Muography: A novel method of density measurement for mining and surveying

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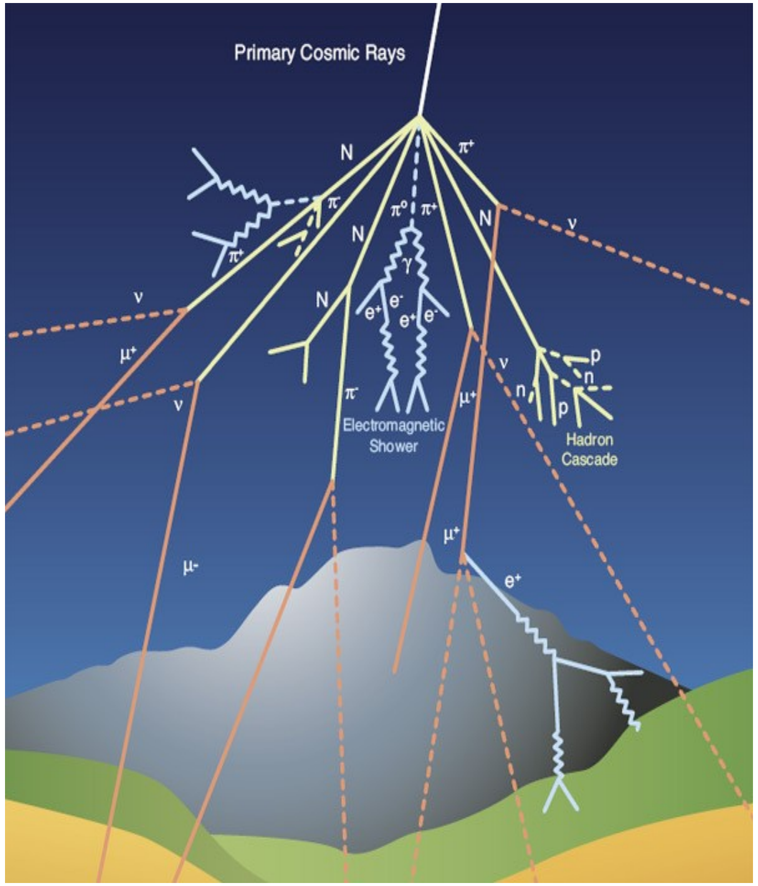
Principles of muography

- Muons are charged particles that are part of the **secondary cosmic radiation** *[2]*
- They have a **steady**, angle dependent **flux** on the surface *[3]*
- They can **penetrate** hundreds of meters of **rock** *[4]*
- Muons are continuously being **absorbed** by the rock along the path *[5]*
- The number of absorbed muons depends on the **density of the rock along their trajectories** *[5]*

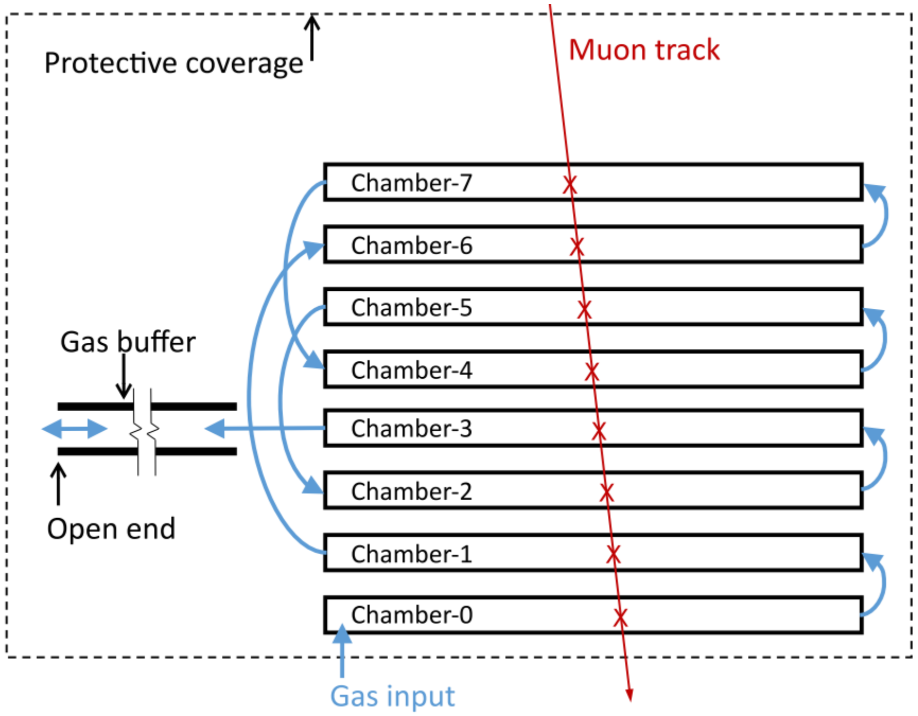


Cosmic radiation visualised *[1]*

Muographic detectors

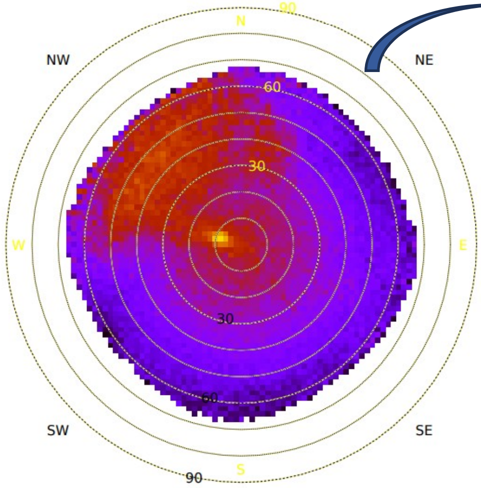
- Muons have the same charge as an electron → detection possible by **electron multiplication in ionised gas**
- Electron multiplication takes place **in the vicinity of high voltage wires** (MWPC technology) *[6]*
- Perpendicular **wires record X** and **Y** coordinates, position of chambers records **Z** *[7]*
- The result is an **inexpensive, durable, high efficiency** (99%) tracking device *[8]*

Angle dependent muon flux above the position of the detector can be measured *[9]*

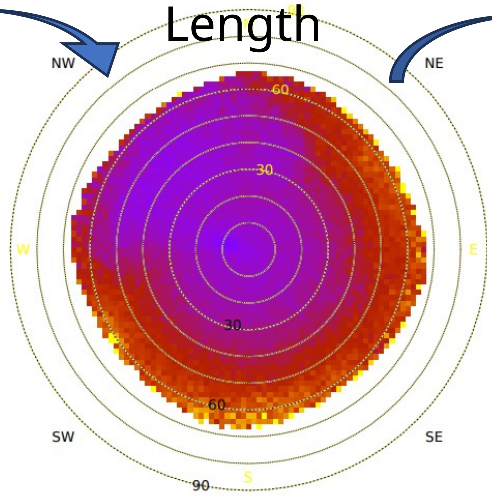


Schematic 2D drawing of a muograph *[7]* on the left, and the „Mtl1” detector inside Esztramos Hill on the right

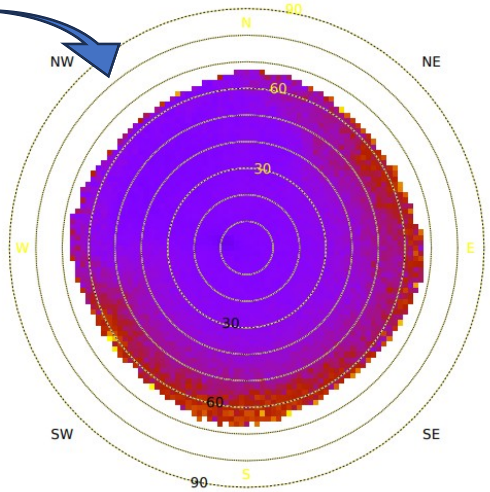
Measured Flux



Measured Density-Length

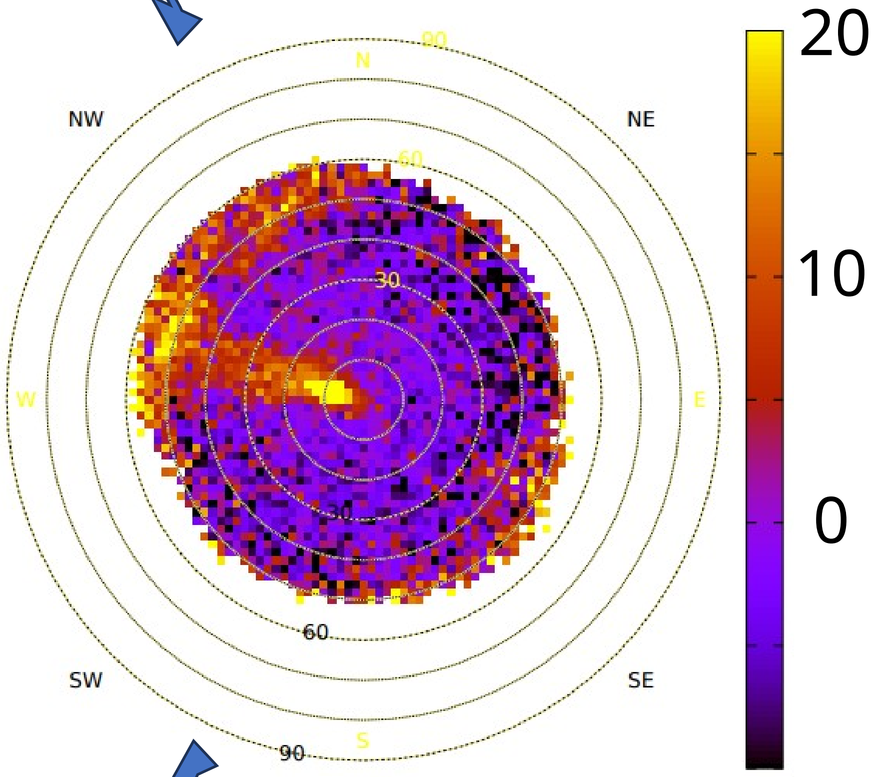


Measured Rock Length



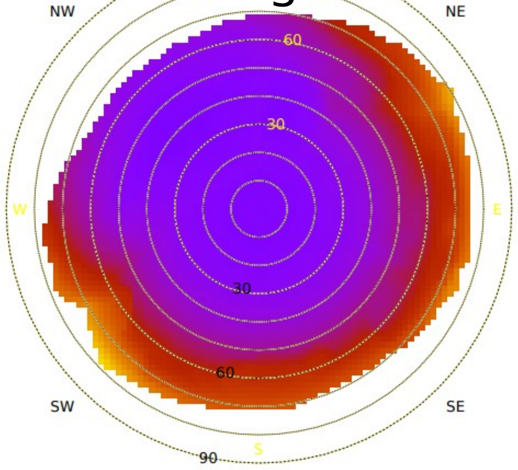
Muographic detectors

Missing Rock [m]



- **Measured Flux** can be mathematically converted to the product of the path length and average density along the trajectories → **Measured Rock Length** can be determined *[10]*
- Rock Length **can also be modeled** using geoinformatic methods (DEM, lidar, GPS)
- The **difference of the two values** is called **Missing Rock**

Modeled Rock Length



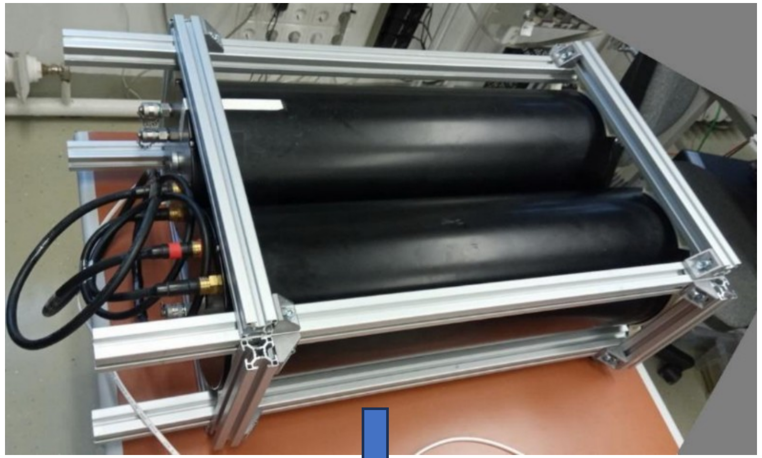
Muographic

Prototype: underwater

MINE.IO
A Holistic Digital Mine 4.0 Ecosystem


Assarel, Bulgar


jce, Bosnia-Herzegovin




bánya, Hungary (water ph level: 1

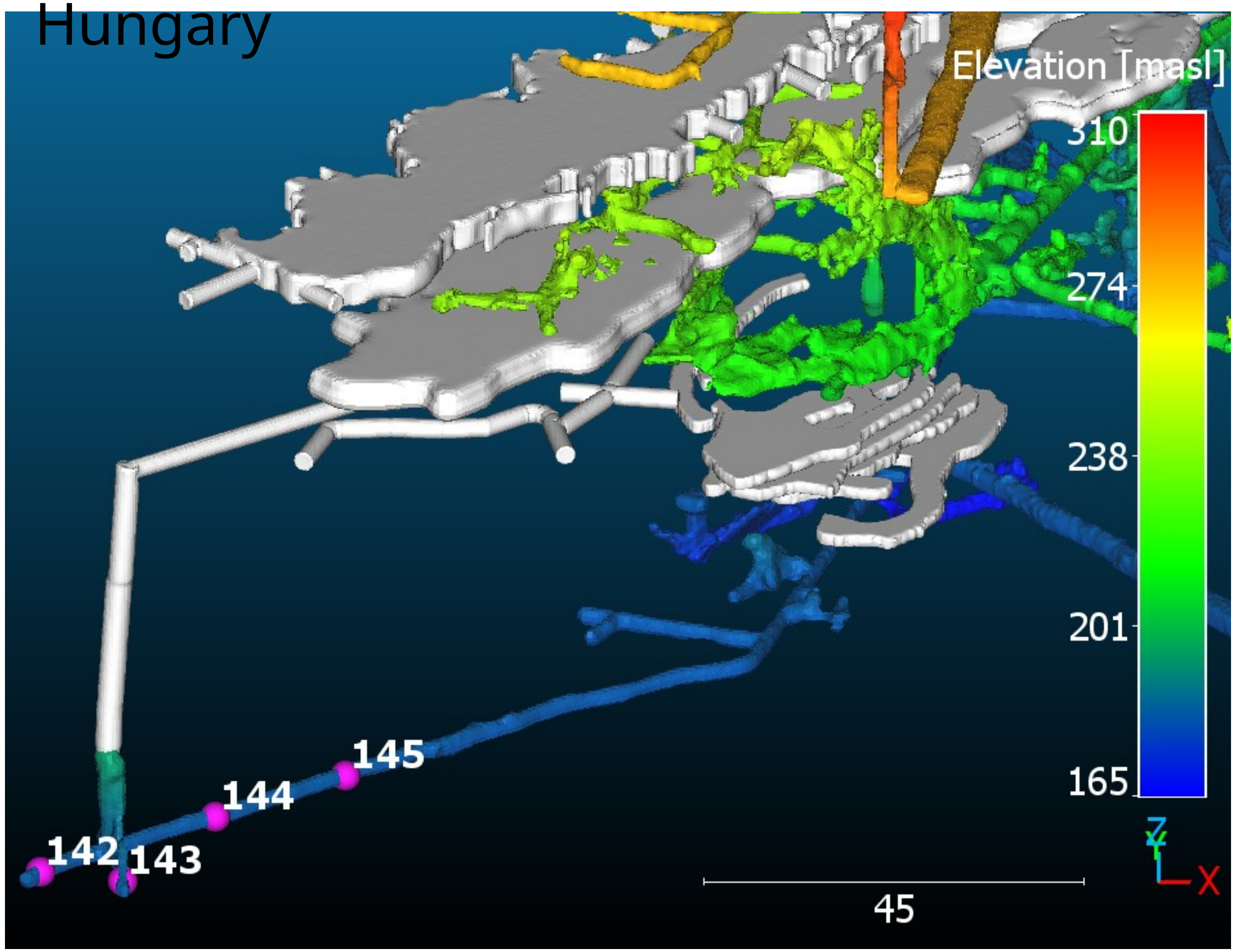

Breitenbrunn, German

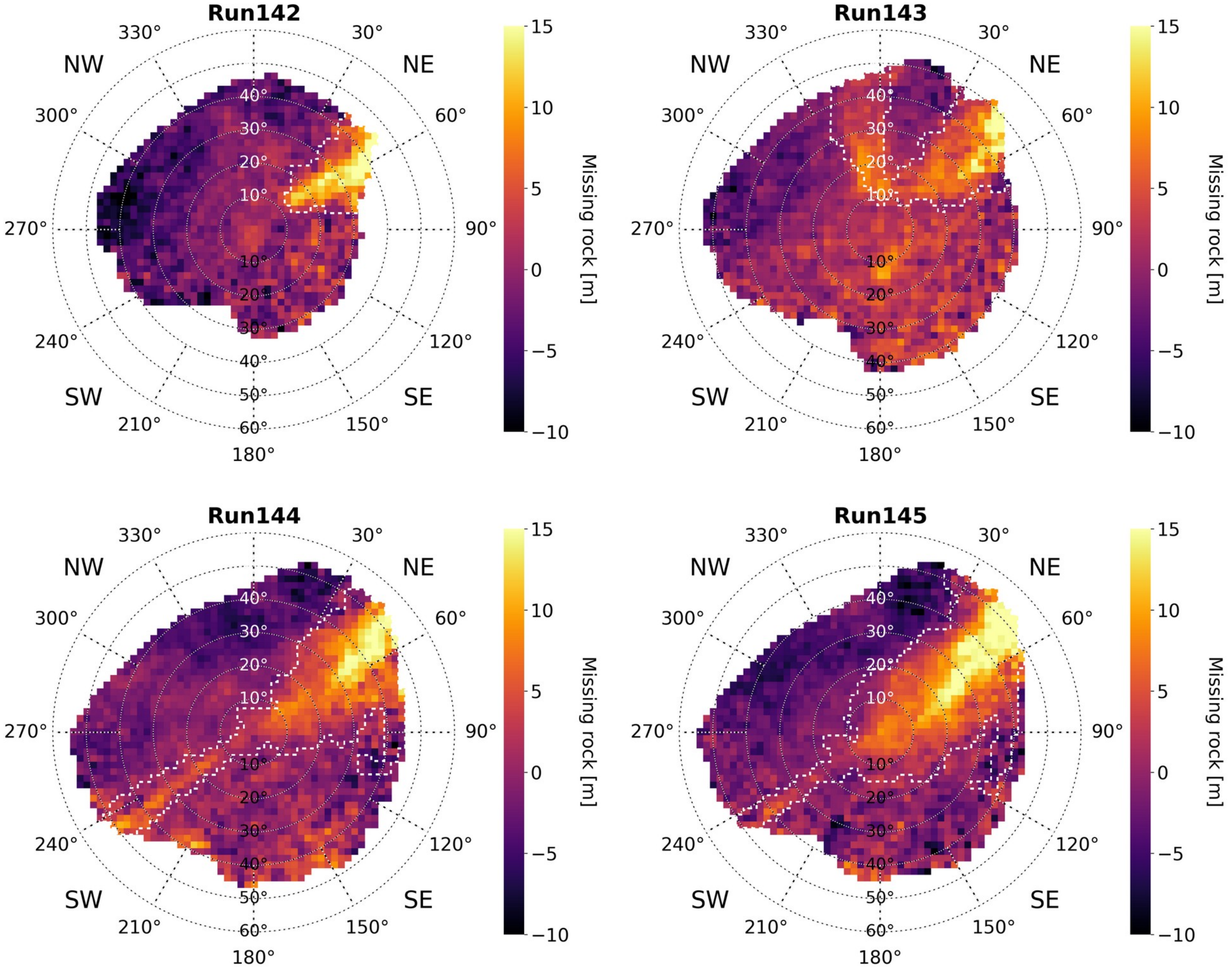
Protective casing for extreme conditions:

°C, 100% corrosive hum


Lubin, Poland

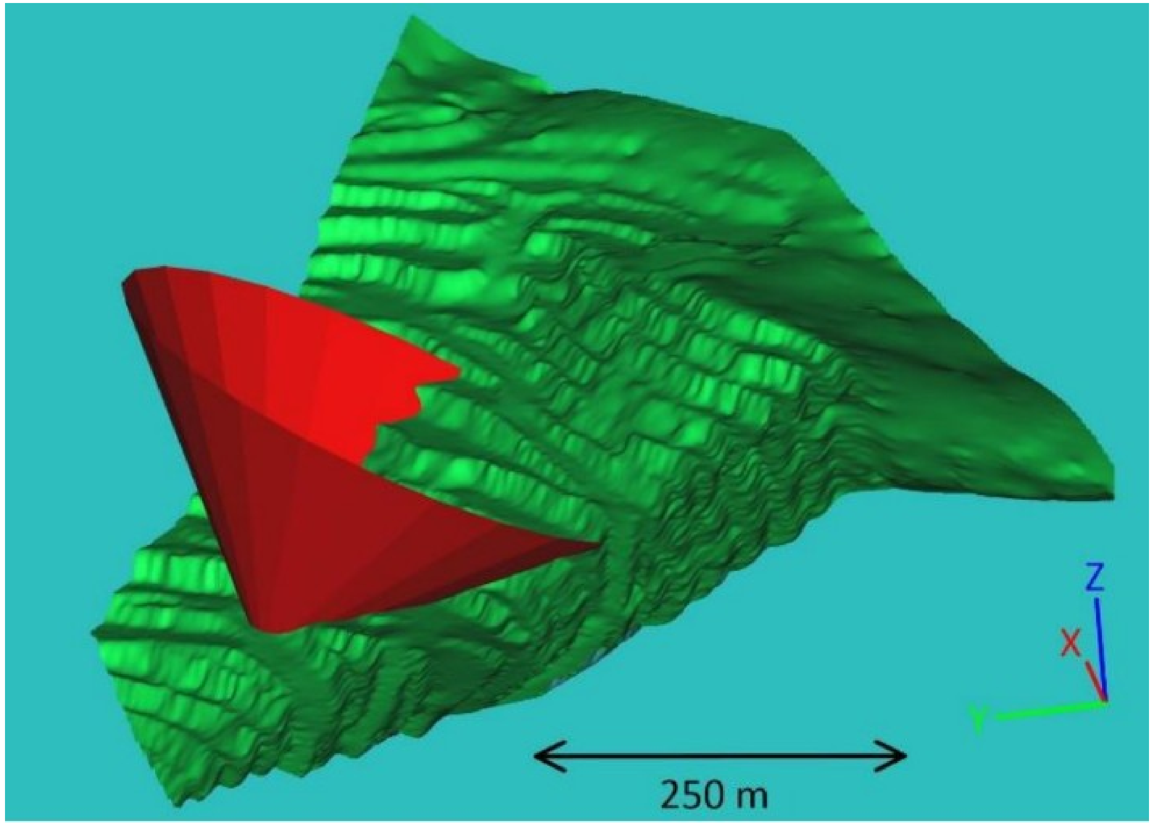
Applications – Surveying the abandoned iron ore mine of Esztramos Hill, Hungary

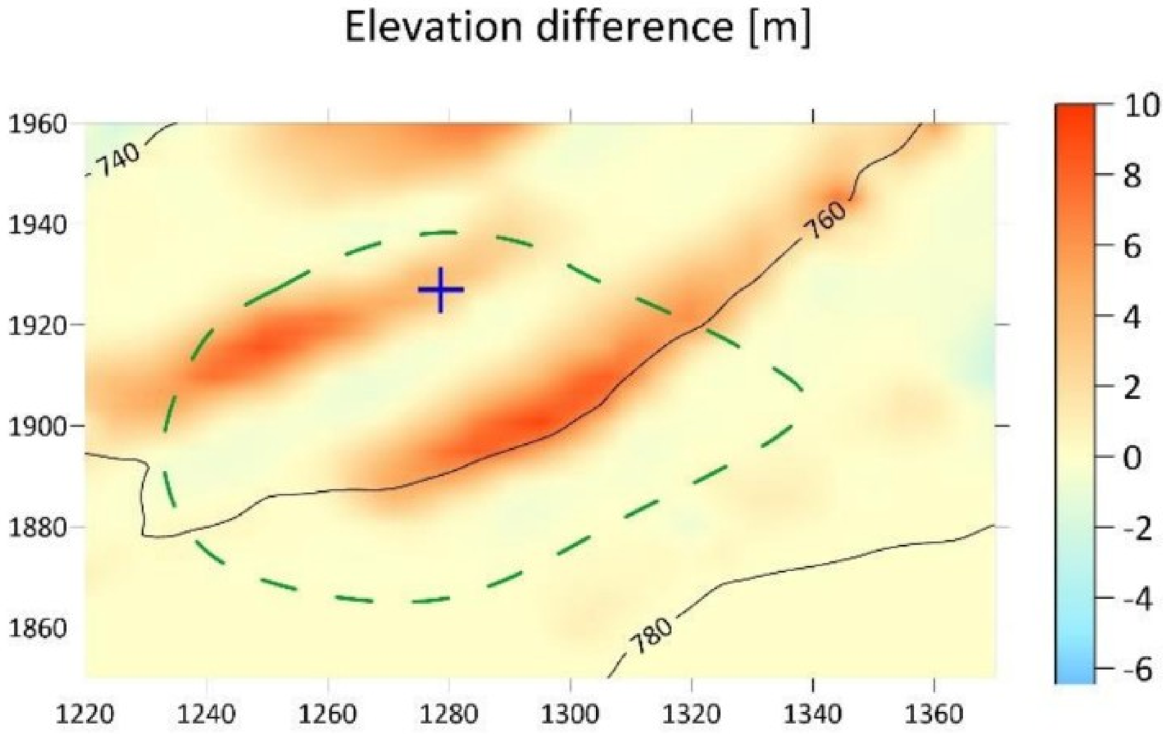




The mines have partially collapsed and have been inaccessible for over 80 years.
The maximum **extent** of mining operations was **succesfully confirmed.** *[11]*

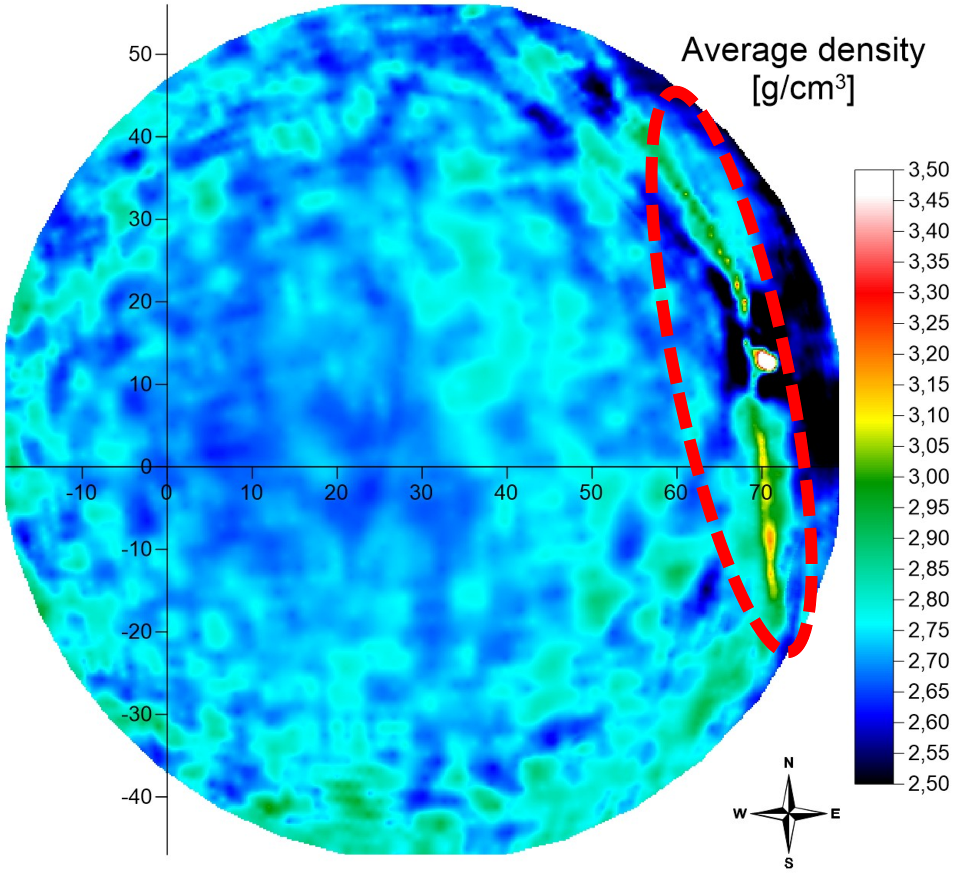
Applications – Open pit mine monitoring





The elevation difference over one month of operation was calculated.
Data can be used to validate the **mass of the mined out rock.**

Applications – Ore body identification



Ore bodies and geological structures with different average density compared to the surrounding rock **can be identified**

Thank you for your attention!

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