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3D Electrical Resistivity Imaging (ERI) Investigations of Surface Tailings Facilities and Underground Mine Operations

Presented by:
Michael (Max) Maxwell
Rob Eso

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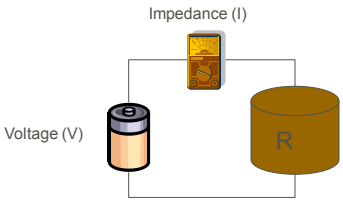
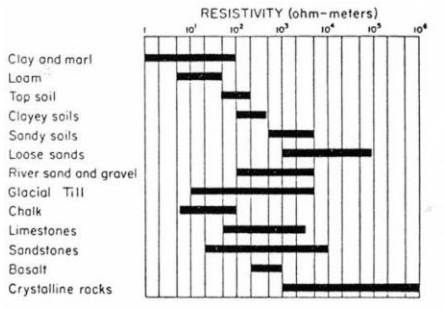
Electrical Resistivity

Electrical Resistivity is a measure of how easily electricity flows through a material



- Measured in Ohms: R = V/I



Modified After Culley et al. (1975)

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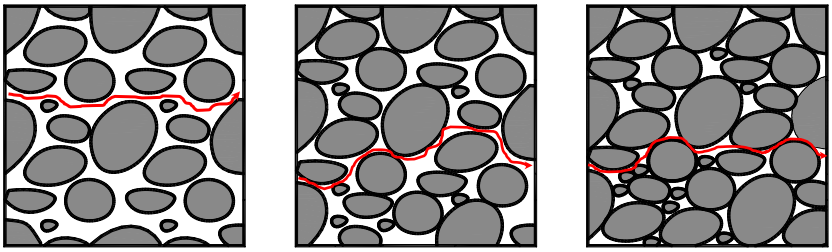
Resistivity Variations in Soil / Rock

Magnified Grain Distribution of Soil



Low Resistivity
- High Porosity
- Interconnected Pores

Higher Resistivity
- Lower Porosity
- Fewer Interconnected Pores

Highest Resistivity
- Low Porosity
- No Interconnected Pores

Special Case: Clays and Metallic Ores – Minerals are Polarized and enable passage of current

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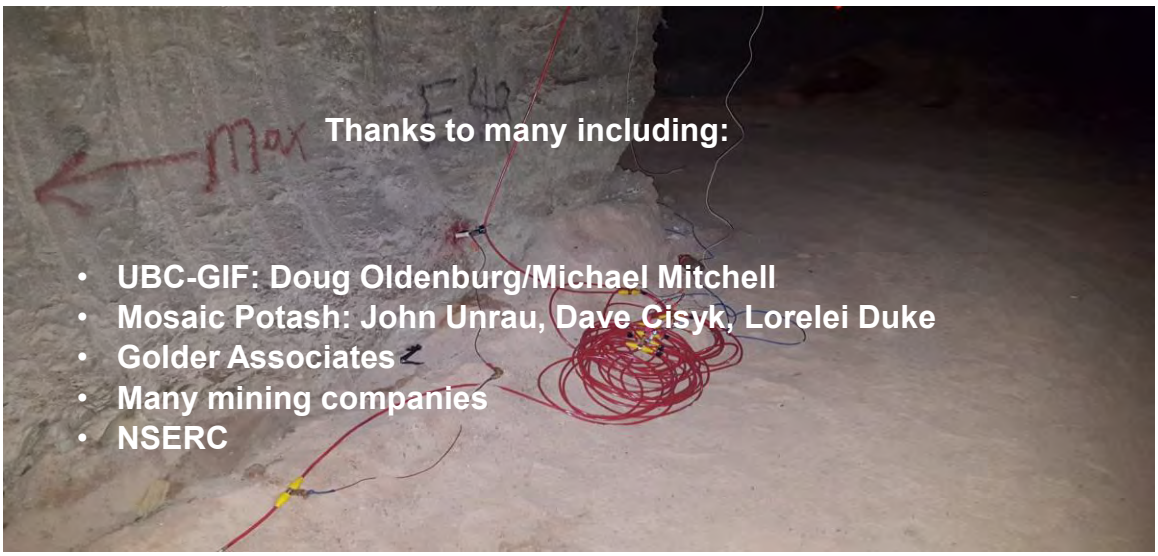

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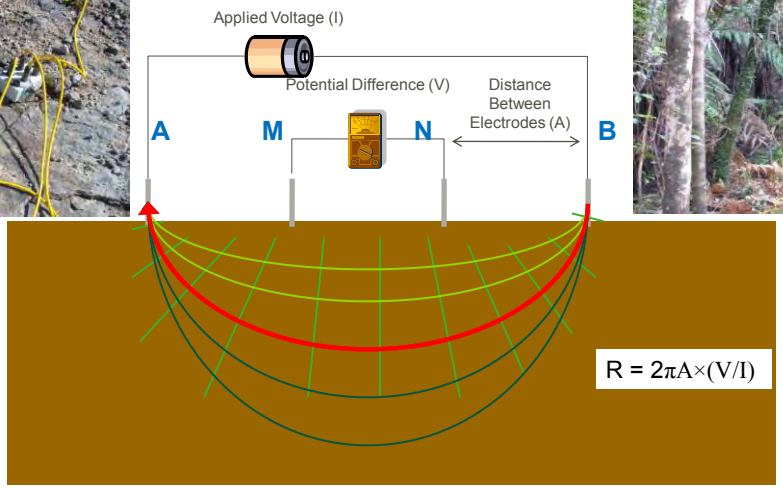
Electrical Resistivity Testing



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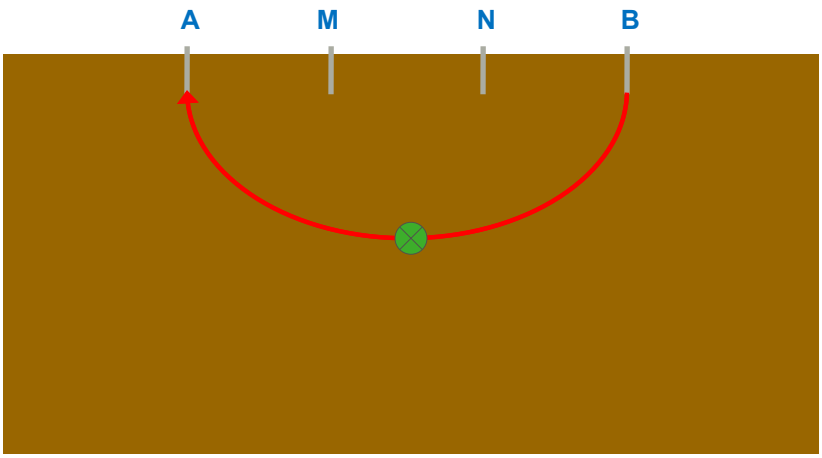
Electrical Resistivity Testing



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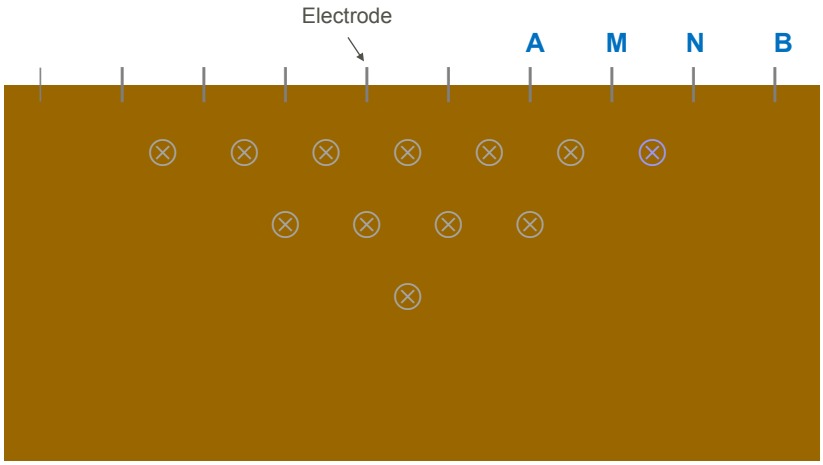
Electrical Resistivity Testing



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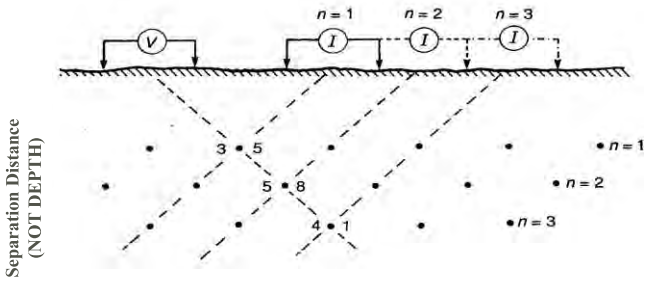
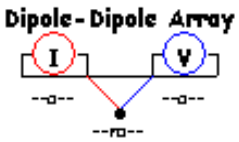
PSEUDOSECTIONS

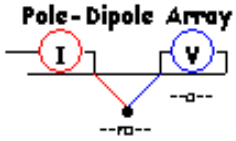
Plotting Conventions



DP-DP EXAMPLE: Value is plotted at the intersection of 45° lines from the middle of the Tx & Rx dipoles

MIMEX CONVENTION: Value is plotted at the midpoint of the closest Tx & Rx electrode





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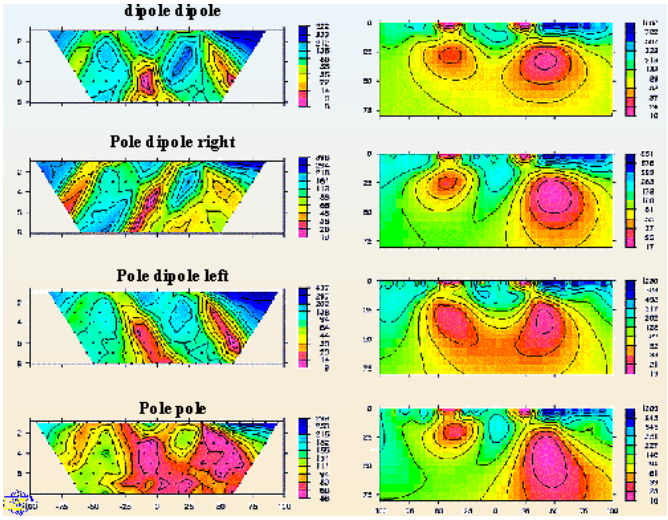
RESISTIVITY PSEUDOSECTIONS versus 2D Inverted Images



App. Res PSEUDOSECTIONS INVERTED MODELS

PSEUDOSECTIONS ARE ONLY FOR DISPLAYING RAW DATA AND QC

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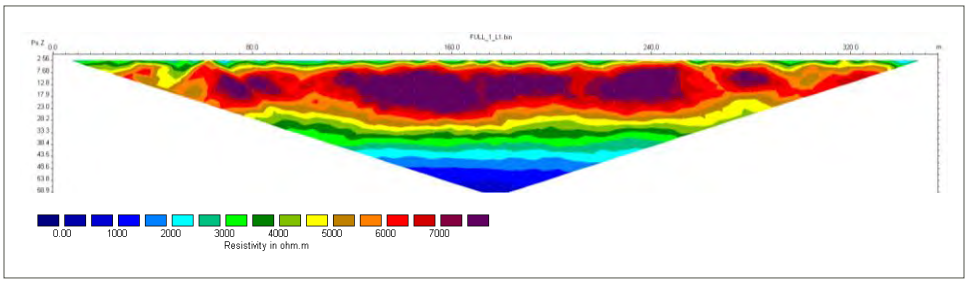
Electrical Resistivity Imaging

Plot of Measured Resistivity Values:

Called a 'Pseudo-section' – not true representation of resistivity profile with depth



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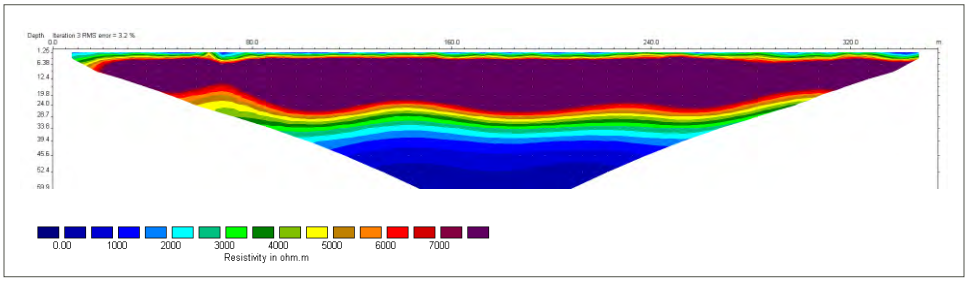
Electrical Resistivity Testing

Pseudo-section data is modeled using a 2D least squares inversion algorithm to yield a geoelectrical cross-section of the subsurface



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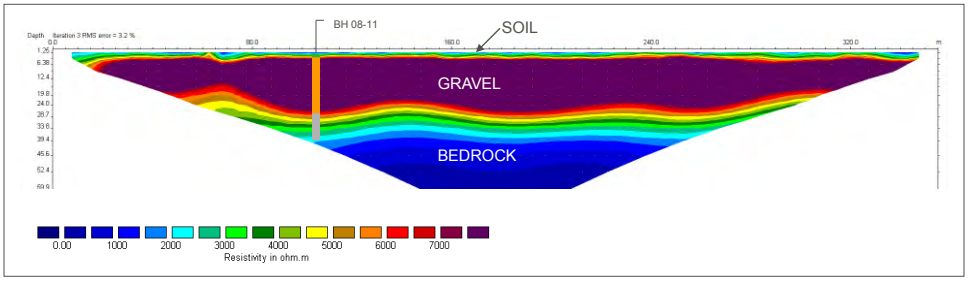
Electrical Resistivity Imaging

Additional subsurface information is then combined with the ERI model and an interpretation of the subsurface conditions is made.



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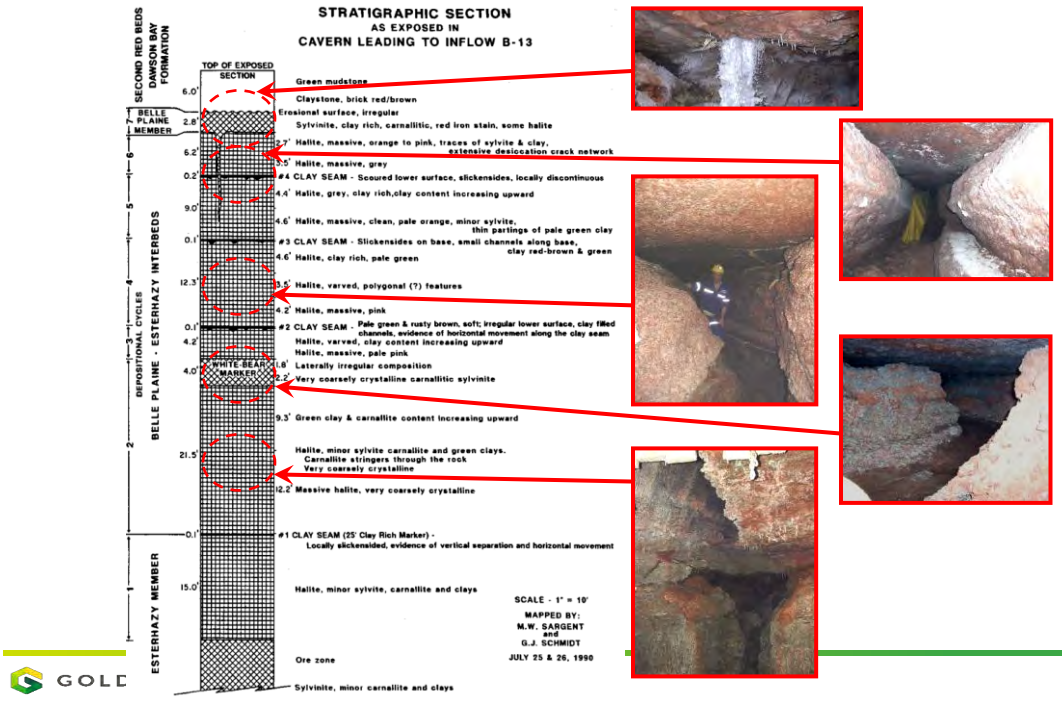

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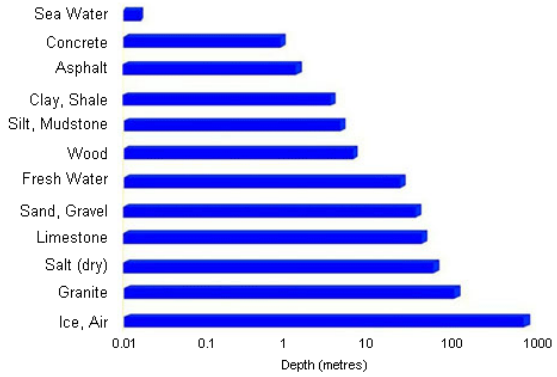
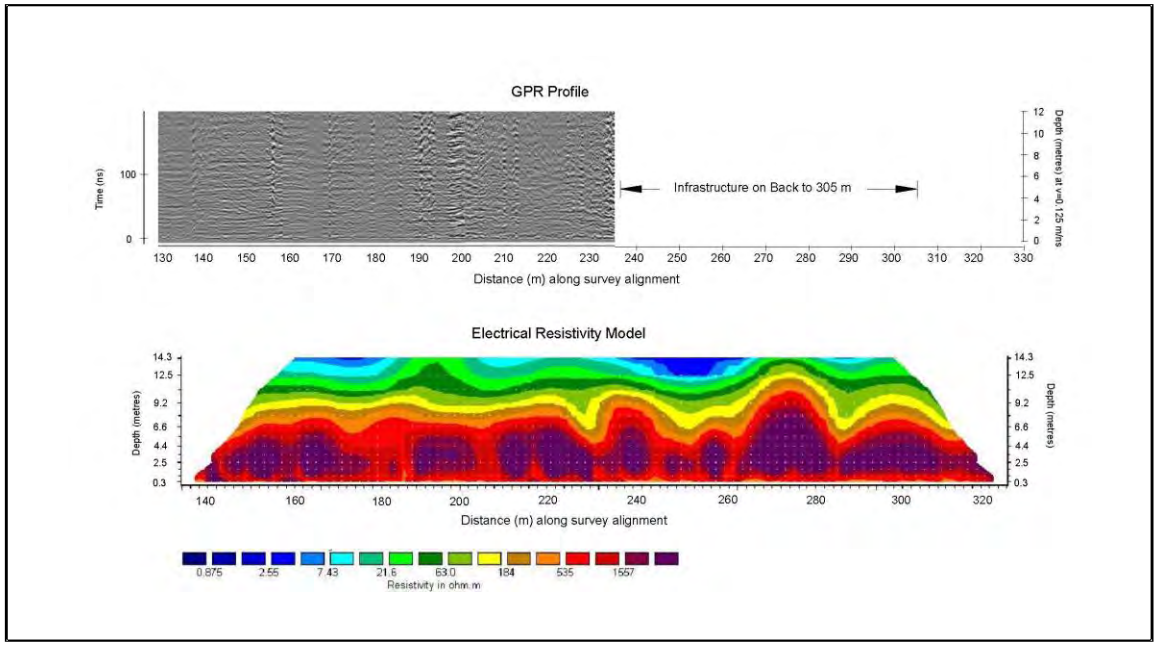
Mosaic

GPR Depth of Investigation

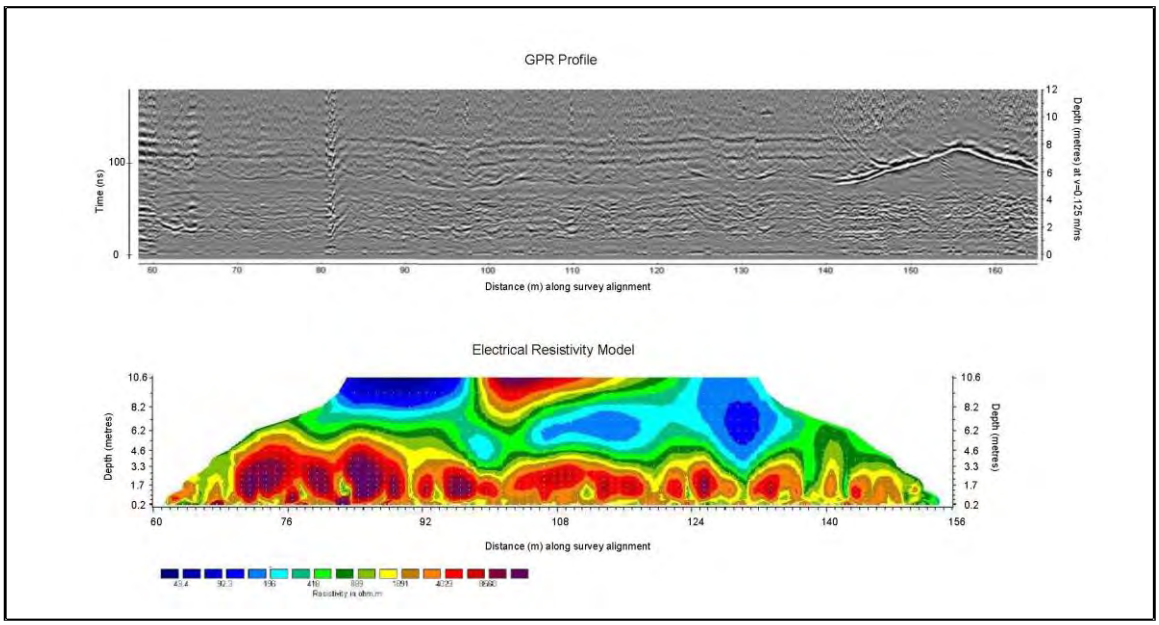
D =~ 35 / Material Conductivity





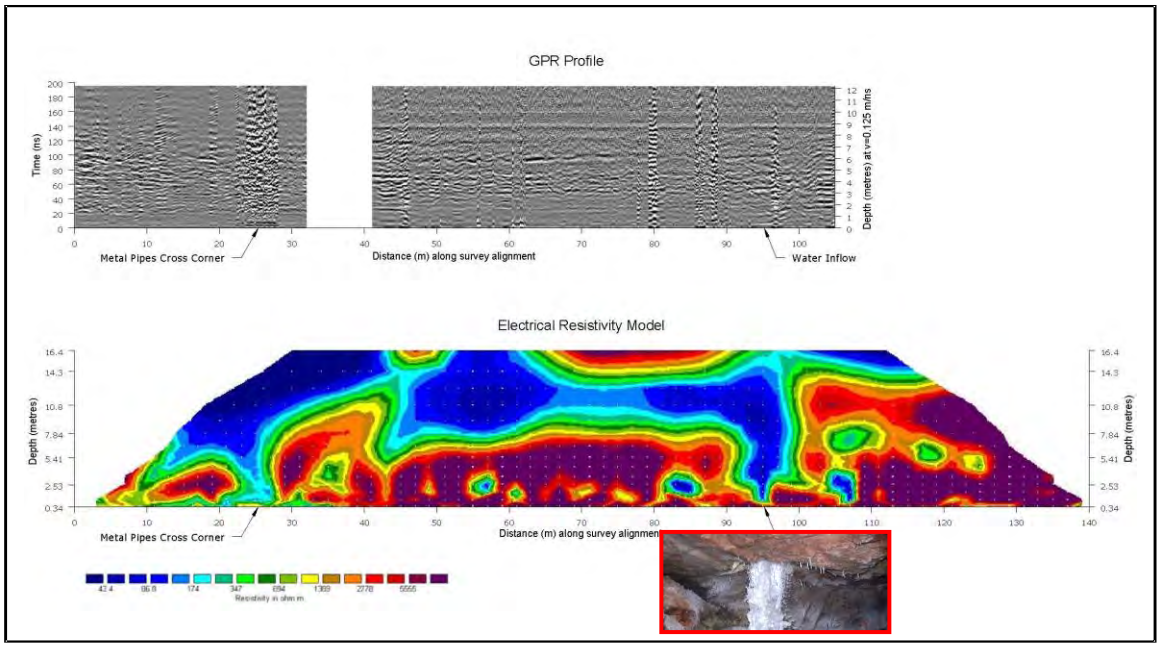
GOLDER

Mosaic Golder Associates GIF



GOLDER

Mosaic Golder Associates GIF



GOLDER

Mosaic Golder Associates GIF

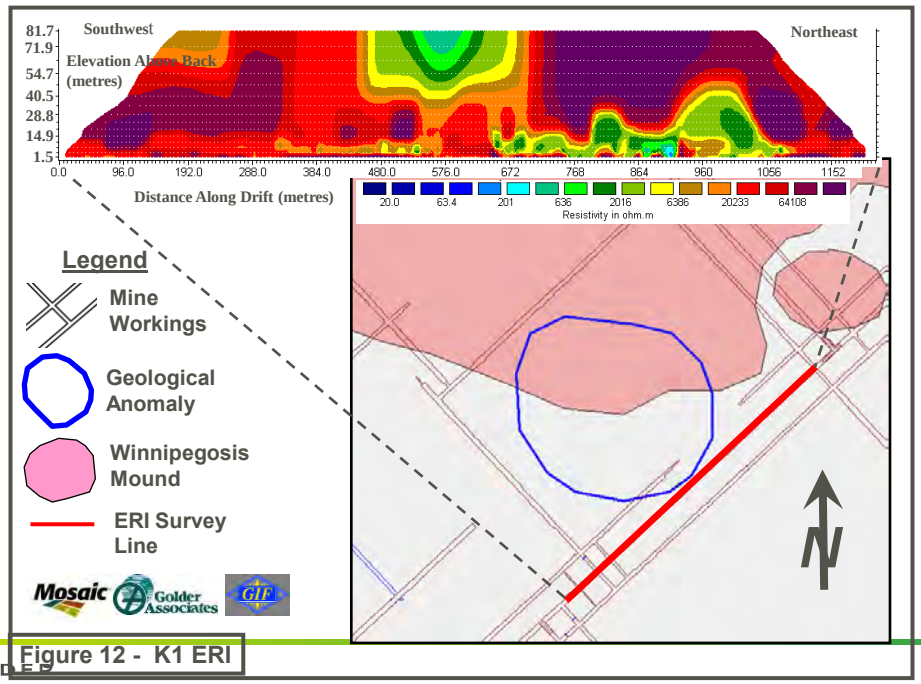
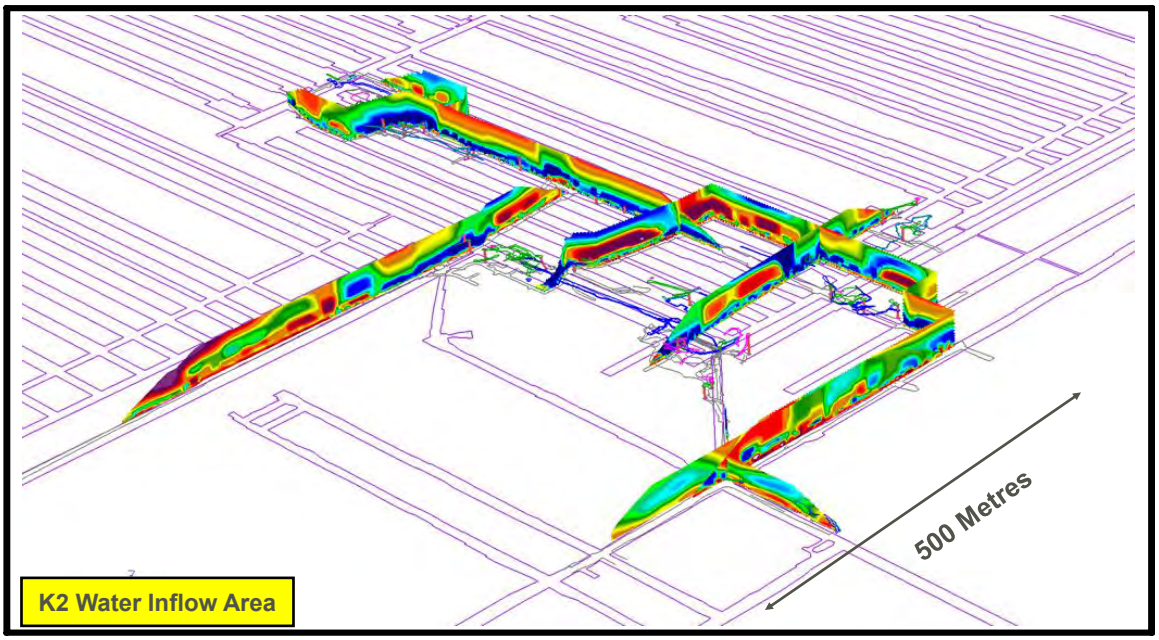


Figure 12 - K1 ERI

GOLDER



GOLDER

Mosaic Golder Associates GIF

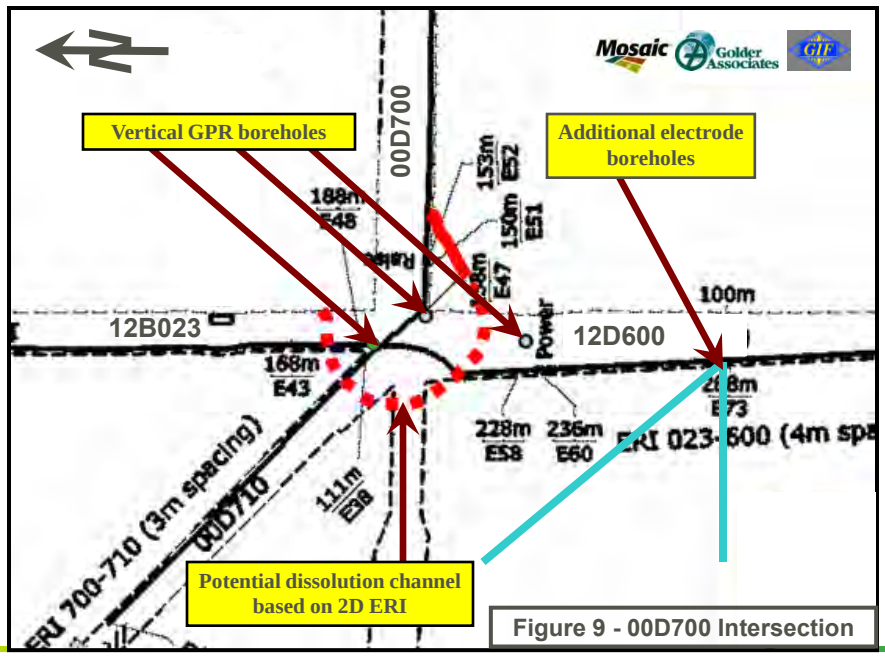
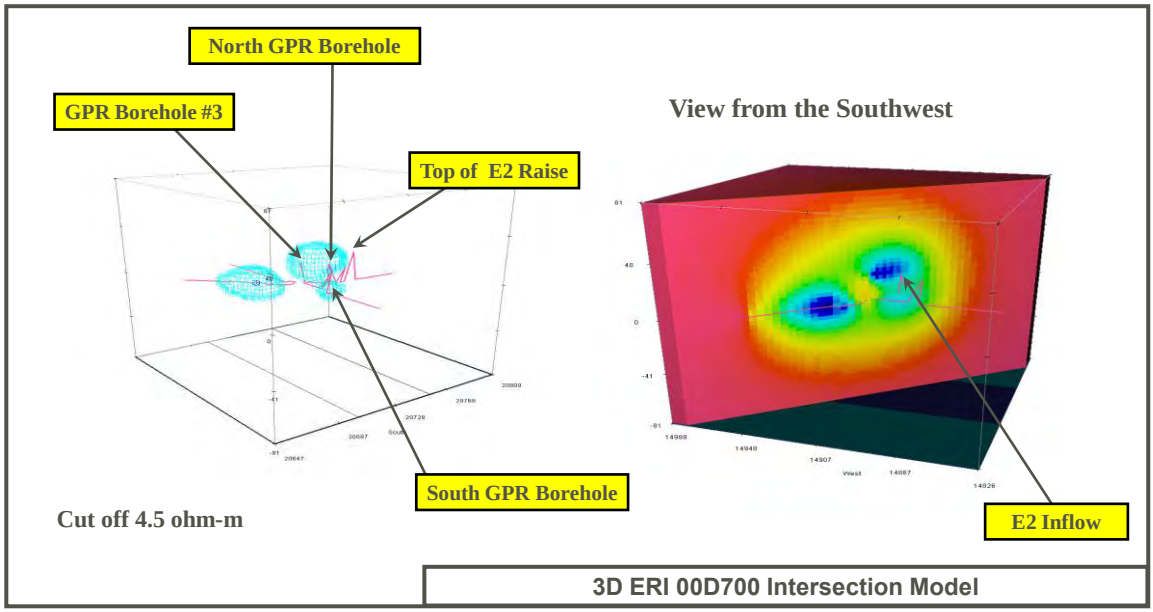
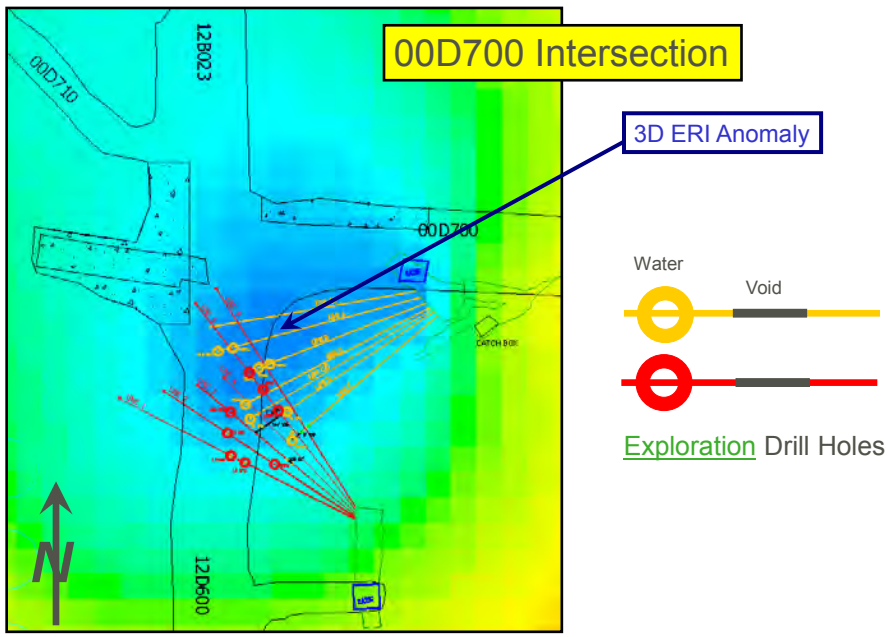


Figure 9 - 00D700 Intersection

GOLDER



GOLDER



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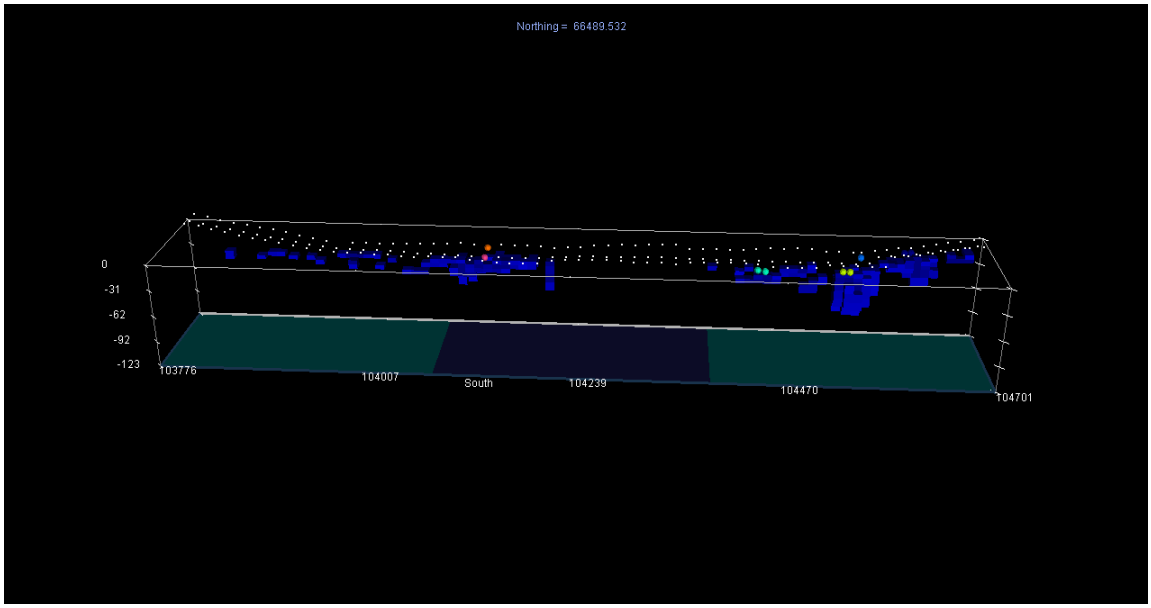
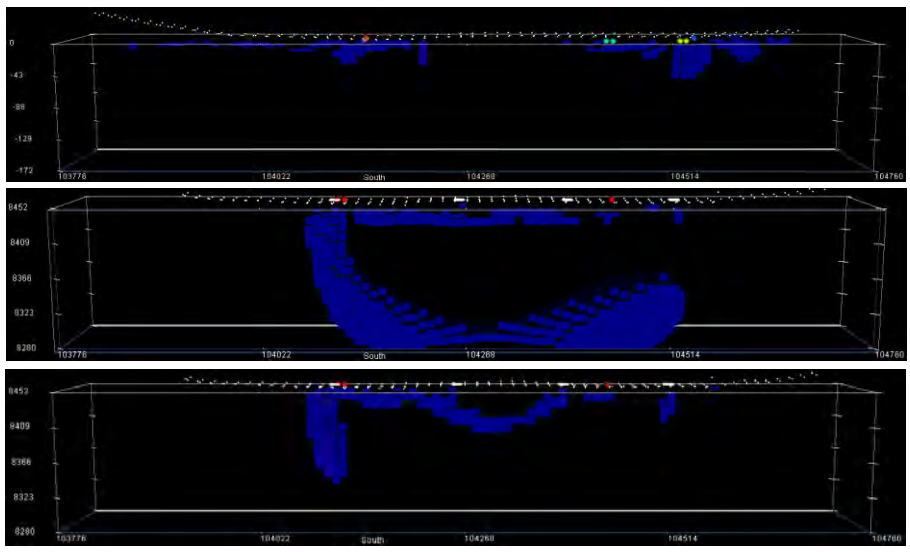


2010
100 Cutoff

2014
100 Cutoff

2016
100 Cutoff



Conductive Cutoff Volumes - View From South

Electrical Resistivity – Dam Seepage

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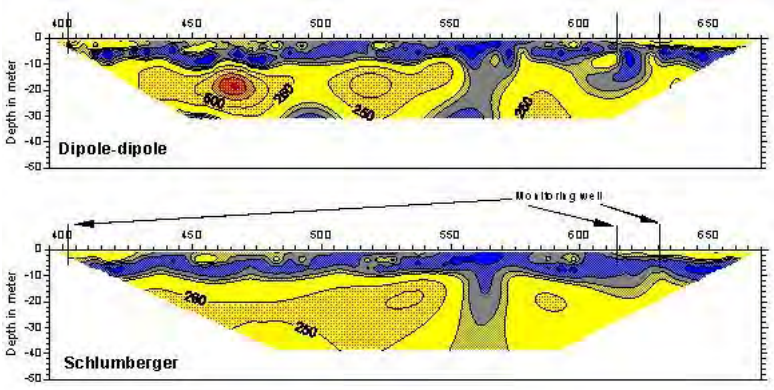
Resistivity Imaging - Dam Seepage



Low resistivity indicates seepage zone
for placement of monitoring wells

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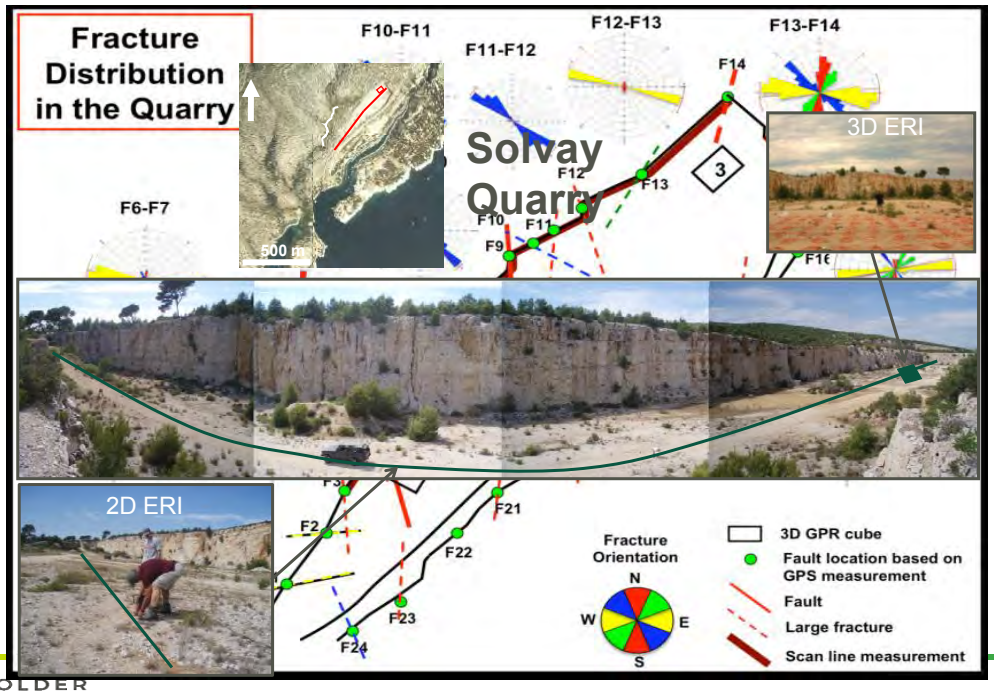
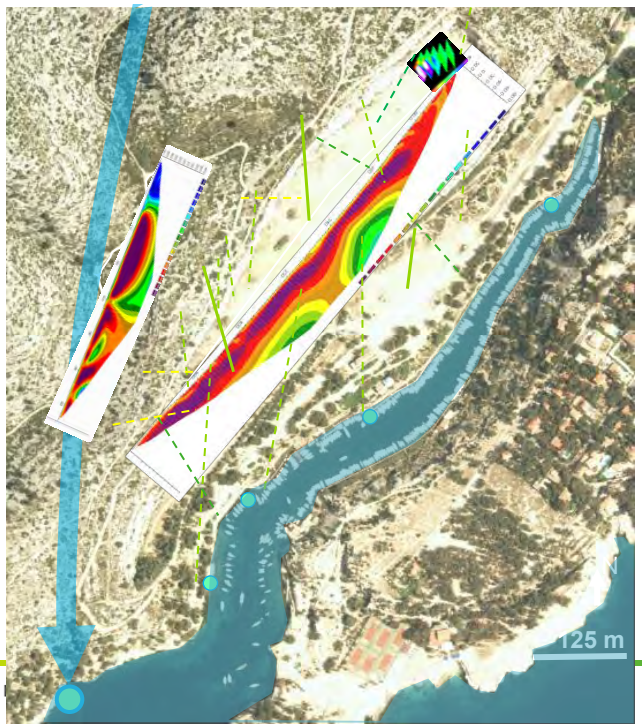
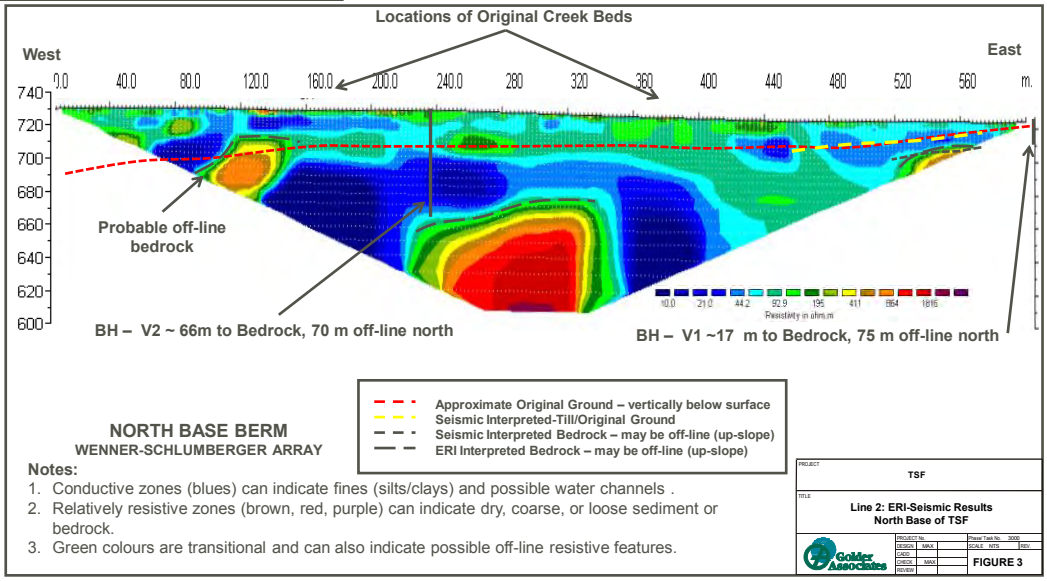




Réseau de fractures et karstique dense permettant une intrusion marine dans des zones préférentielles (conduits et fractures)
Zone à égale distance entre une source d'eau saumâtre et l'eau de mer→la résistivité mesurée sous le niveau zéro est due à la zone de mélange des eaux.

2D ERI – TSF Stratigraphy



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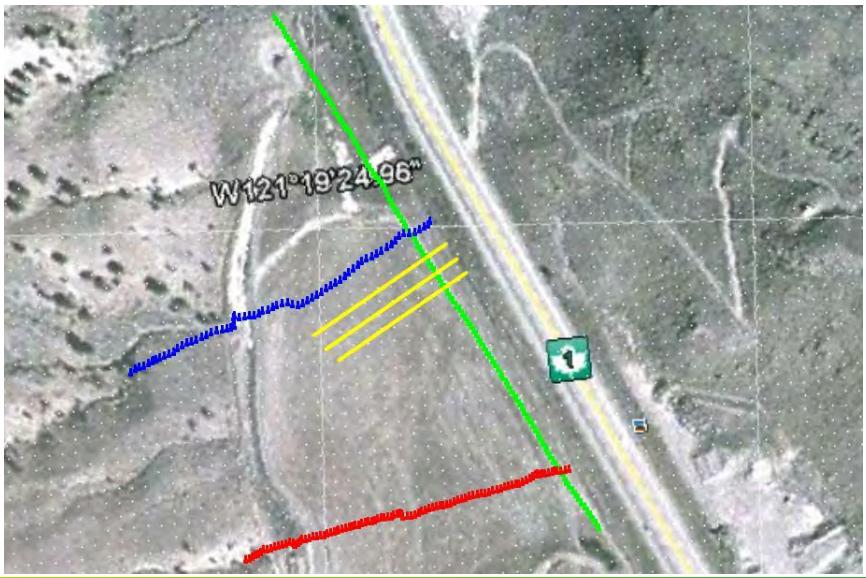
Groundwater Conductivity Mapping 2D/3D ERI



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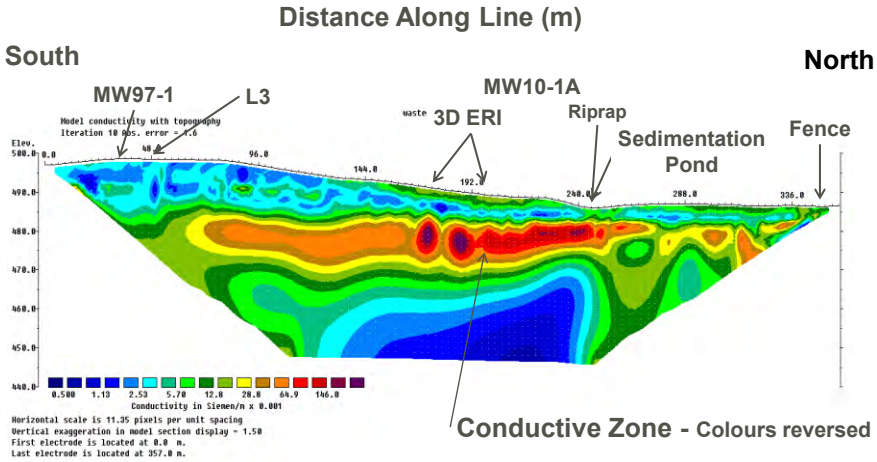
ERI Line 1 - Conductivity



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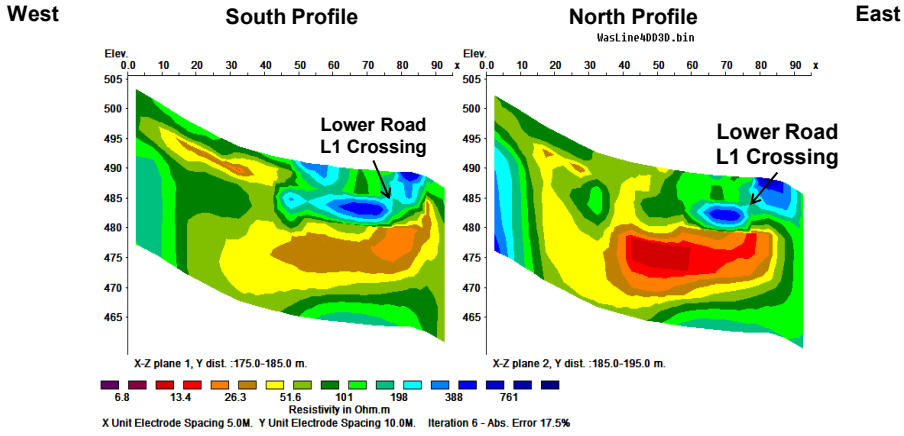
3D ERI – Slices 180m and 190 m



1. Dipole-dipole array used.
2. Data shown as centre of model blocks in between lines.
3. Y distance refers to distance along 2D ERI Line 1.
4. South Profile is 10 m south of North Profile.

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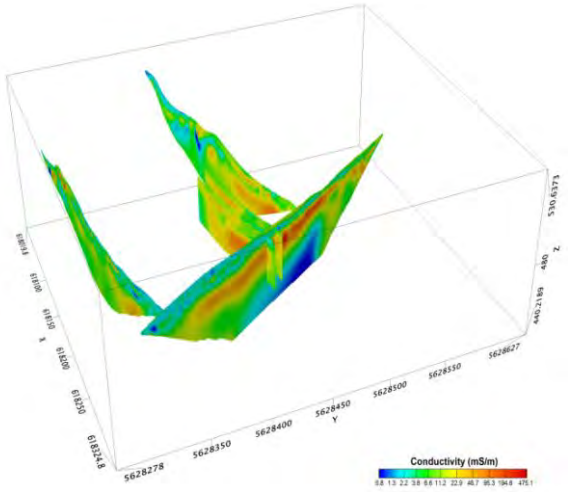
Groundwater Conductivity Mapping



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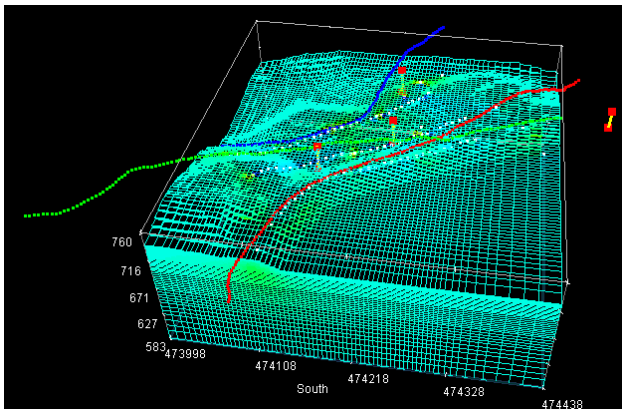
Survey Design

- 2D or 3D
- or both



- Millions of possible data combinations that can be measured
- Only several thousands (20,000-60,000) can be measured and inverted
- Inject current using a variety of surface, borehole, and borehole-to-surface currents and measure the potential in all the boreholes and on the surface

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Survey Criteria – e.g.

- Volume size and resolution
- Array type – 2D or 3D
- Hardware – #/type of electrodes
- Cables and spacing
- Soil/rock surfaces - contact resistance
- Power requirements/availability
- Time
- Personnel, cost

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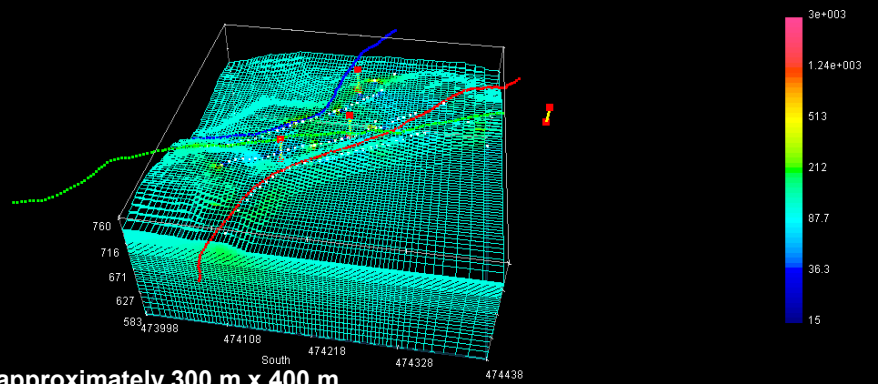
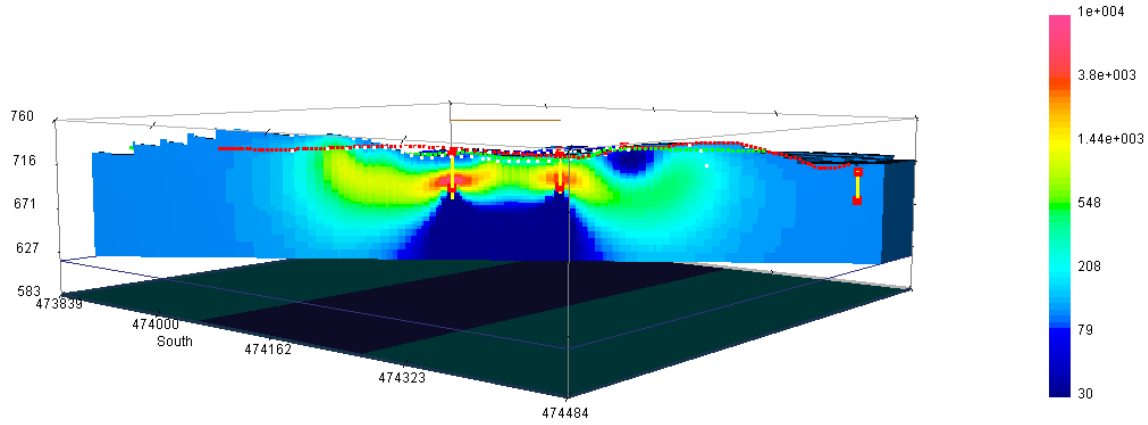
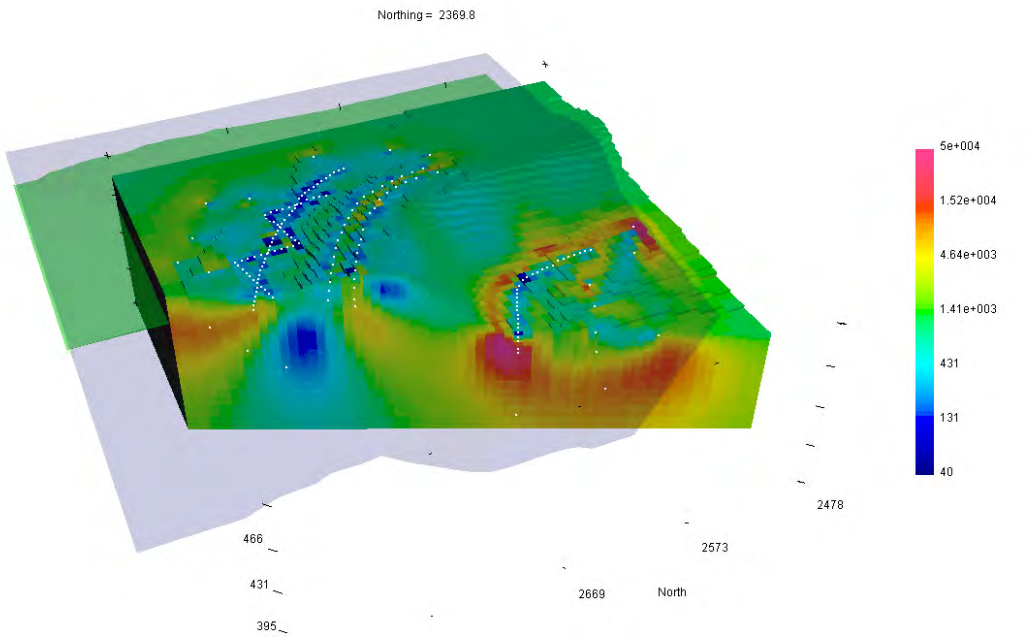
3D ERI - Dam Characterization

Model Mesh and ERI Survey Layout



1. **Surveyed area approximately 300 m x 400 m**
2. **Coloured dots are 2D electrodes**
3. **White dots are 3D electrodes**


760
716
671
627
583
473839
474000
South
474162
474323
474484
1e+004
3.8e+003
1.44e+003
548
208
79
30


Northing = 2369.8
5e+004
1.52e+004
4.64e+003
1.41e+003
431
131
40
2478
466
2573
431
2669
North
395

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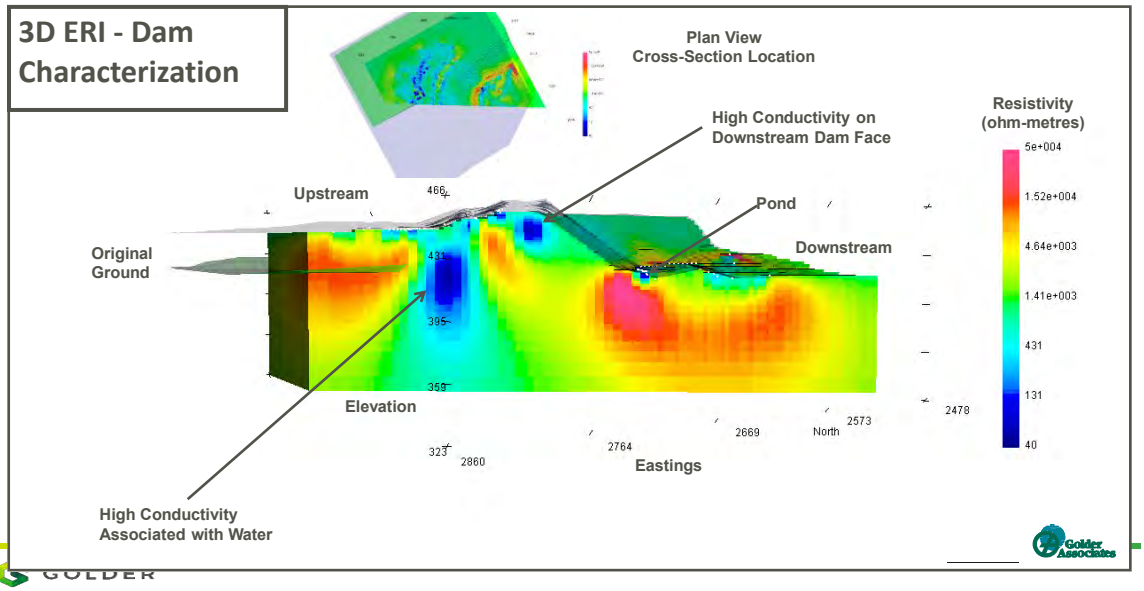
3D ERI - Dam Characterization



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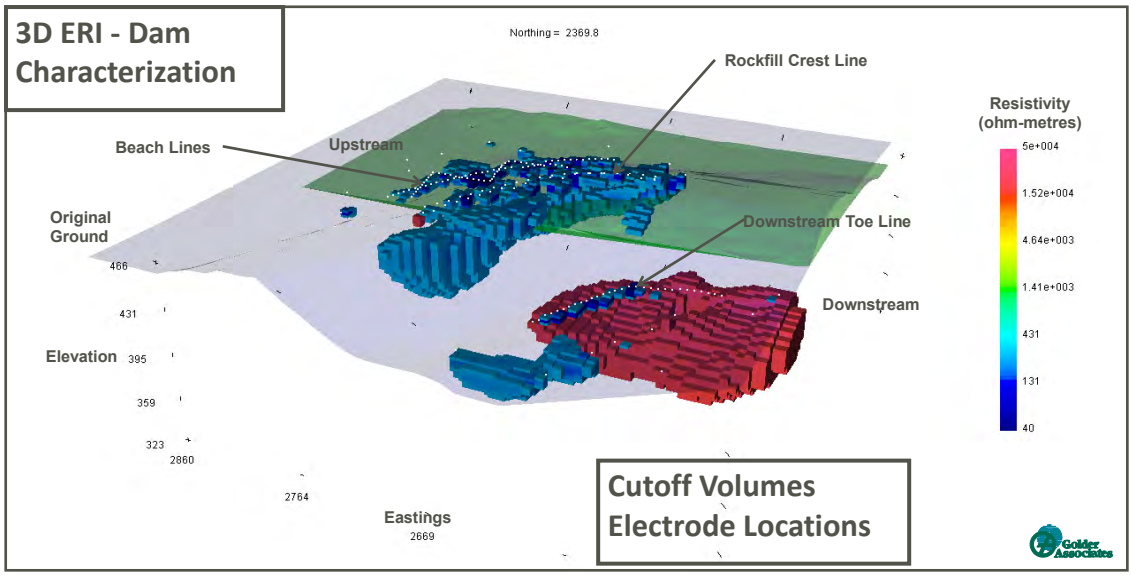
3D ERI - Dam Characterization



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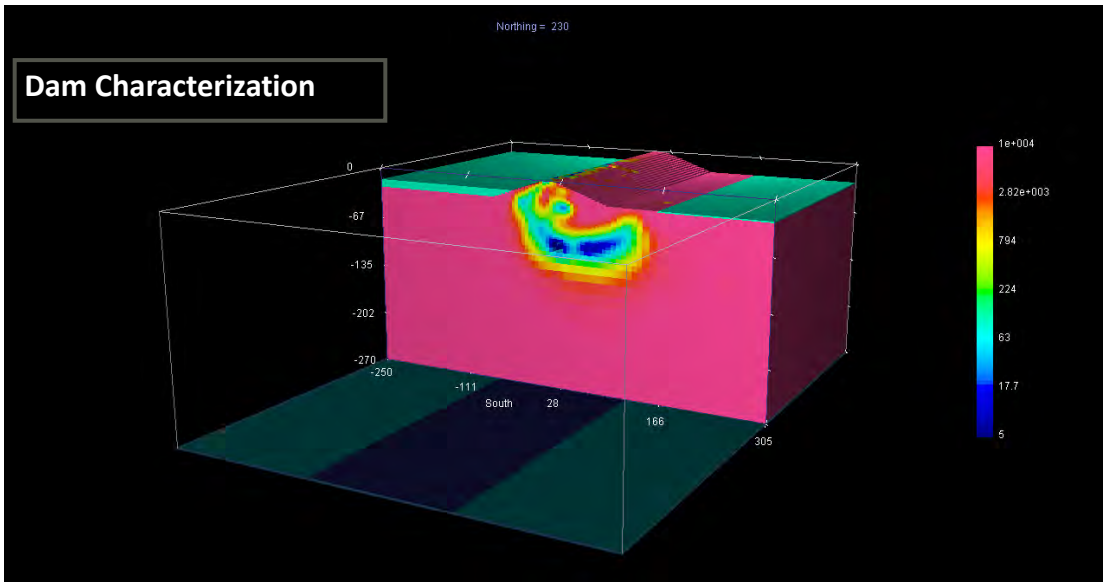
Electrical Resistivity – 3D



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Data Quality – Contact Resistance
- Can be high but within 1-2 orders

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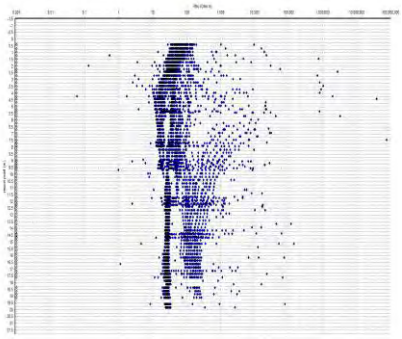
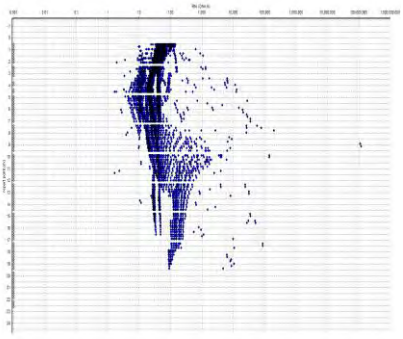
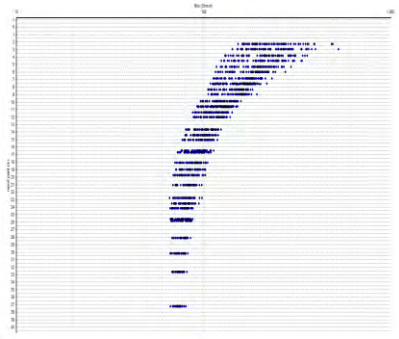
2D ERI – Good Data/Bad Data



Problem Data



Problem Data



Good Data

#	Filename	Spa.1	Spa.2	Spa.3	Spa.4	Rho	Dev.	M	Sp	Vp	In	Rx-Check	Vab	Tx-Bat	Rx-Bat
4381	Dipole Dipole	43.00	45.00	62.00	65.00	173.29	0.03	0.00	-11.93	23.419	315.501	0.00	64	13.52	12.84
4382	Dipole Dipole	43.00	45.00	65.00	68.00	-942.49	0.09	0.00	-12.01	91.604	315.501	0.00	64	13.52	12.84
4383	Dipole Dipole	43.00	45.00	68.00	71.00	-19278.94	0.06	0.00	17.54	603.266	315.501	0.00	64	13.52	12.84
4384	Dipole Dipole	43.00	45.00	71.00	63.00	3088.60	0.06	0.00	24.21	-703.768	315.501	0.00	64	13.53	12.84
4385	Dipole Dipole	43.00	46.00	63.00	66.00	317.40	0.12	0.00	-43.01	86.685	315.501	0.00	64	13.52	12.84
4386	Dipole Dipole	43.00	46.00	66.00	69.00	-472.50	0.47	0.00	-59.23	35.708	315.501	0.00	64	13.52	12.84
4387	Dipole Dipole	43.00	47.00	69.00	73.00	2393.05	0.36	0.00	104.37	-686.079	967.278	0.00	187	13.53	12.84
4388	Dipole Dipole	43.00	47.00	73.00	77.00	30.30	0.11	0.00	20.57	5.628	967.278	0.00	187	13.53	12.84
4389	Dipole Dipole	43.00	47.00	77.00	70.00	6449.56	0.03	0.00	-19.12	2501.744	967.278	0.00	187	13.53	12.84
4390	Dipole Dipole	43.00	47.00	70.00	74.00	3760.86	0.00	0.00	-1.61	-2526.615	978.440	0.00	188	13.55	12.84
4391	Dipole Dipole	43.00	47.00	74.00	78.00	31.08	0.13	0.00	12.46	5.787	978.440	0.00	188	13.55	12.84

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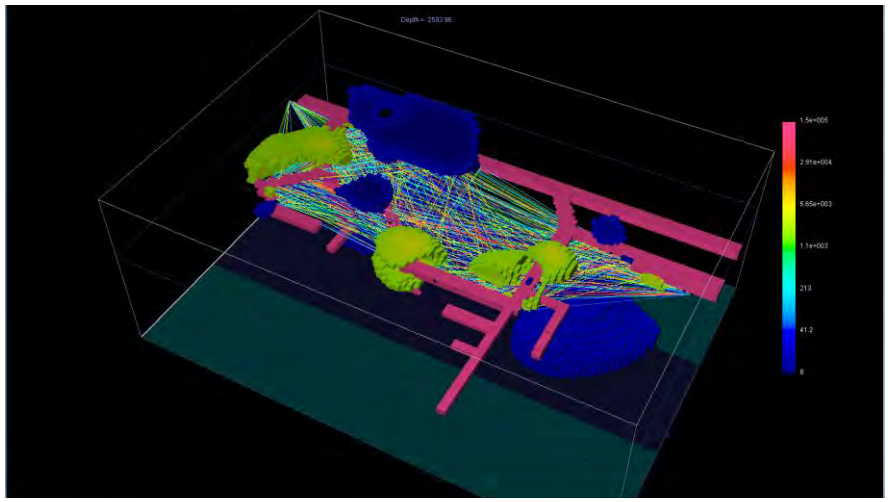
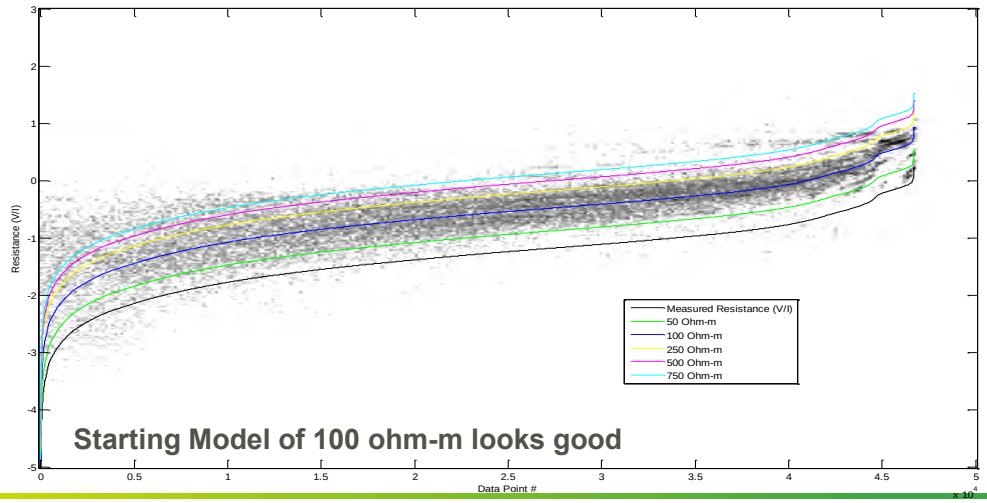
3D ERI – Data Evaluation

Current Injection Transmitter Plot



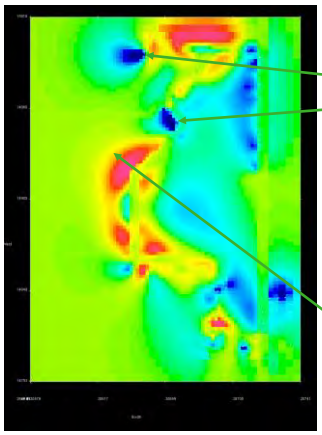
GOLDER

3D ERI – Data Evaluation



GOLDER

3D ERI – Model Evaluation



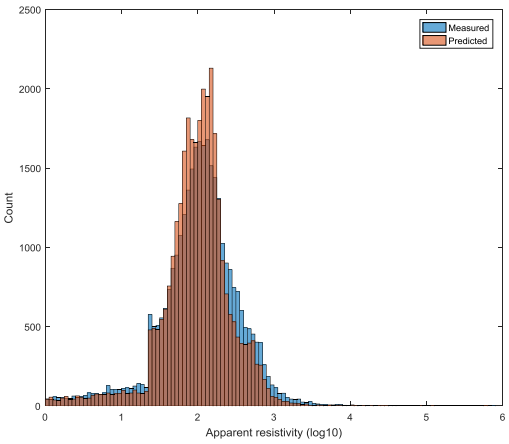
Features to watch for when viewing the models

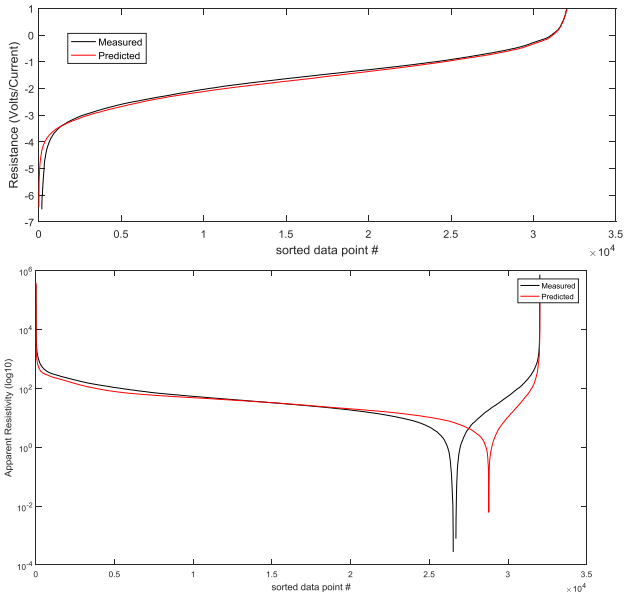
- **Features that seem to be tied to a single electrode location**
- **Very sharp boundaries, while possible, are a bit suspicious, as the modelling attempts to create models that are 'smooth' and 'small' (small as measured as the difference between a reference model, here it is a 200 Ohm-m full space). The sharp feature here pointed to was in a region with dry drifts. Suggests there is infrastructure or something conductive connecting these electrodes together.**
- **Features that go 'outside' the foot print of the electrodes, as these areas are less constrained than regions near electrodes, or regions bound on both sides by electrodes**

Plan view image at floor level (2582meters)

GOLDER

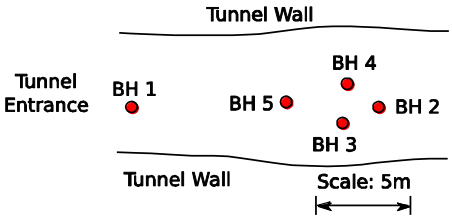
Observed and Predicted Data plots



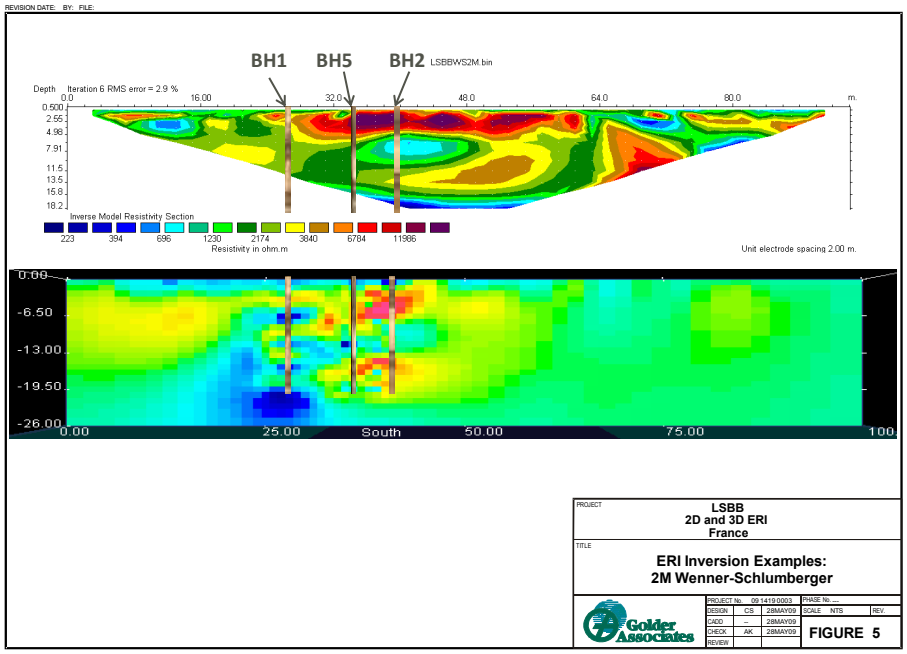


GOLDER

2D/3D ERI/GPR – Underground/Boreholes

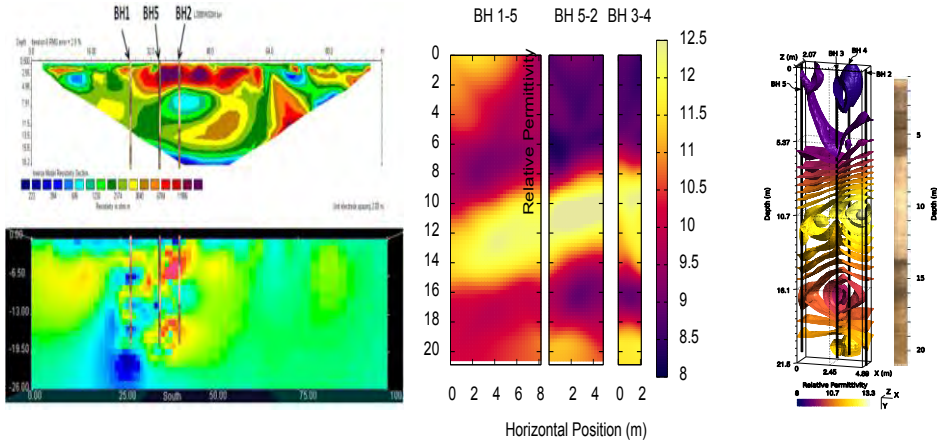


GOLDER



GOLDER

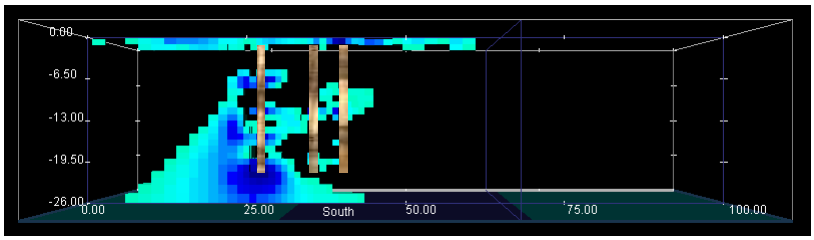
ERI and GPR

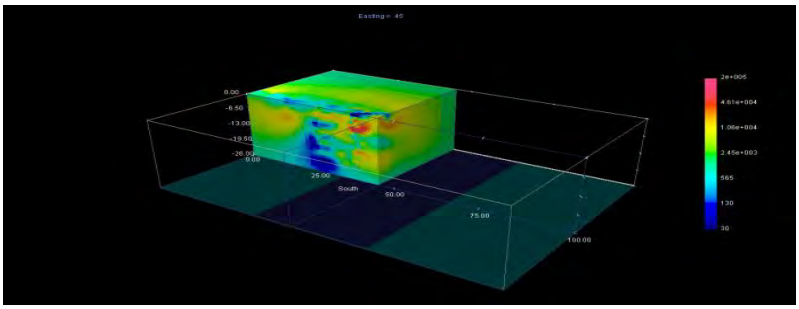


2D (top) and 3D ERI 2D (Borehole GPR) 3D

GOLDER

3D ERI – Underground Aquifer

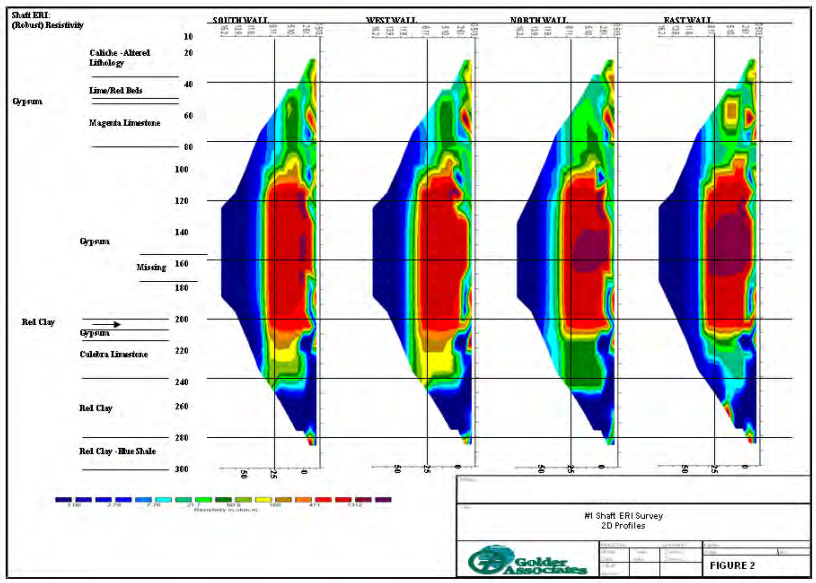




GOLDER

3D ERI – Mine Shaft

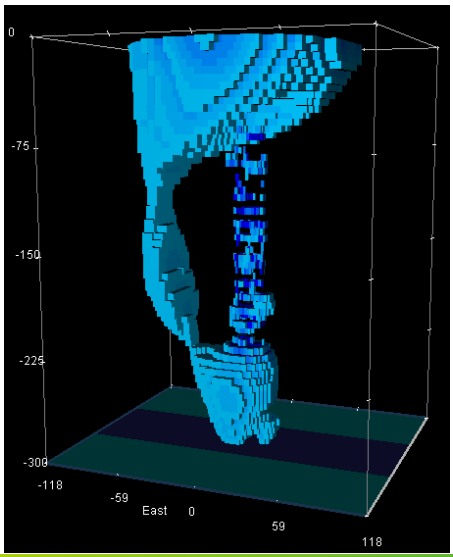
GOLDER

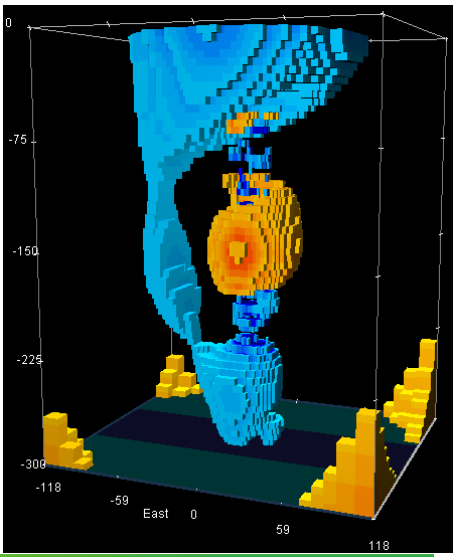


GOLDER

3D ERI – Mine Shaft

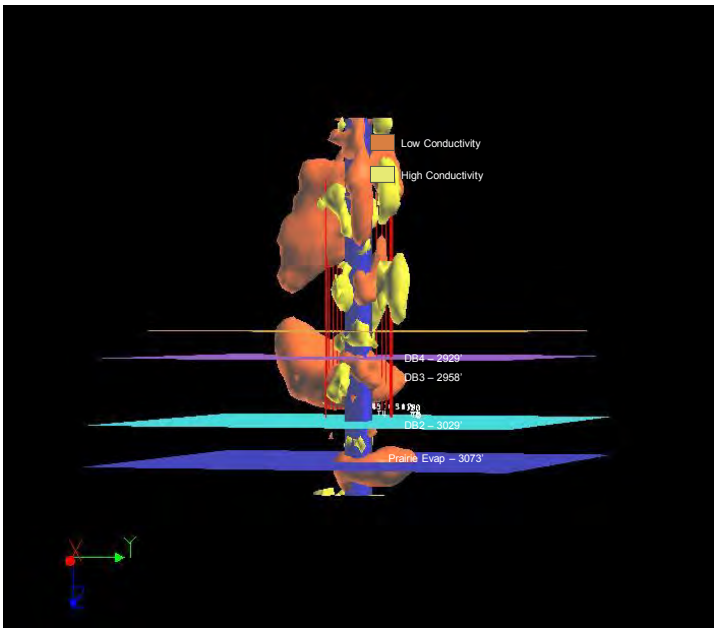
Water is flowing behind concrete in proximity to the shaft.





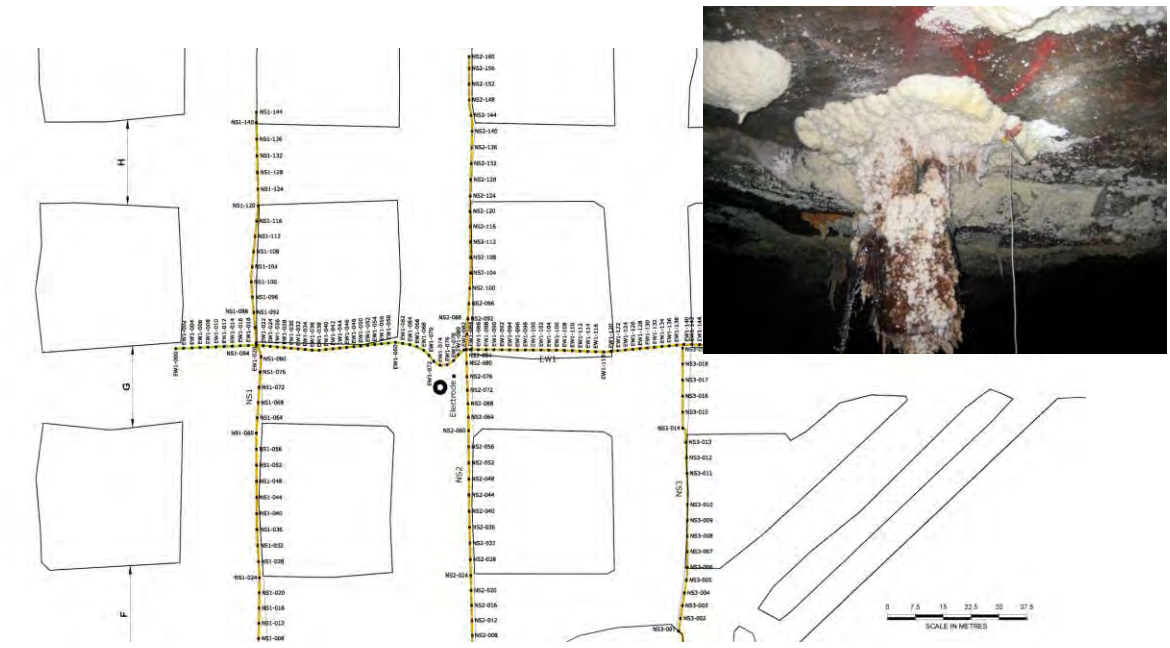
GOLDER

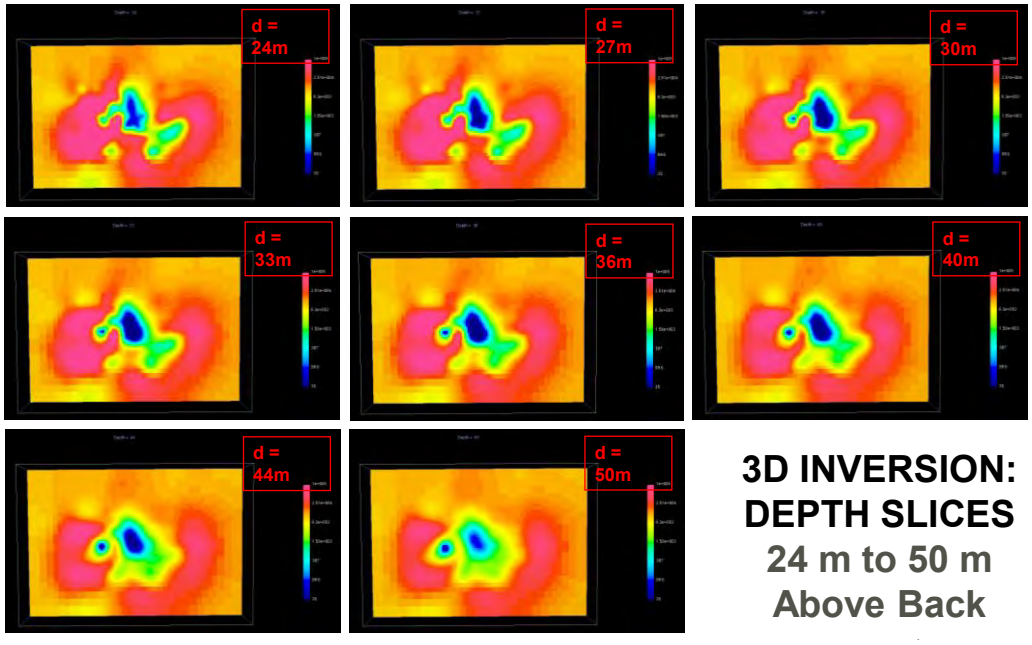
3D ERI – Mine Shaft



GOLDER

Mosaic Golder Associates GIF





3D INVERSION: DEPTH SLICES
24 m to 50 m Above Back

GOLDER

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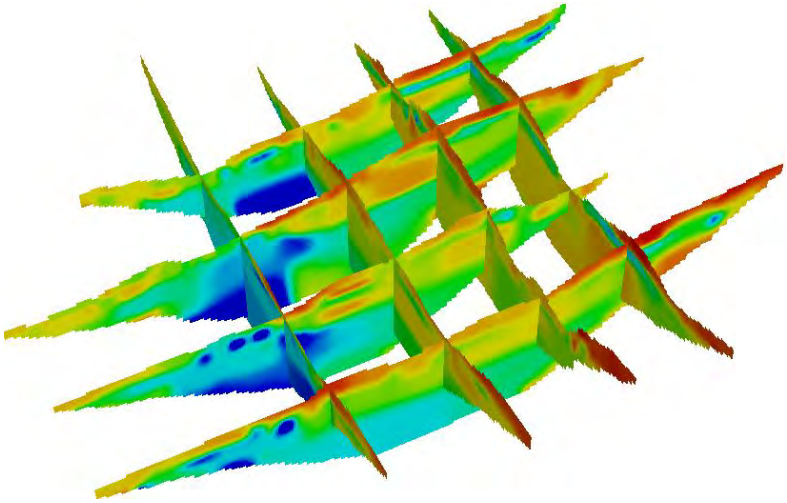
ERI – 2D to 3D



GOLDER

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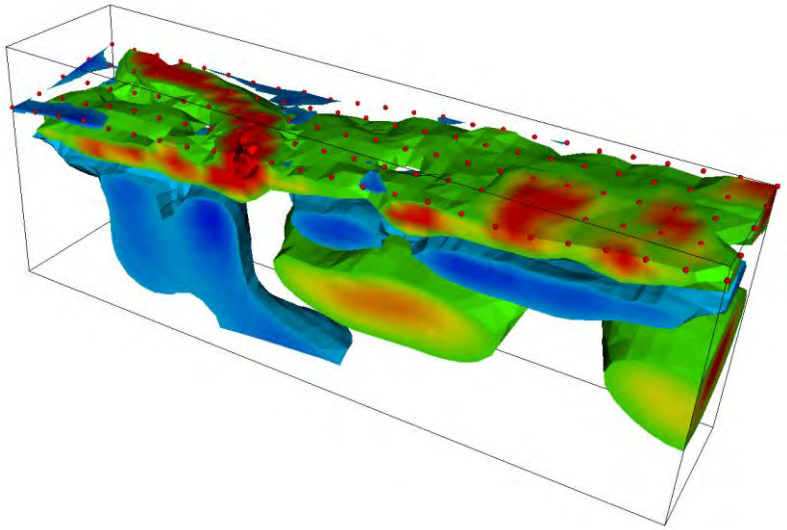
3D ERI – Mine Voids



GOLDER

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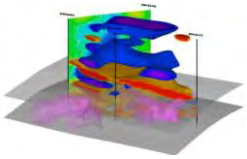
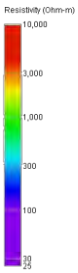
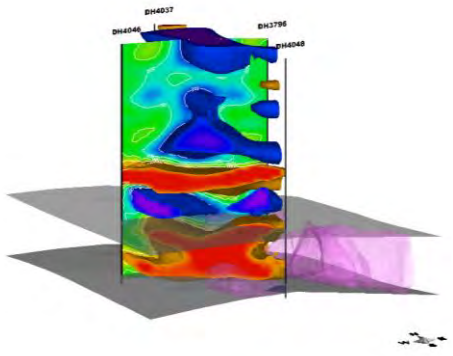
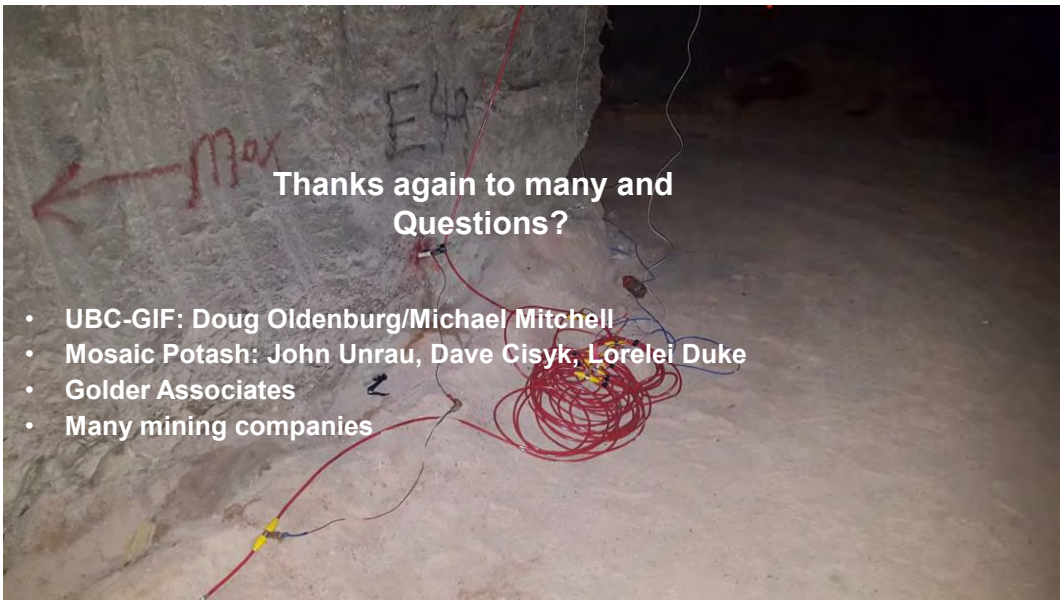
Four Hole Cross-hole ERI







GOLDER


Thanks again to many and
Questions?
• UBC-GIF: Doug Oldenburg/Michael Mitchell
• Mosaic Potash: John Unrau, Dave Cisyk, Lorelei Duke
• Golder Associates
• Many mining companies

GOLDER