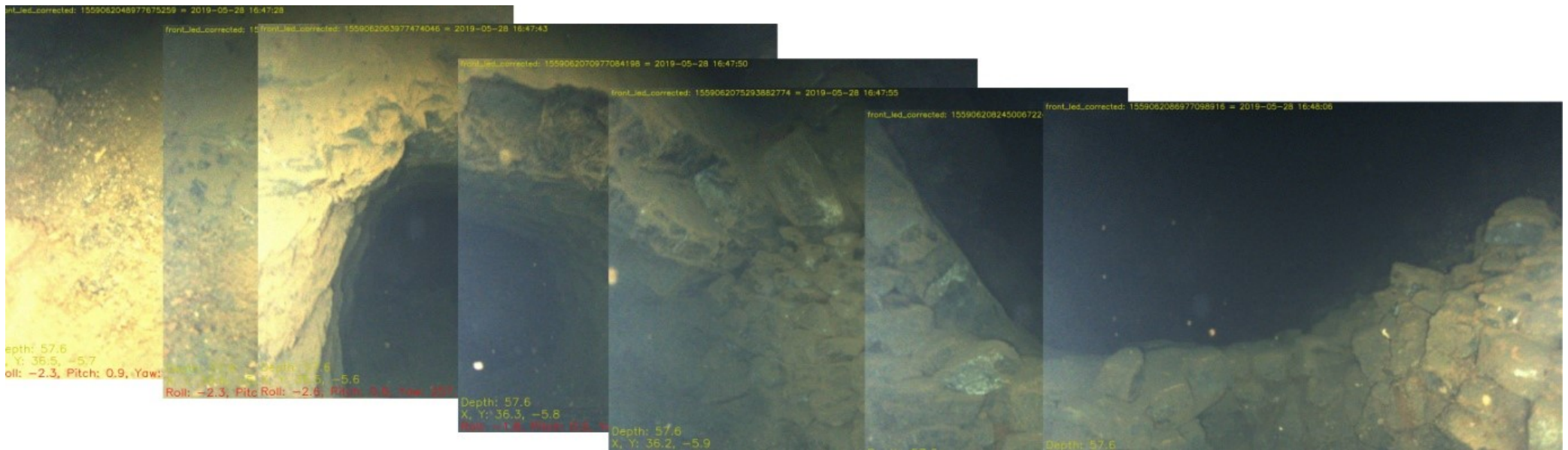


Slickensides on bedding plane  
65m, winding shaft

# MINERALISATION: MULTIPLE GENERATIONS OF CALCITE VEINING



# UPPER PIPE WORKINGS – 58M DEPTH



**Left:** 3m crosscut to winding shaft. **Right:** pipe workings continue downward  
Miners took advantage of the anticline structure in driving the crosscut

# ARCHAEOLOGY

Winding shaft, 58m depth

This is directly opposite the very short (3m) cross-cut from the pipe workings. Timbers appear to have fallen, but what is the metal hoop and why is it there?



## APES TOR 34FM BOAT LEVEL?

- 65m depth in pumping shaft
- Wall or dam. Seems to be mortared. Either canal or cistern?



## 80M DEPTH

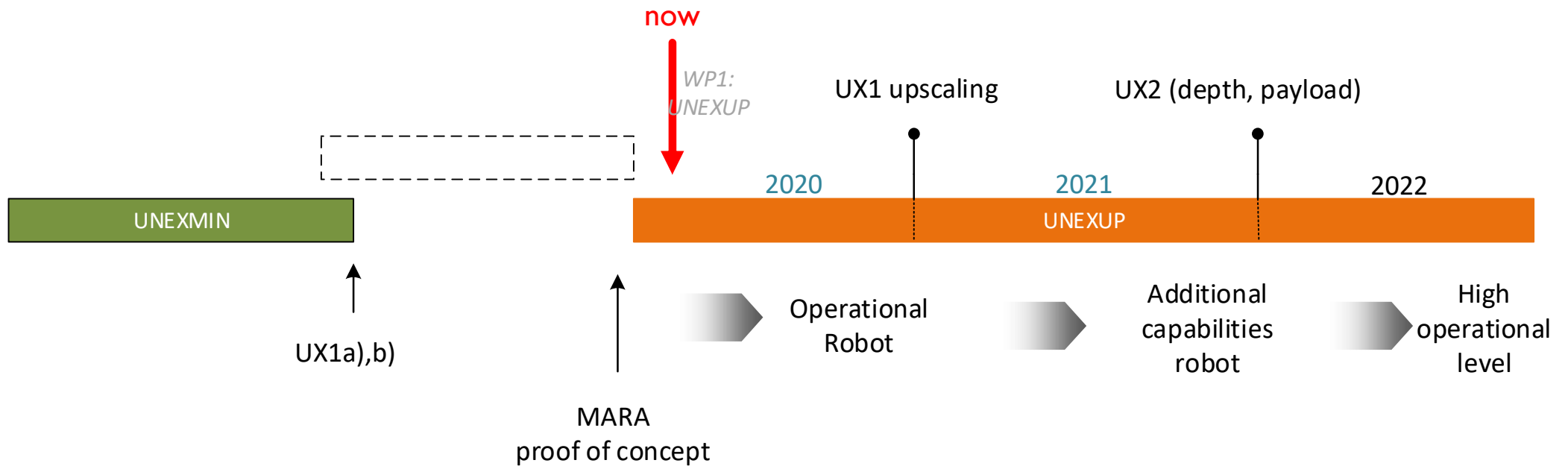
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Depth: 80.1  
X, Y: 12.0, -20.4  
Roll: 0.0, Pitch: -0.0, Yaw: 259.1

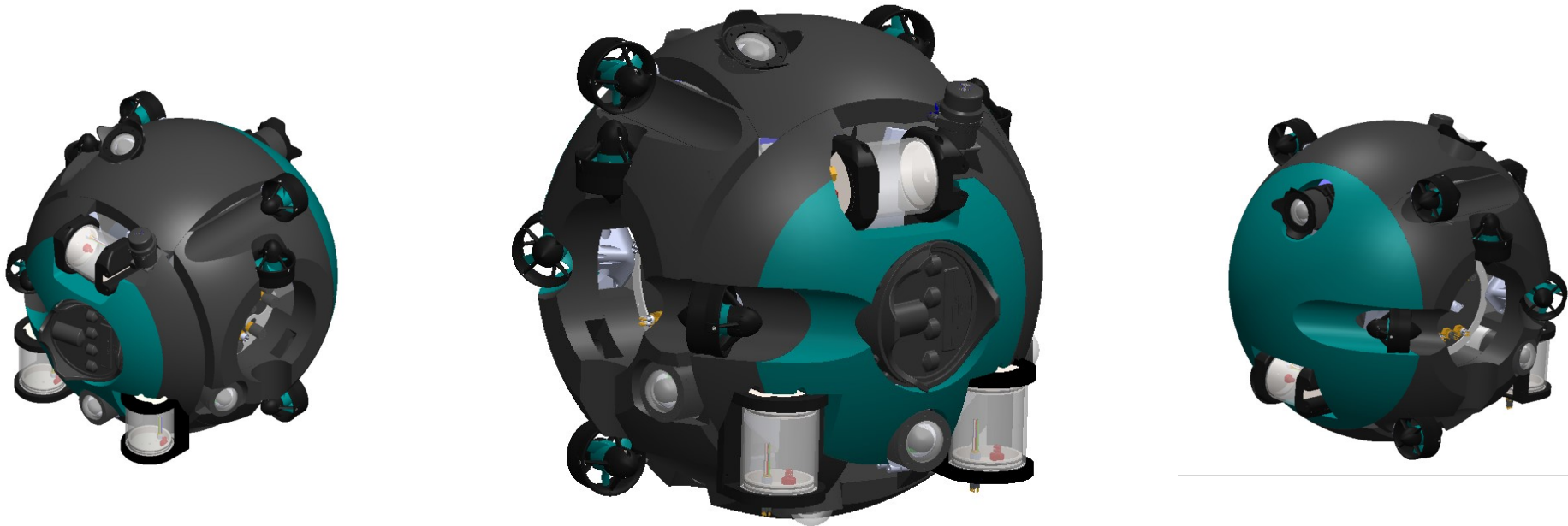
- Cross-cut from pumping shaft to winding shaft
- This was used to transfer ore in 1786-1788 when the pumping shaft was temporarily deeper than the winding shaft

# FROM UNEXMIN TO UNEXUP





# MARA



# MARA

- Modular
- Full 6DOF thruster control
- Pendulum
- Same dimensions as UX1 robots
- One additional SLS/cam on back (5 SLS, 6 cams)
- Space for UX1 payload sensors



# “MARA” ROBOT AT INESC-TEC, PORTO, FEB.2020





Thank you  
for your  
attention

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[www.unexmin.eu](http://www.unexmin.eu)