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Geophysical mapping for mine planning

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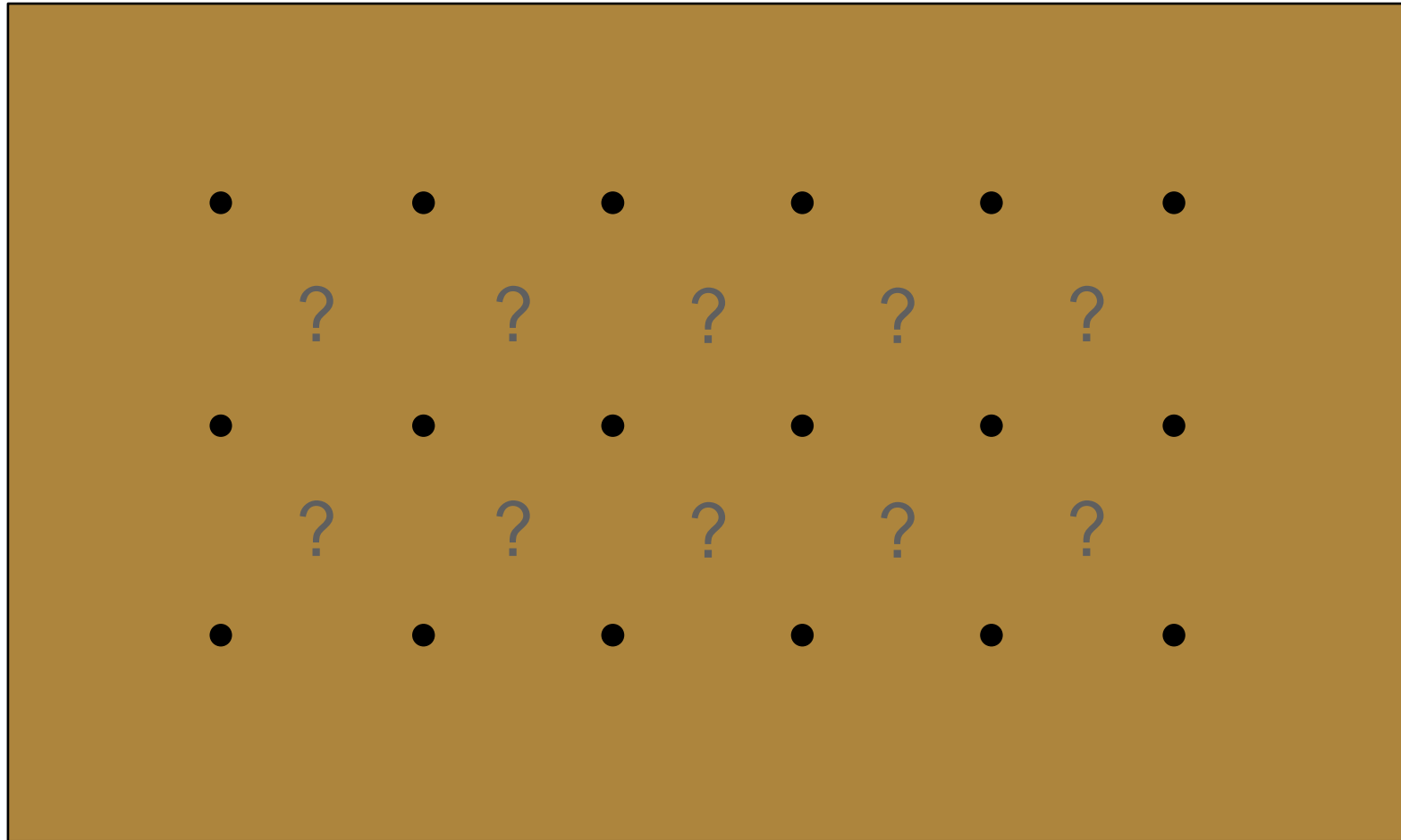
Outline

Case study in mine infrastructure planning

- Problem: find shallow bedrock under glacial till for siting the primary crusher
- Solution: map depth of till via electromagnetics
- Comparison with post-EM datasets
 - 3D seismic tomography
 - Actual excavation depth of pre-strip over pit
- Discussion
 - Drill holes vs geophysics



Geophysics reduces uncertainty



Drillhole information

- RC hole diameter = 14 cm (5.5 in) OD ~ 11.5 cm inner diameter
- Grade control with 10 m hole spacing
 - e.g., one hole per mining block
- Volume of drill hole per mining block = **0.04 %**
- DDH (HQ) at 50 x 50 m → **0.000127 % = 1.27 ppm**

Geophysics is the only option for filling in the space between drillholes with measured data



How to use geophysics to reduce uncertainty?

- Interpolation tool to reduce uncertainty between drillholes
 - NB: geophysics will probably not match the drill hole → measurement volume, properties mapped
- Provides information (from surface, from downhole) that can be used to do a better job of connecting the dots (lithology, SG, RQD)
- Caveat: the geophysical data need to represent the volume of interest
 - greater depth = greater uncertainty
 - need to isolate specific depth intervals?



Kevitsa mine site



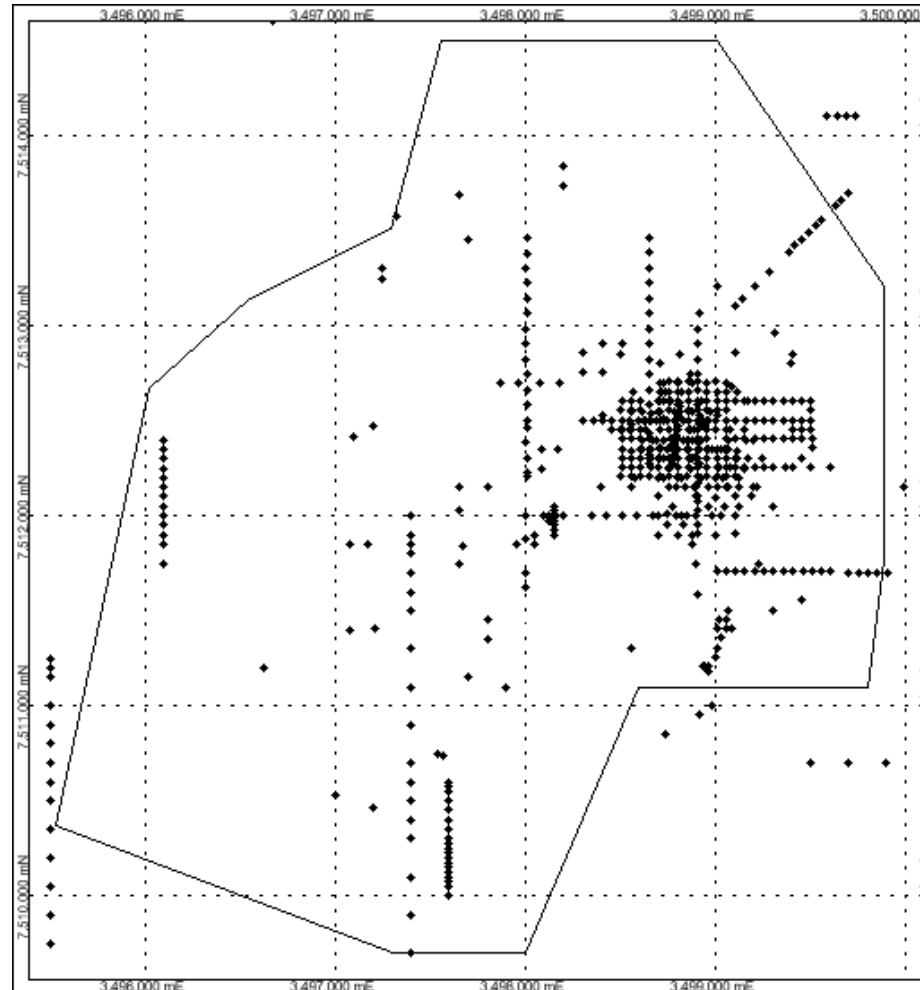
Problem: siting mine infrastructure

- Problem: glacial till and peat needs to be excavated down to solid bedrock at crusher site
- Solution: find shallow bedrock site to minimise excavation



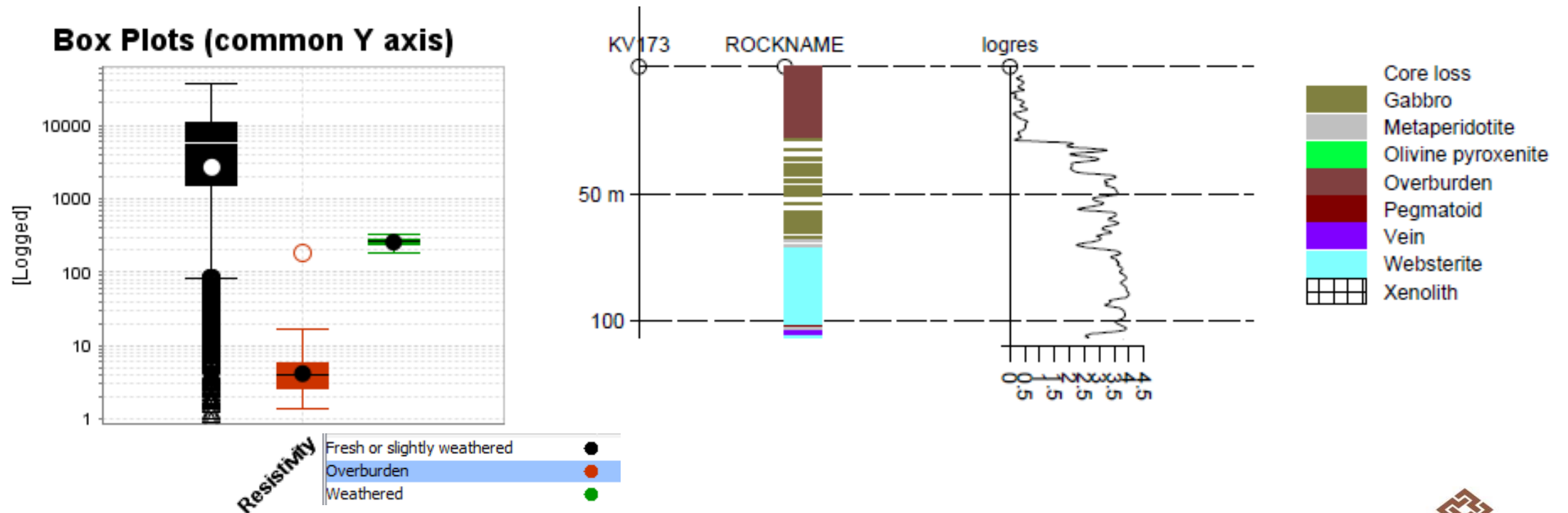
Problem II: drill hole coverage

- Drilling over resource (of course)



Electromagnetics: shallow mapping

- Electrical properties of overburden/regolith
 - sandy (not clay), no permafrost
 - more conductive than the fresh rock below even when bedrock is highly fractured and weathered



EM survey specifications

- SkyTEM 304 system
- 25 Hz high-moment and 222.5 Hz low moment
- 1 ms low-moment pulse width
- earliest gate centre 6 μ s (low-moment)

- 50 m line spacing
- 30 m flight height
- survey speed 85 km/h

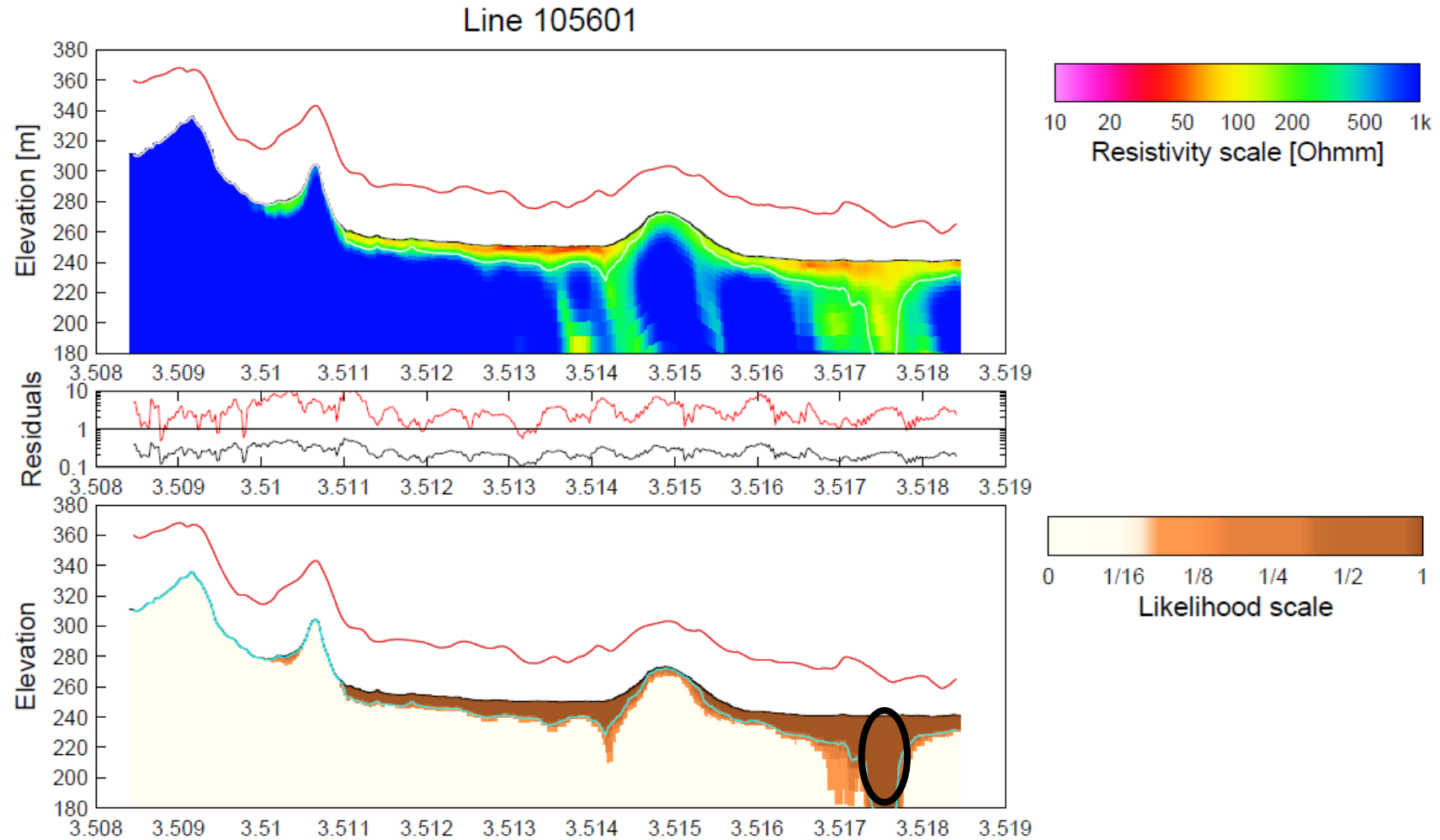


EM inversion specifics

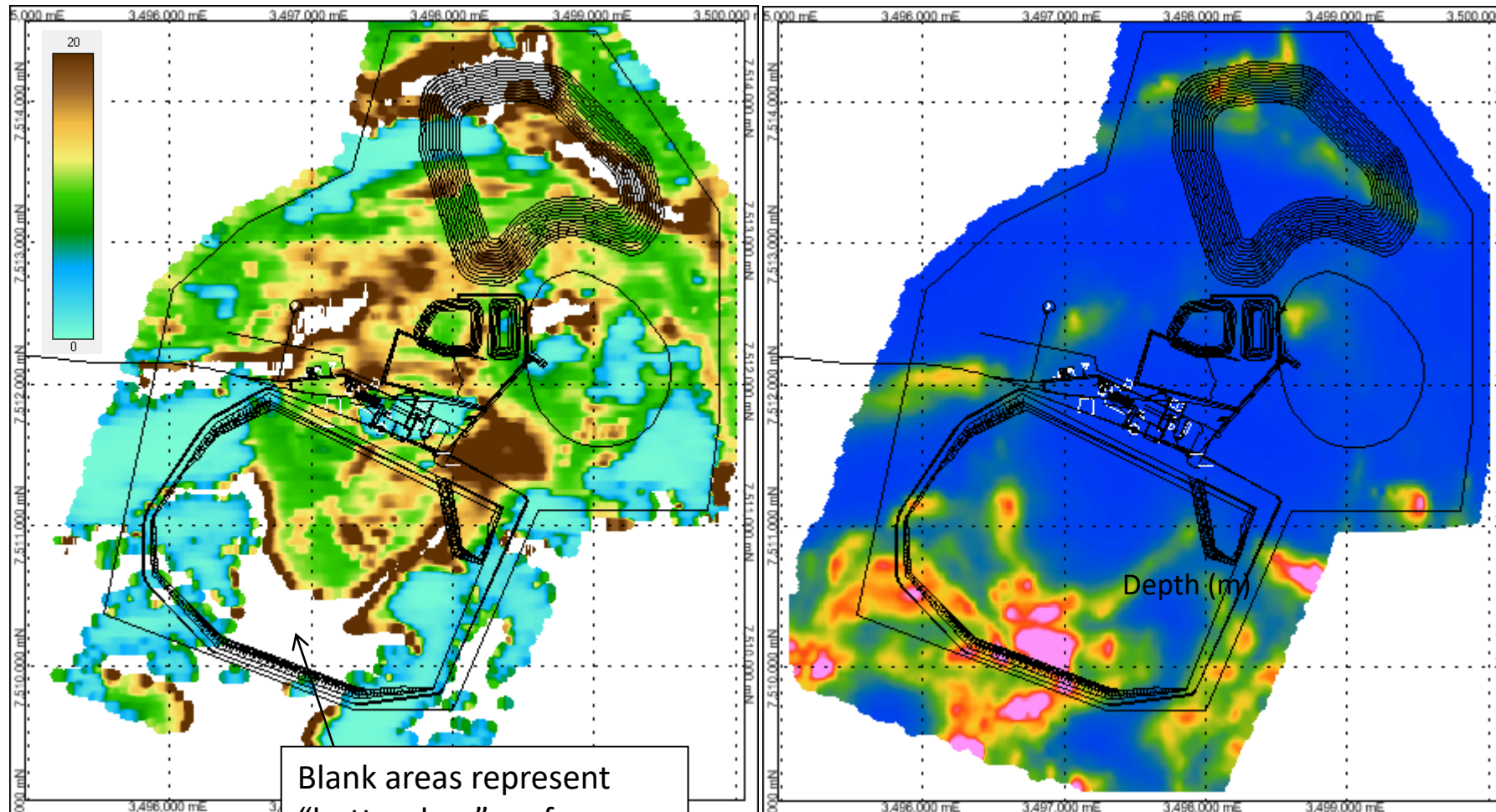
- Laterally-constrained 1D inversions along flight lines
- Overburden generally < 10 m thick, beyond resolution of even low-power SkyTEM → statistical inversion approach
- Multiple realisations (1000) of the inversion using perturbations to initial solution, find > 50% probability that each layer < threshold resistivity (500 ohm.m)
- Pick threshold resistivity interface as depth of overburden



Statistical inversion approach



EM-derived overburden depth for 500 Ωm

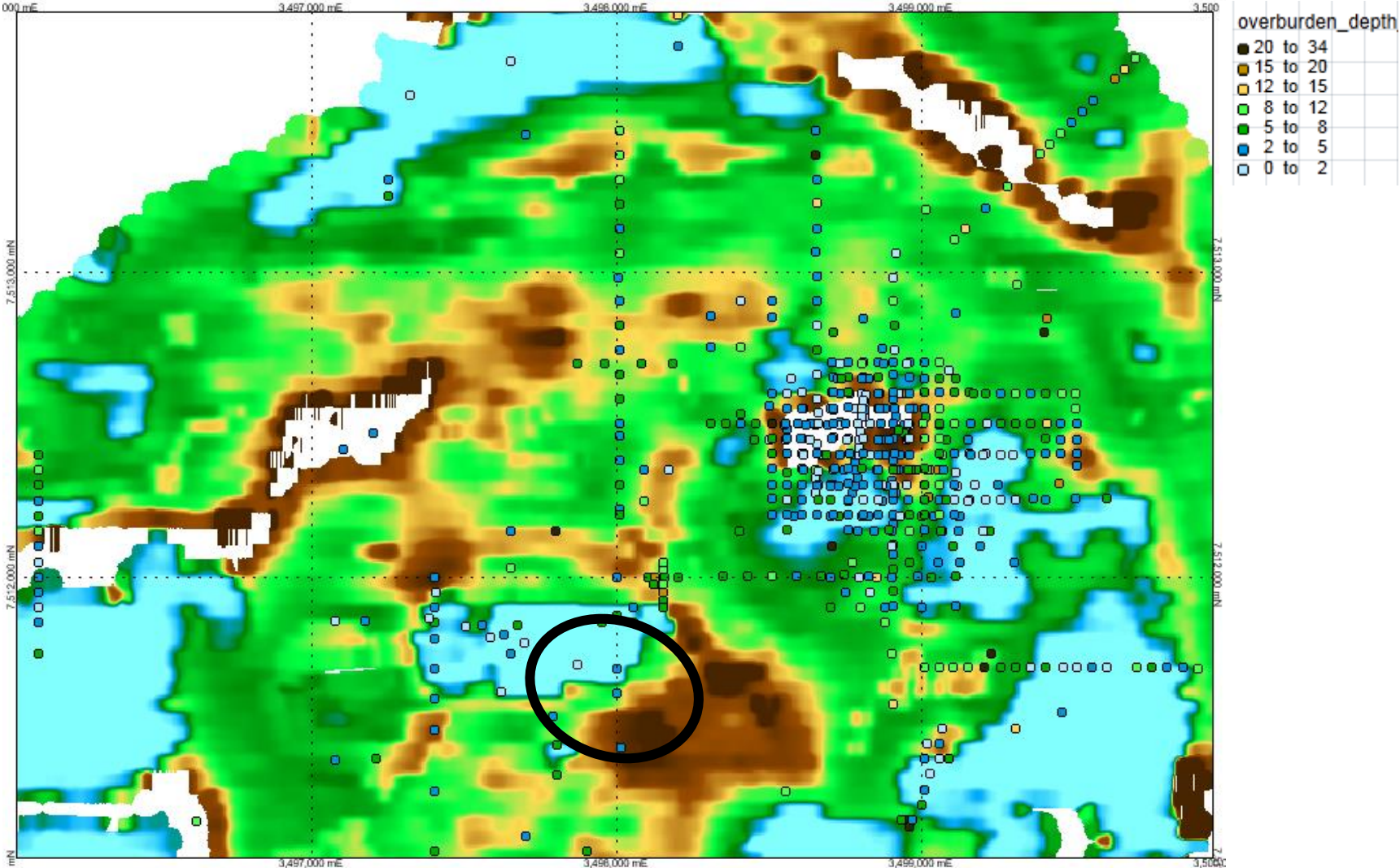


Blank areas represent
"bottomless" surface
conductivity over shallow
bedrock conductors

285 $\mu\text{s dBz/dt}$

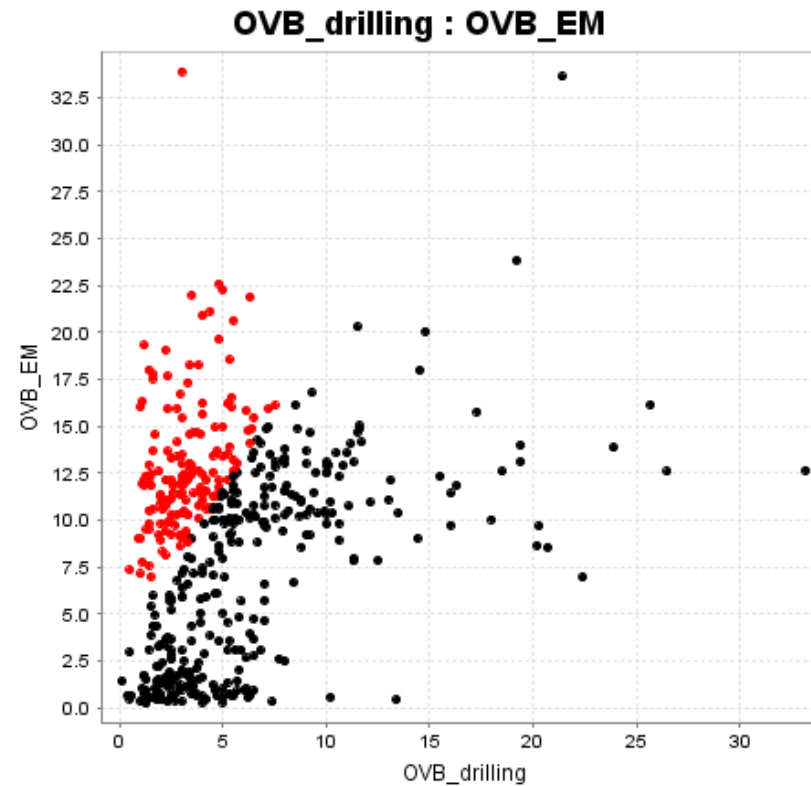
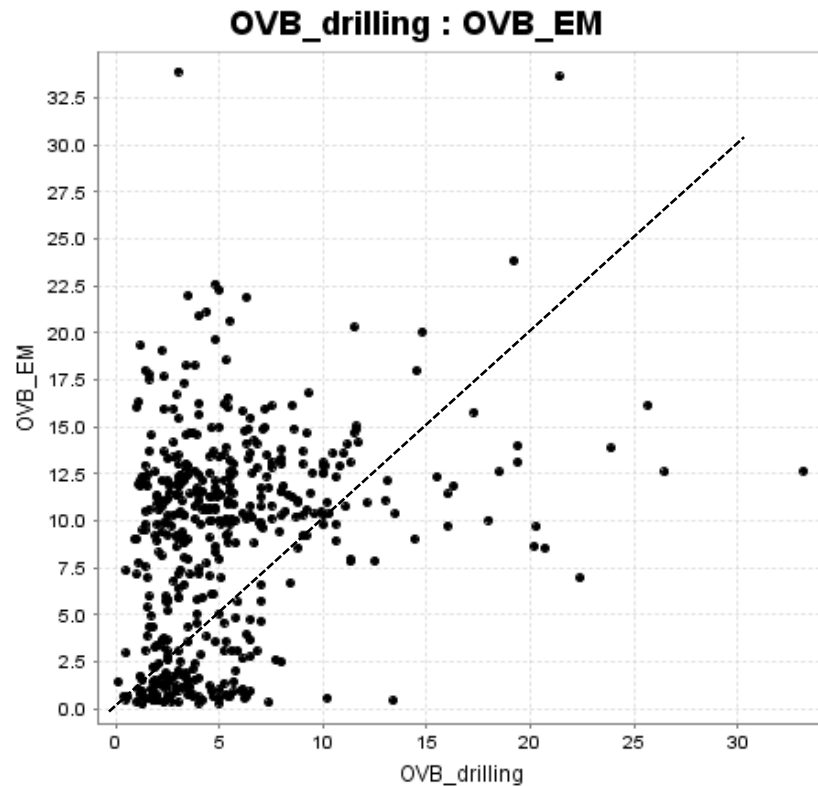


Overburden depth: drilling vs AEM

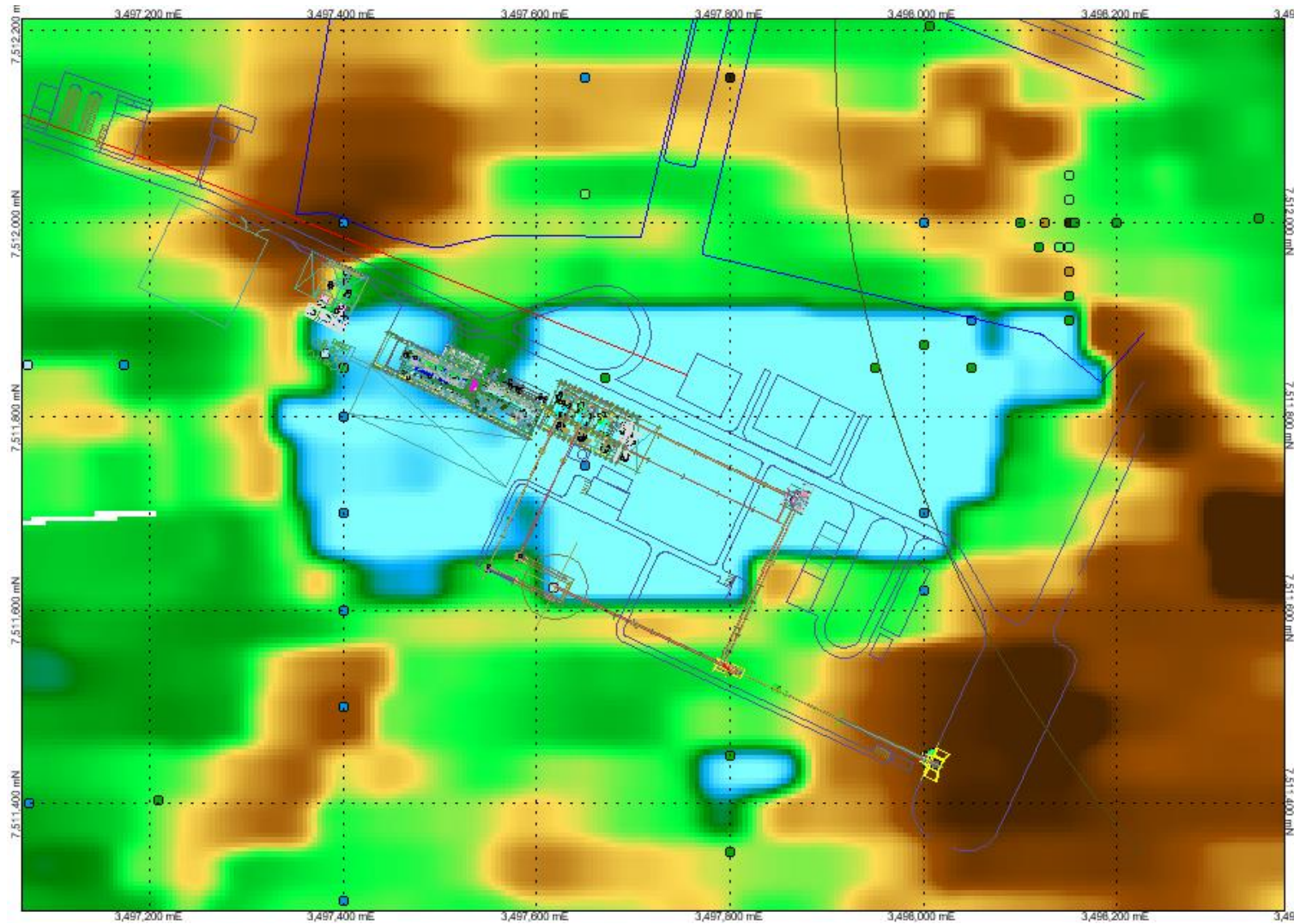


“Truth test”: EM vs drill logging

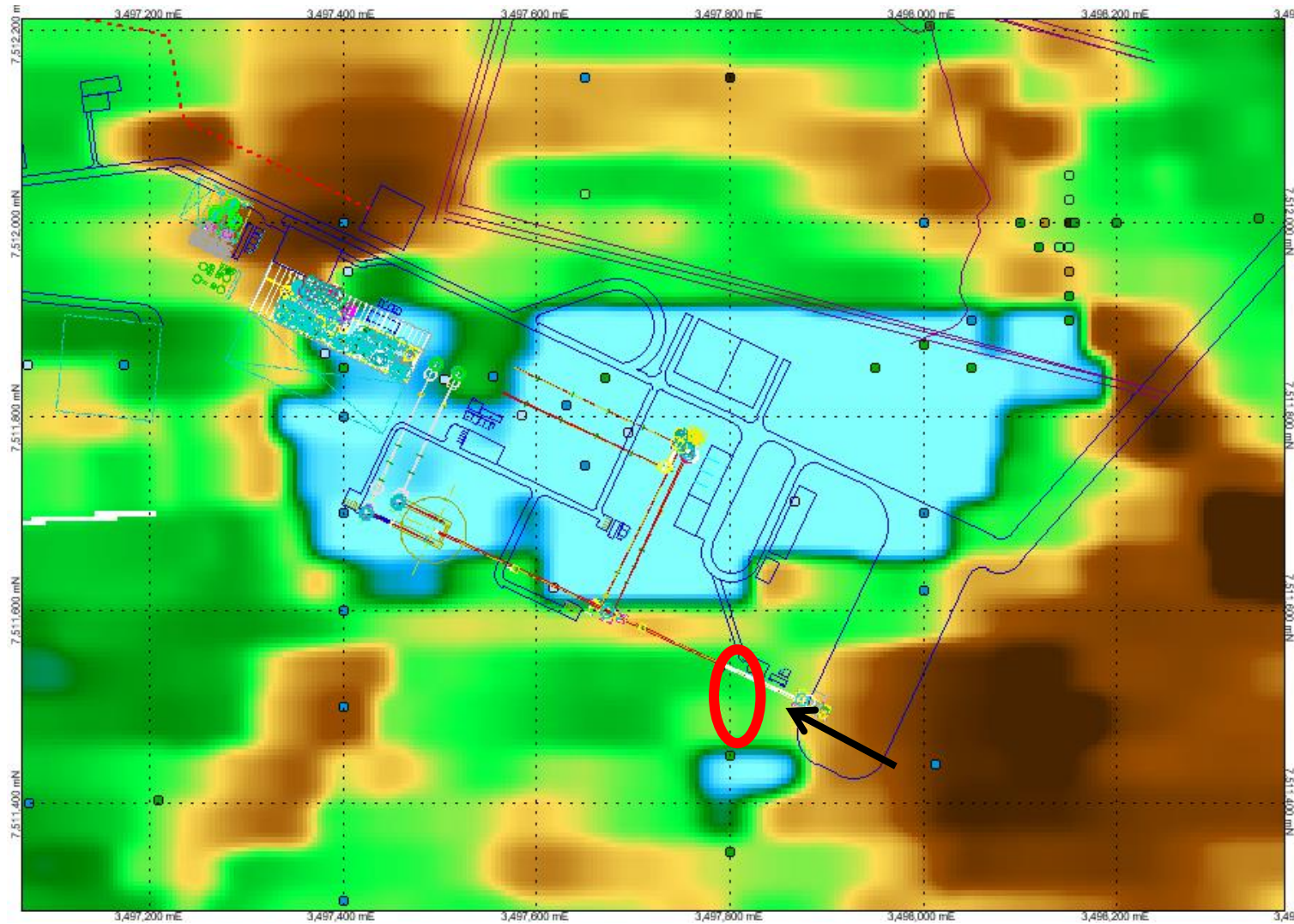
- Poor quantitative correlation, a lot of apparent overestimation by the EM (red pts > 2 x logged depth)



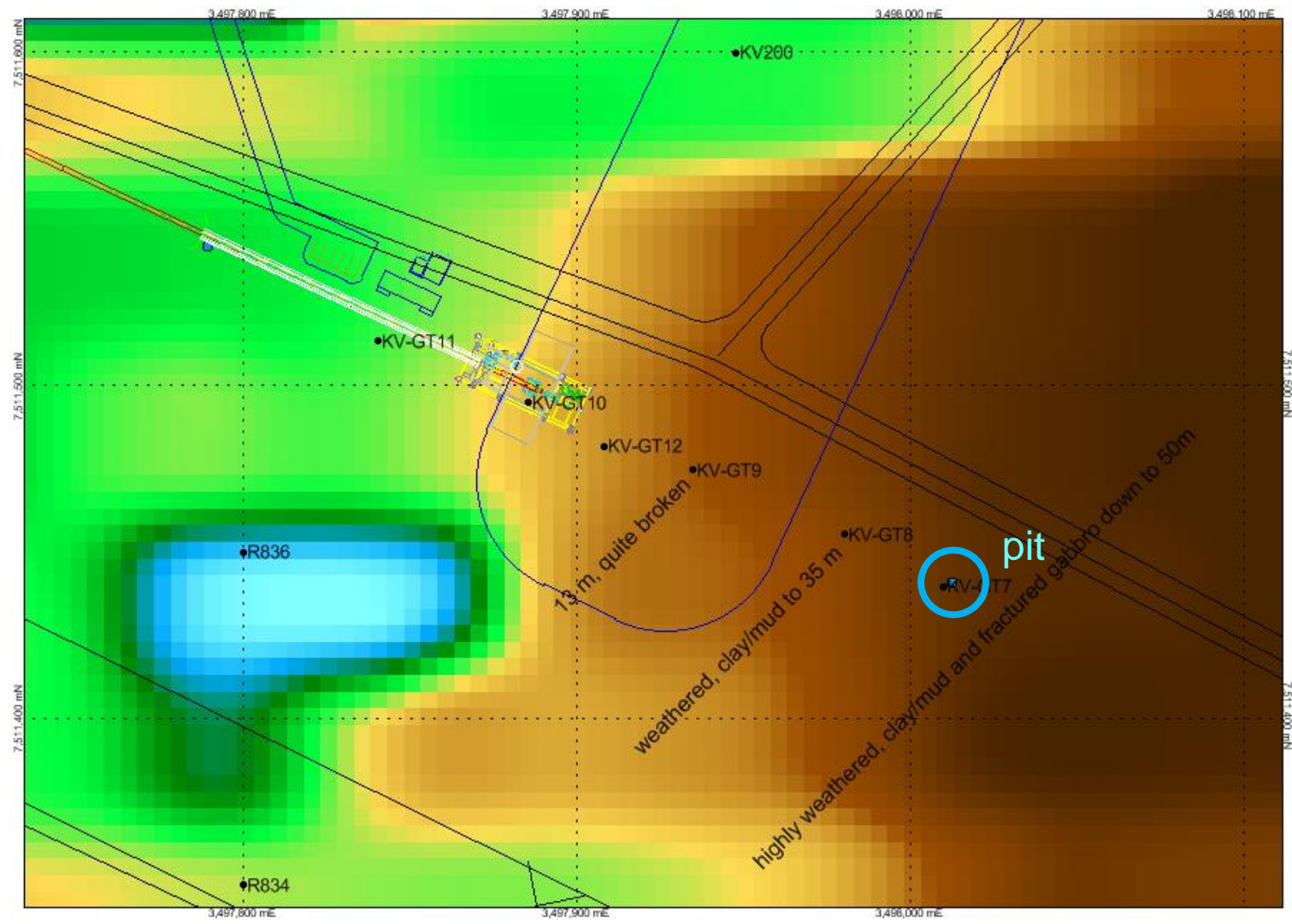
Initial crusher location vs EM ovb depth



Final crusher location vs EM ovb depth

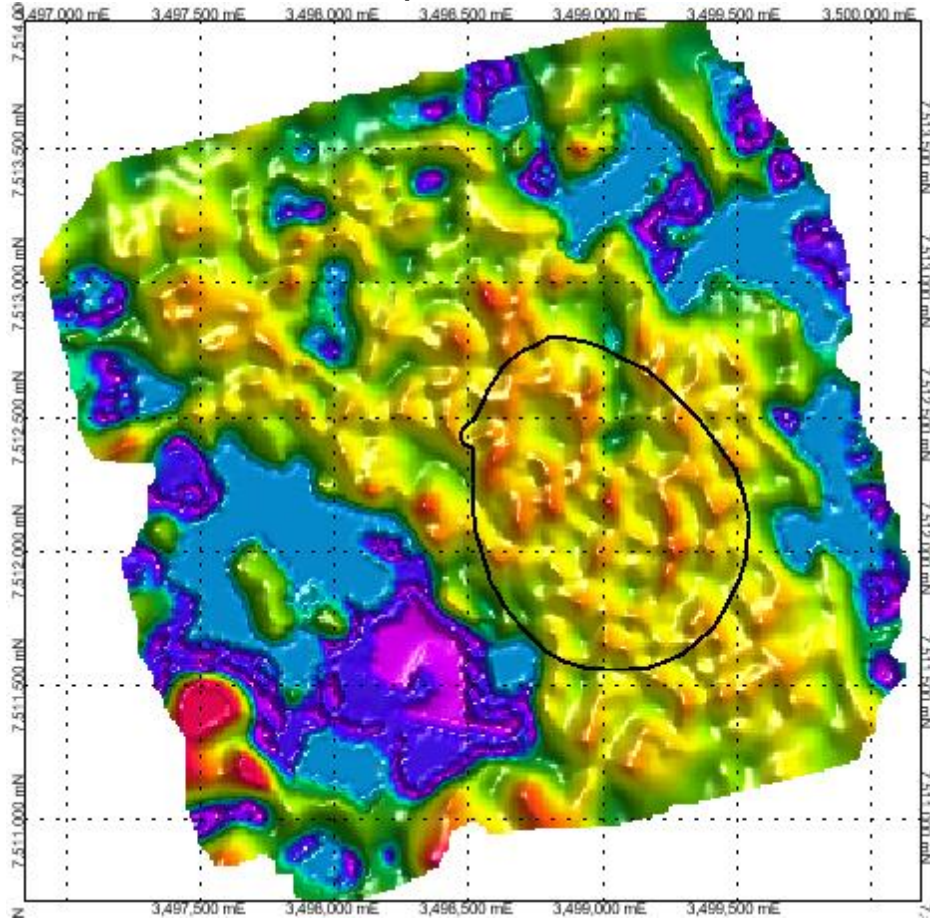


Geotechnical drillholes confirm EM model

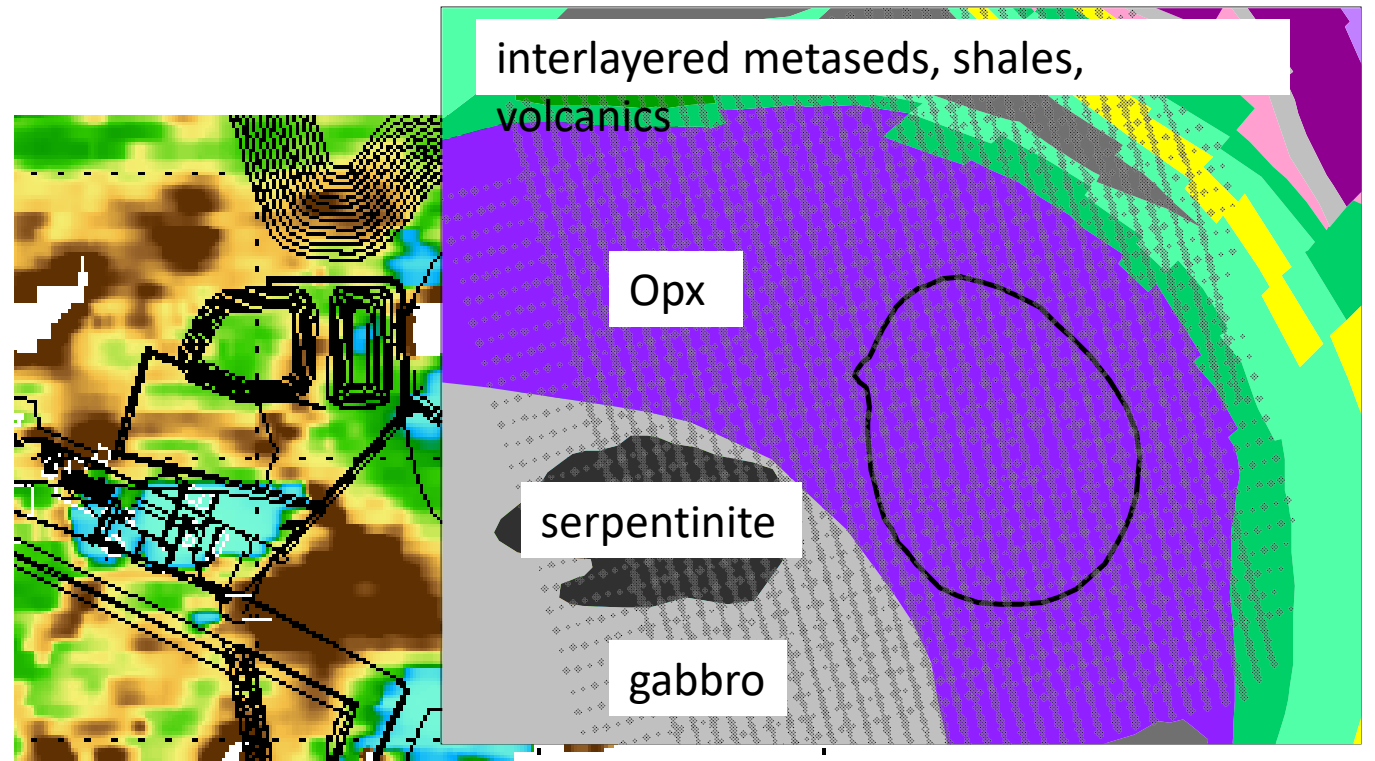


Seismic tomography

- V_p as proxy for rock hardness: till/fractured vs bedrock

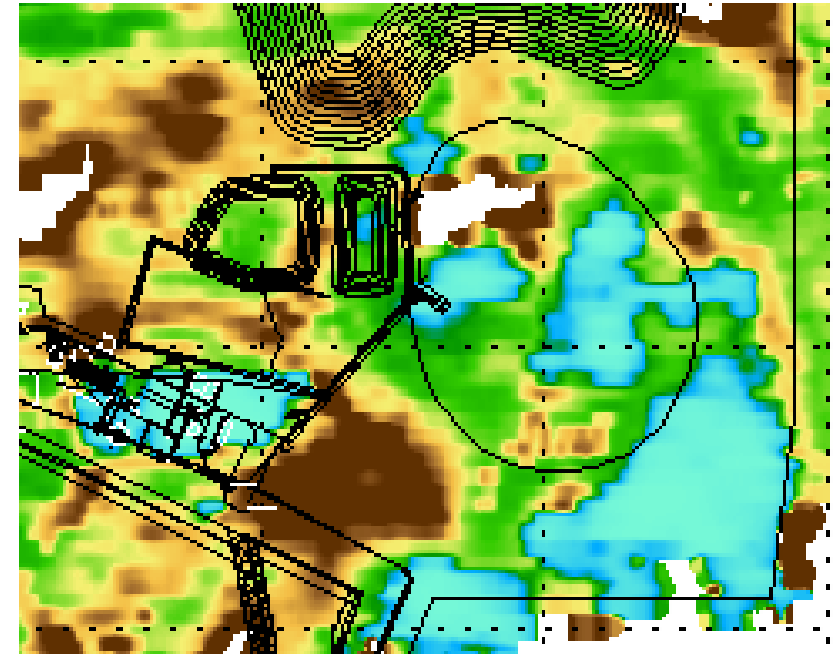
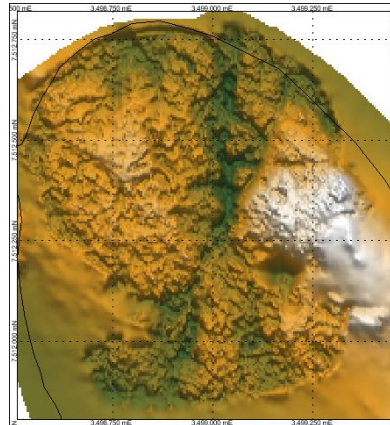
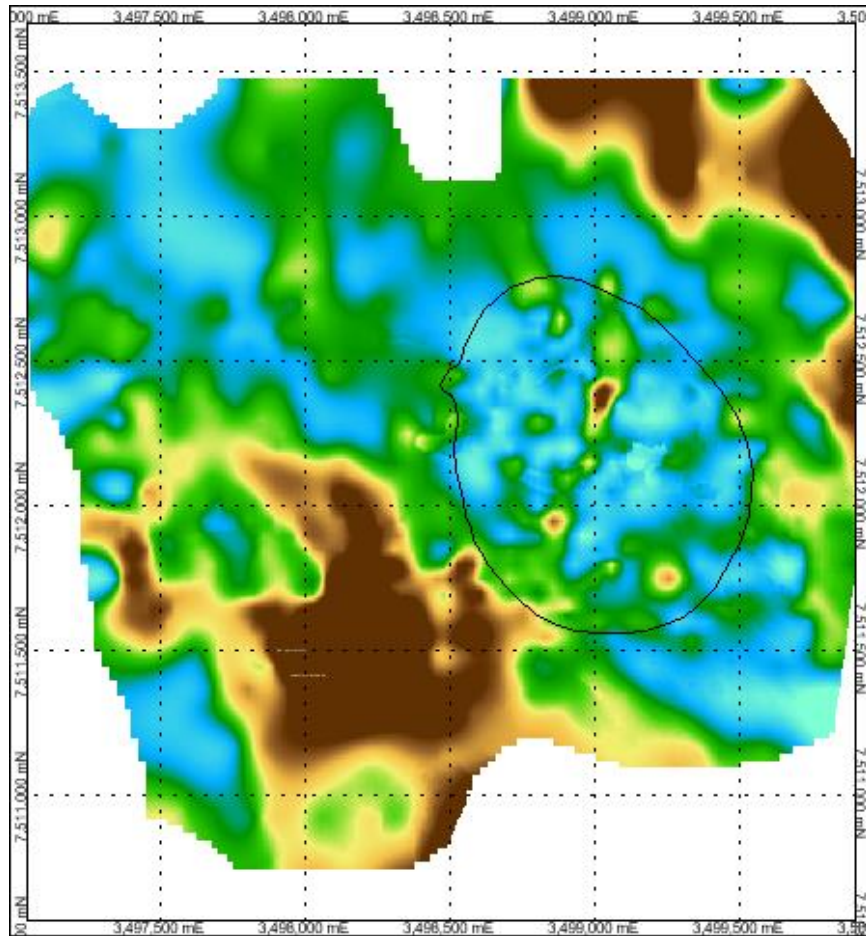


10 m below surface



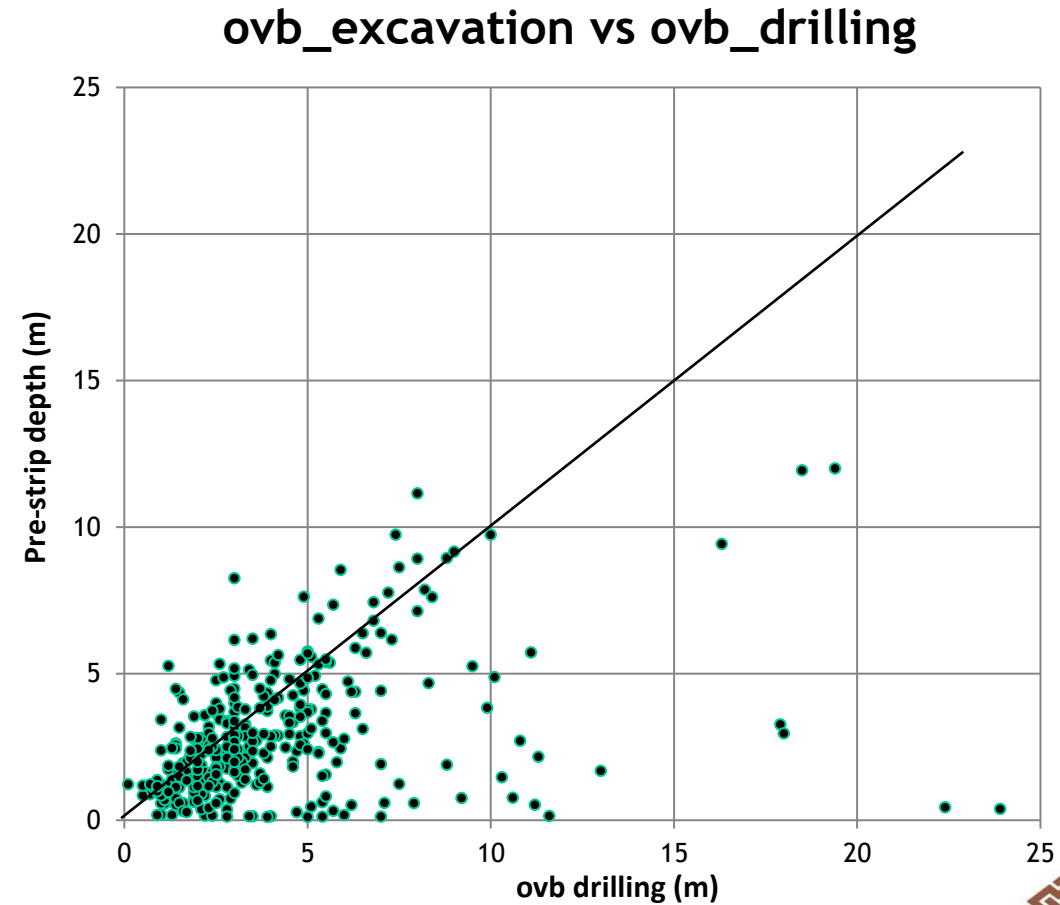
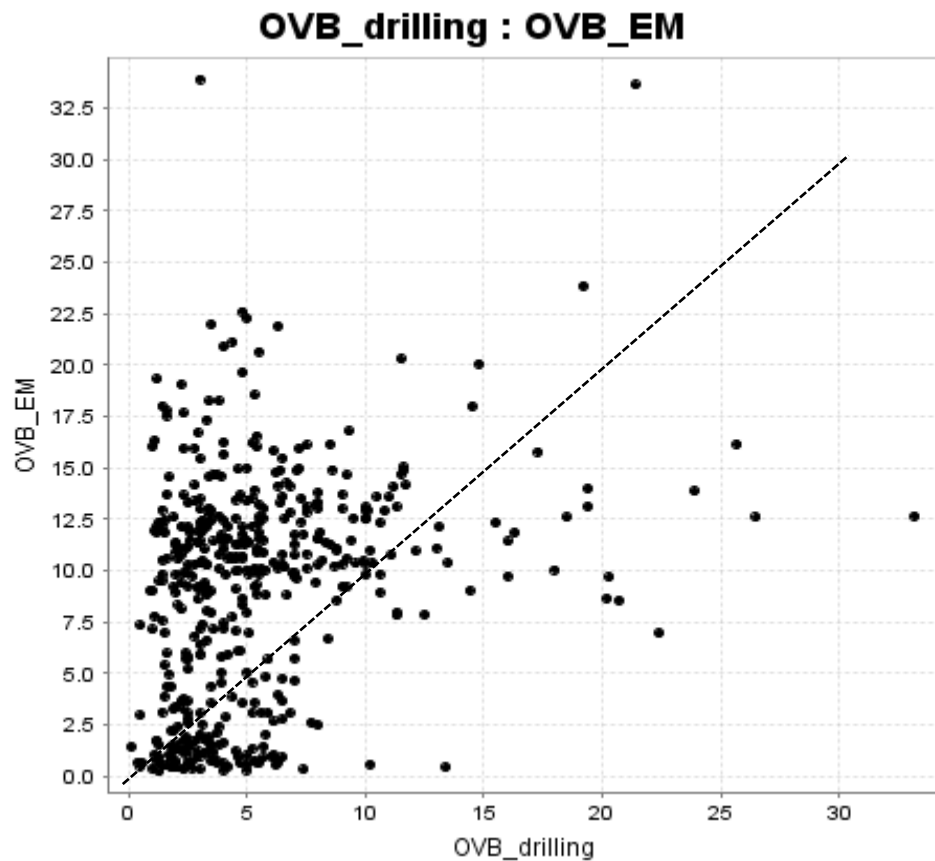
Depth to bedrock comparisons

- Seismic tomography (left), pre-strip excavation (centre), and EM (right)



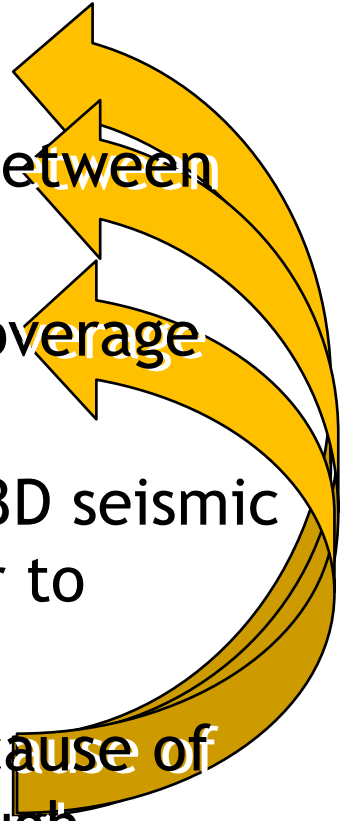
Drill holes vs geophysics

- Drillholes vs drilling (left) and pre-strip (right)



Conclusions

- Geotechnical investigation via drilling alone is dangerous
- Geophysics can be used as an interpolator to reduce uncertainty between drill holes
- Given a *suitable conductivity contrast*, AEM offers *consistent* coverage for depth to bedrock mapping
- In the case of Kevitsa, AEM depth to bedrock compares well with 3D seismic tomography depth to bedrock → fractured rock response is similar to overburden
- Drillhole correspondence is poor with AEM and pre-strip depth because of ambiguity between overburden and highly fractured bedrock through multiple years of visual logging by different geologists



Extras



Seismic tomography

- V_p as proxy for rock hardness/RQD

