Interpretation of regional geophysical data for copper exploration, Curaçá Valley, Brazil.

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Introduction

Geological setting

Airborne geophysical surveys

Interpretation

Targeting

Siriema discovery

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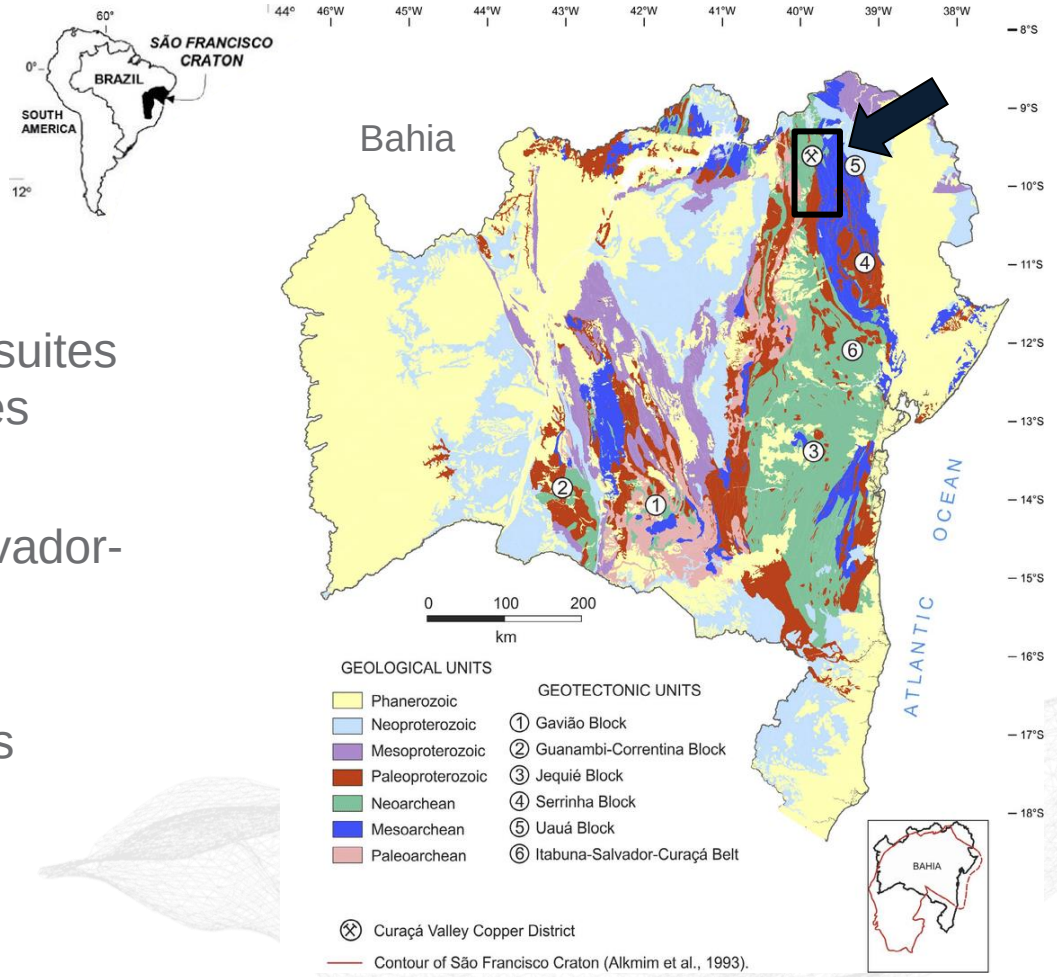
Geological setting

Archean geological province

Mafic to ultramafic intrusive rock suites metamorphosed to granulite facies

Deformed during the Itabuna-Salvador-Curaçá Orogeny

Granitic to syenitic intrusive suites



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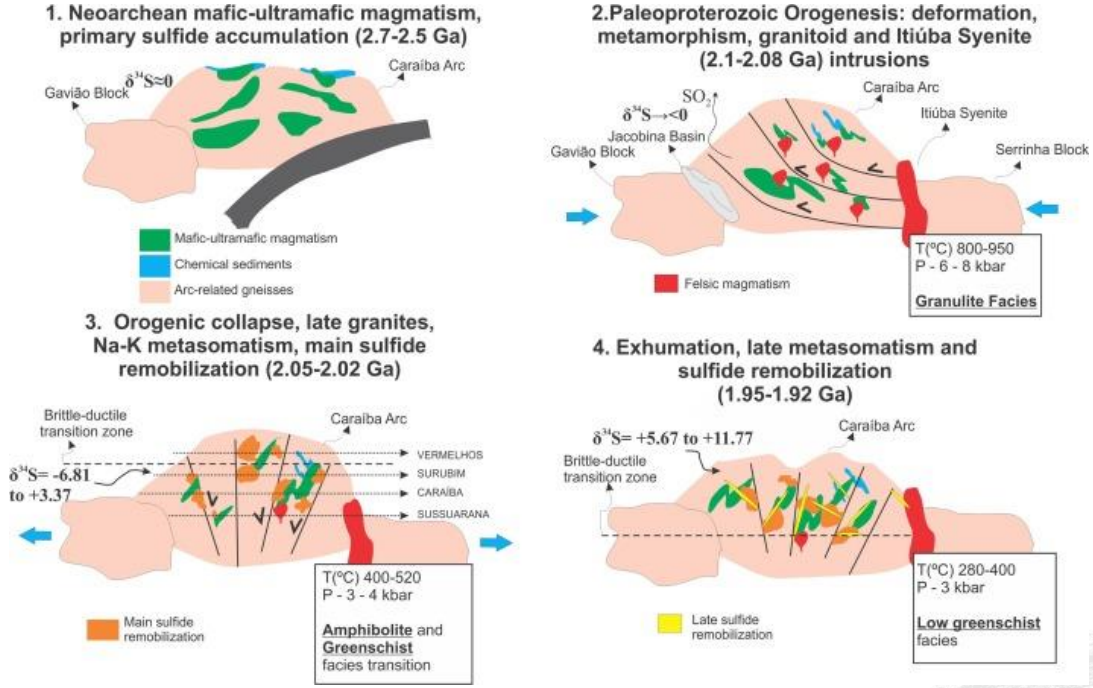
Geological setting



- Cu-Ni Mineralization associated with mafic-ultramafic rocks (Cpy-Pn-Mag)
- Pyroxenite alteration directly associated with mineralization
- Broad alteration corridor associated with large-scale structures
- Calc-silicate halo around mineralization
- Potassic alteration

Tectonic and metallogenic evolution of the Curaçá Valley Copper Province, Bahia, Brazil: A review based on new SHRIMP zircon U-Pb dating and sulfur isotope geochemistry
Pedro Maciel de Paula Garcia 2018

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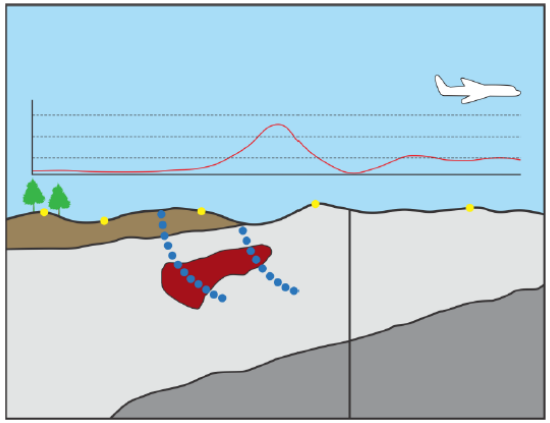
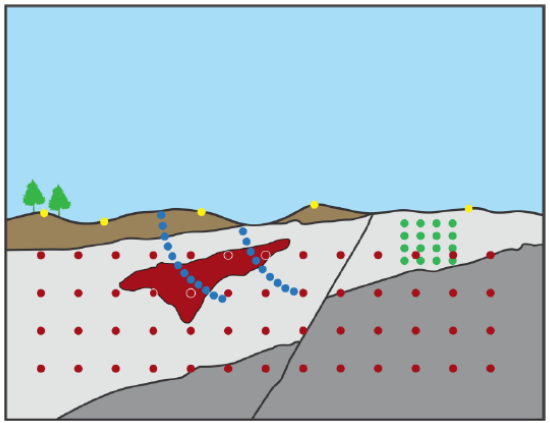
Integrated Interpretation for Targeting

Exploration decisions are only as good as the model they are based on

Every component of the model that is not a direct observation from drill core or outcrop is interpretation

Geophysical data provide our only means of volumetric investigation away from the drill hole or outcrop; it is our only non-drilling means of deep search beyond simple down plunge projection of structure





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Deposits Overview - Vermelhos

Sulfide minerals: Chalcopyrite, bornite and minor pyrrhotite

Textures (main bodies): massive to semi-massive to breccia textures

Vermelhos Mine (2020 Technical Report):

Resources Classification*	Tonnage *(000 tonnes)*	Grade *(Cu %)*	Cu Contained *(000 tonnes)*
Measured	3,389	2.8	94.9
Indicated	4,514	1.19	53.7
Measured & Indicated	**7,903**	**1.88**	**148.6**
Inferred	4,128	0.86	35.5

* Effective date of the resources: July 29, 2020.
Mineral resources are stated inclusive of mineral reserves.
Mineral resources that are not mineral reserves do not have demonstrated economic viability.
2020 Technical Report for the Vale do Curaçá Property (https://www.sedar.com).

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Vermelhos deposit

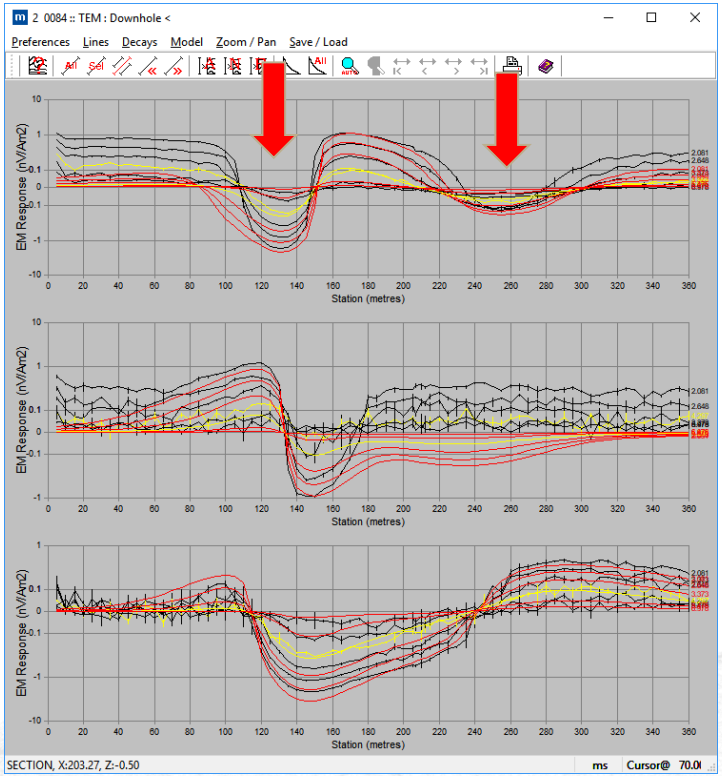
Mineralisation at Vermelhos is known to be conductive based on a VTEM survey (2007) and subsequent DHEM

DHEM conductors are well represented by compact plates typically 200-400S but ranging in one case up to 850S (inside Toboggan orebody)

A

U

V



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Airborne Geophysical data

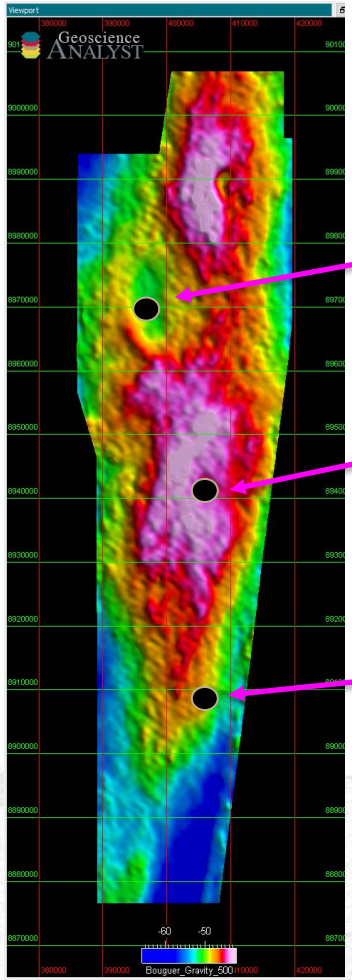
Two very large airborne surveys were conducted simultaneously

Sander AirGRAV ~21,000 lkm

SkyTEM 312HP AEM @ 25 Hz ~21,000 lkm

Survey area ~130 km × 33 km, 200 m line spacing

Government (CPRM) airborne magnetics and radiometrics are also available for the northern ¾ of the AirGRAV/SkyTEM survey block



AirGRAV
500 m HW

Vermelhos

Surubim

Pilar

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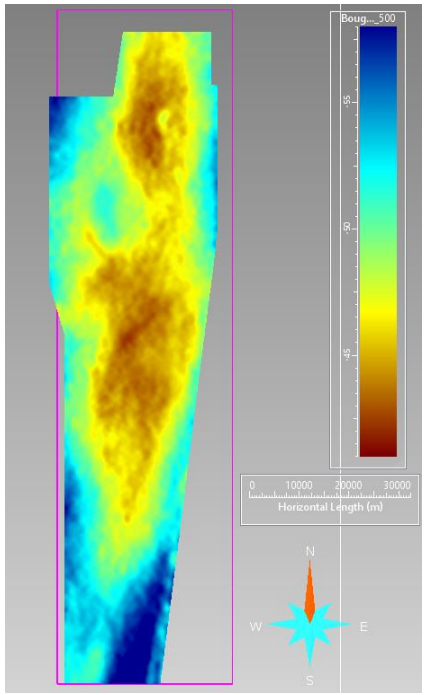
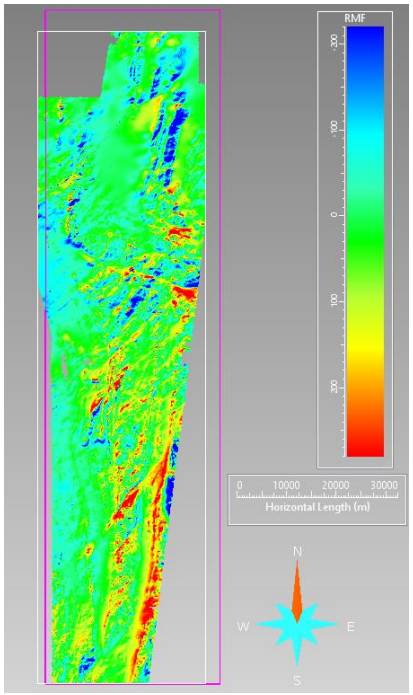
Airborne geophysical data

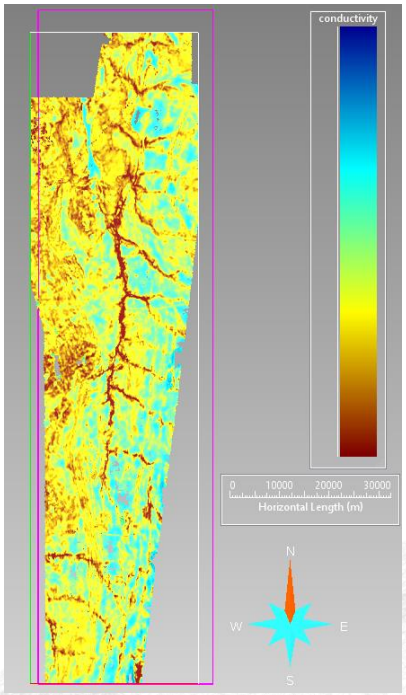
AirGRAV



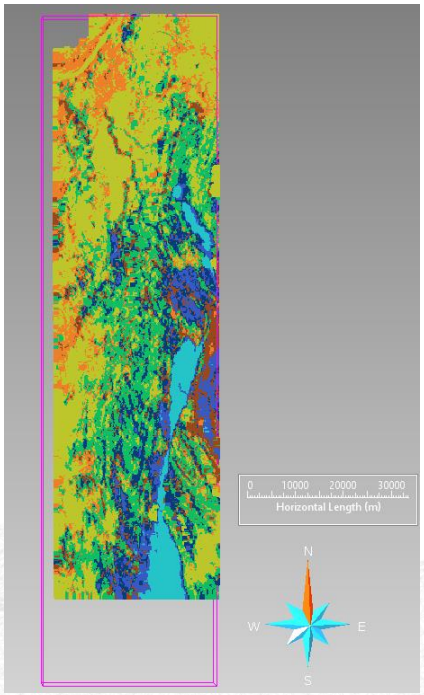
Magnetics



SkyTEM



Radiometrics



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Regional interpretation

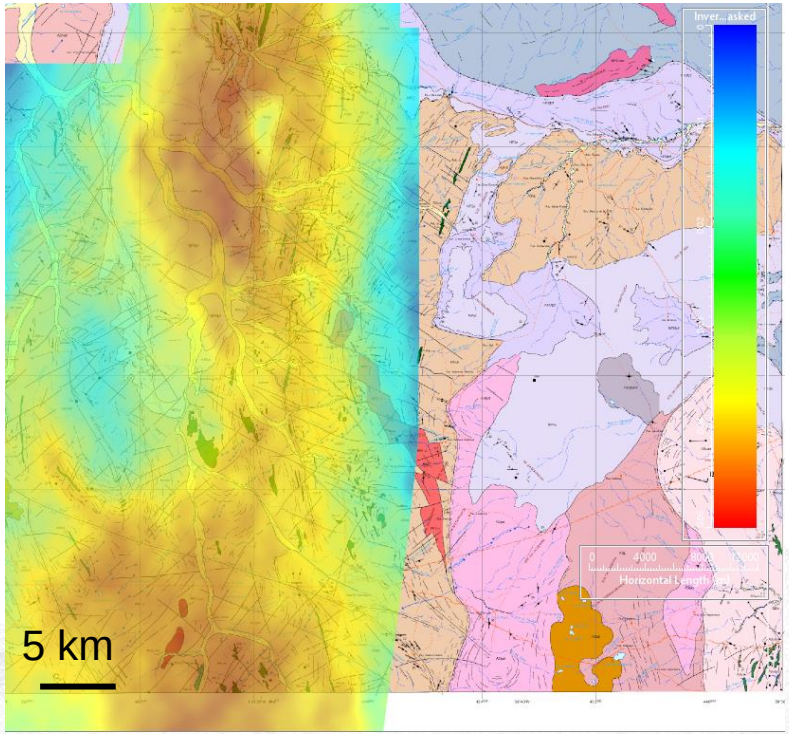
Gravity and AEM surveys were conducted to help define mineralized targets

Early on a misfit between geophysical responses and maps was observed

In order to find new deposits, a proper representation of the Archean geometry, major structures and intrusive sequences was required

AirGRAV

CPRM
250K Geology



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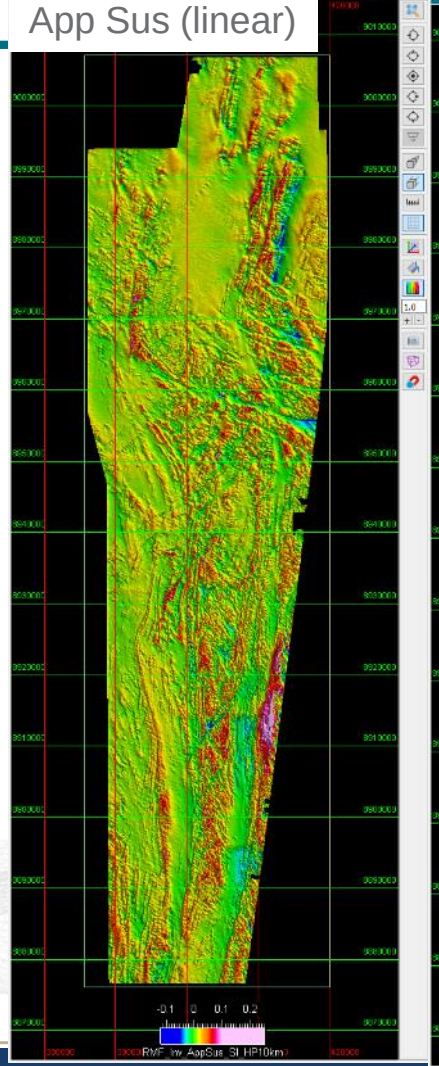
Magnetic interpretation

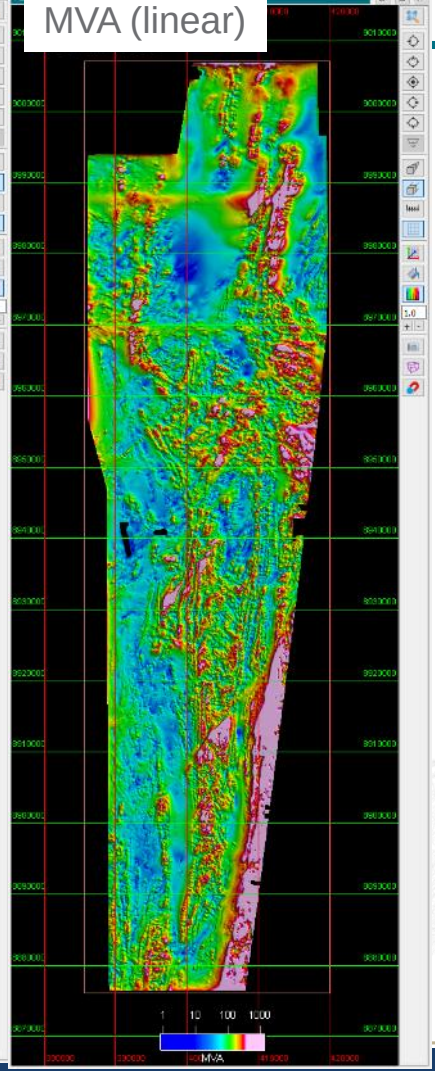
The magnetic data did not show a clear relationship with mineralized bodies

Magnetic images help define contacts, and structural grain

Different litho-structural domains can be differentiated using the magnetics

Magnetic Vector Amplitude was also used - shows a high above magnetic material regardless of remanence direction





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Contribution from the AEM data

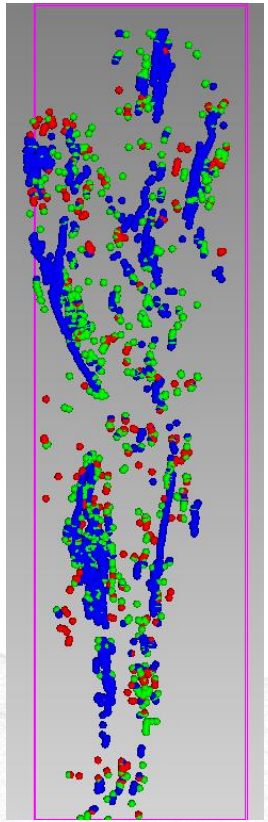
Anomaly picking was conducted – done as part of the daily QC

The anomalies were ranked based on:

1. Continuity; discrete anomalies (small conductive bodies) to continuous anomalies (stratigraphic conductors), and

2. Conductor quality

Conductor dips were also estimated (semi-quantitative)



1 = best

3 = worst

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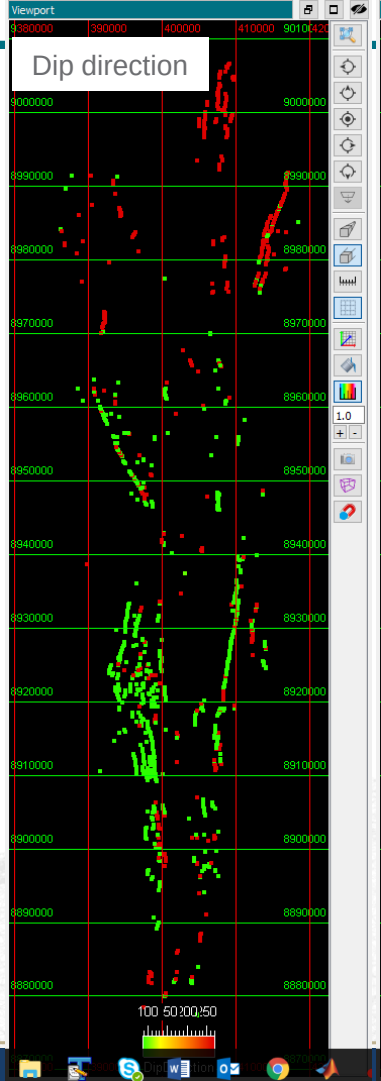
EM anomaly picks

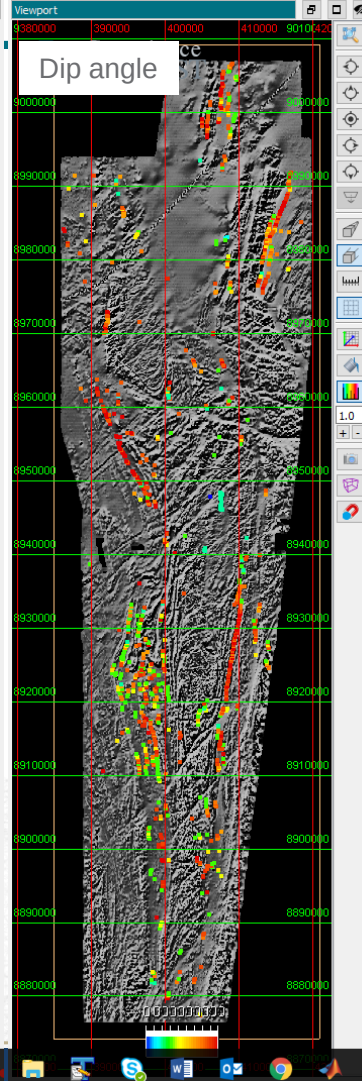
Conductor dips and dip direction have been estimated where possible - mostly for stratigraphic conductors.

Green = east dip

Red = west dip

Provide structural controls on future geological modelling





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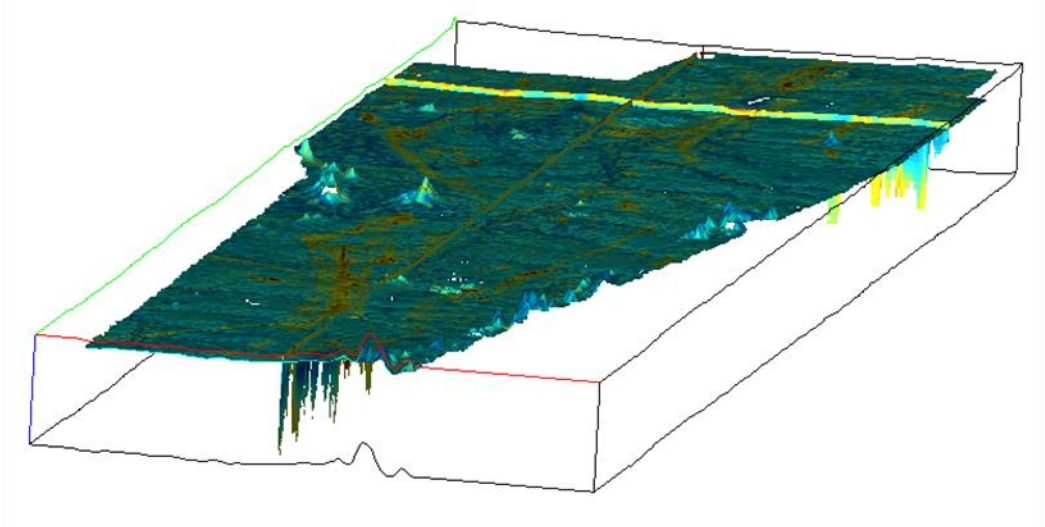
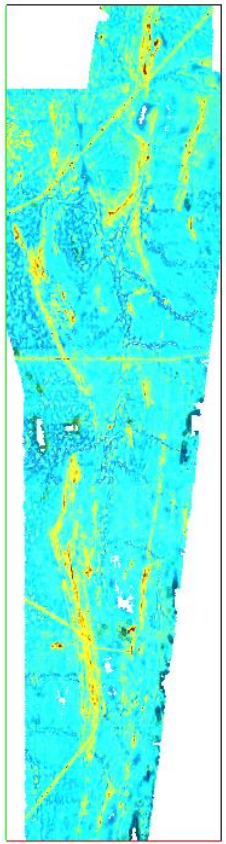
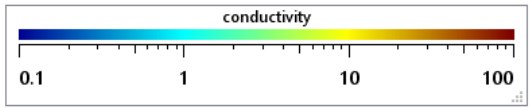
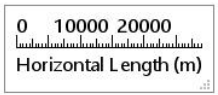
SkyTEM 1D inversion

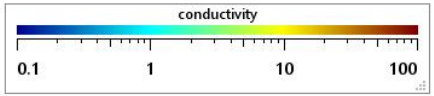
EM inversions provided thickness of post-mineral cover (unconsolidated and consolidated)











SOM classification of radiometric data

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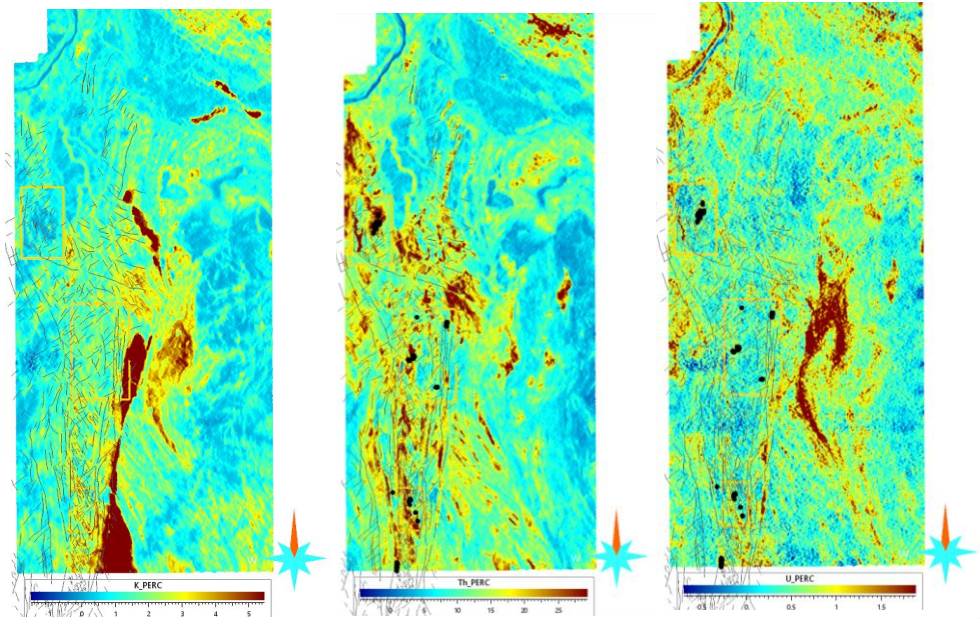

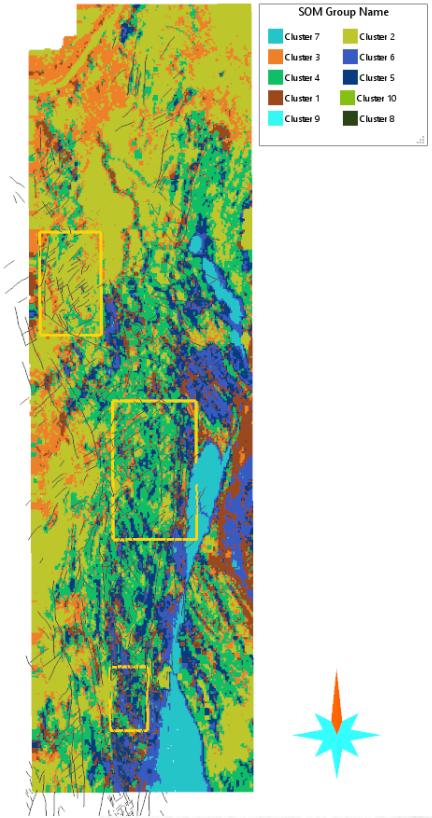

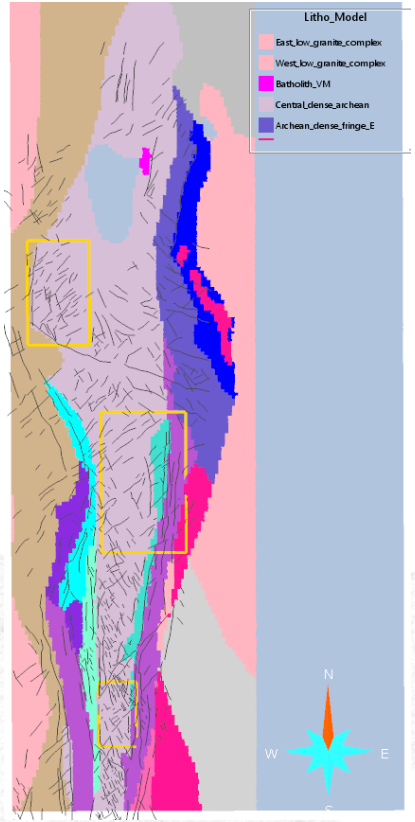

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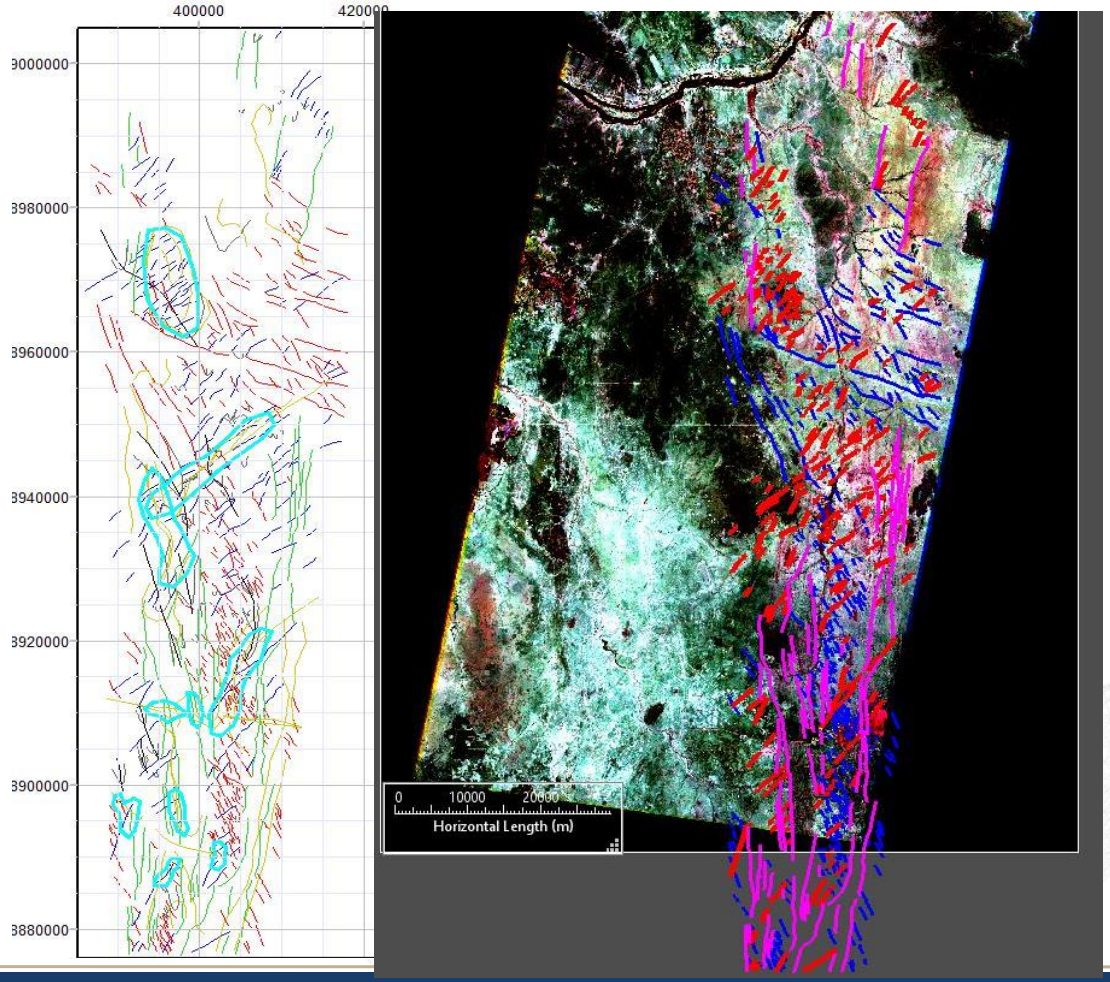
Structural interpretation

Structural interpretation and timing relationships built up from:

Magnetics

Gravity

AEM



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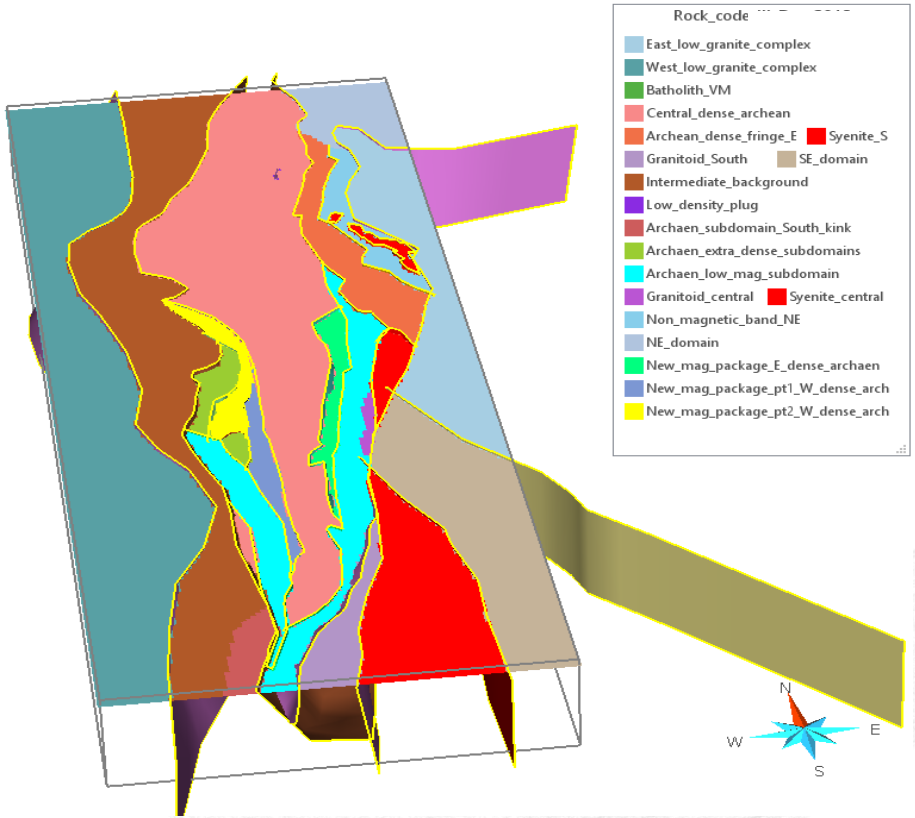
Final pseudo-lithological model

By combining the insight given by the gravity, magnetics, EM and radiometric data, it is possible to construct a 3D representation of the pseudo-lithological units

The model provides the basis for geologically-constrained heterogeneous-unit inversion and targeting



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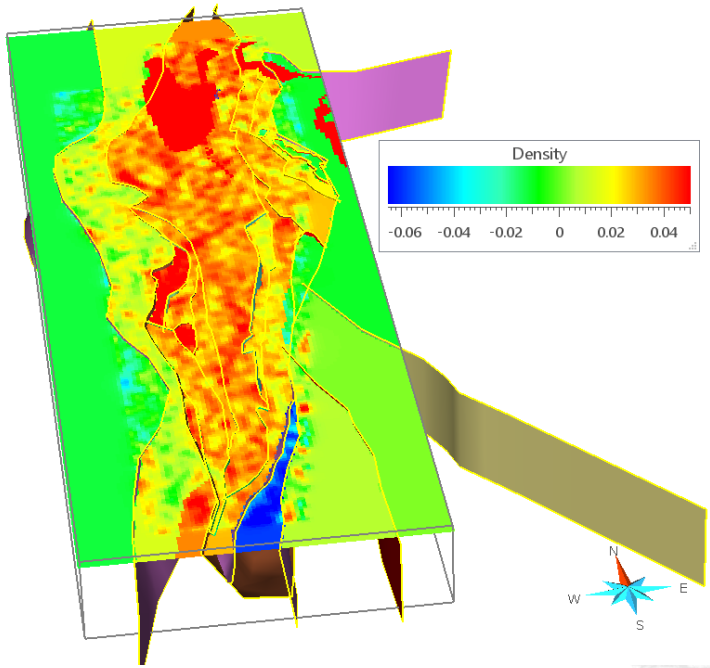
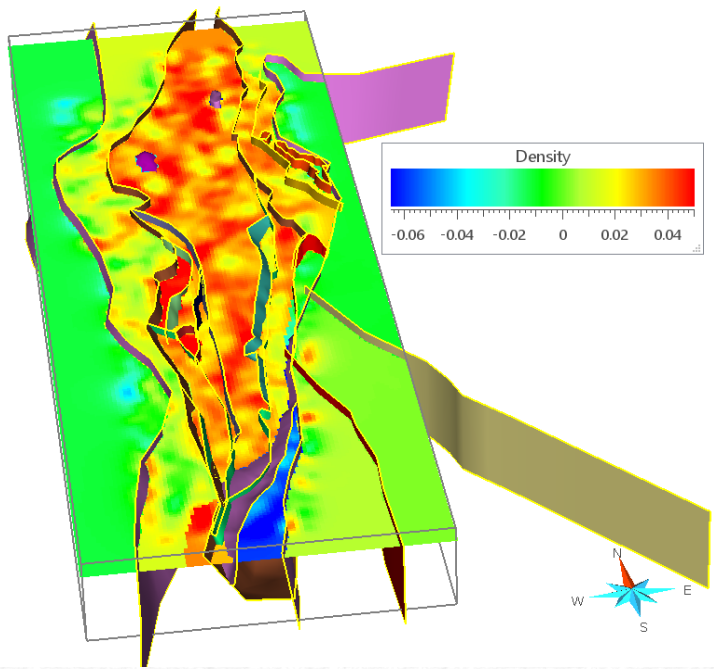
3D AirGRAV modelling – heterogeneous-unit inversion

RL +250 m



RL -750 m



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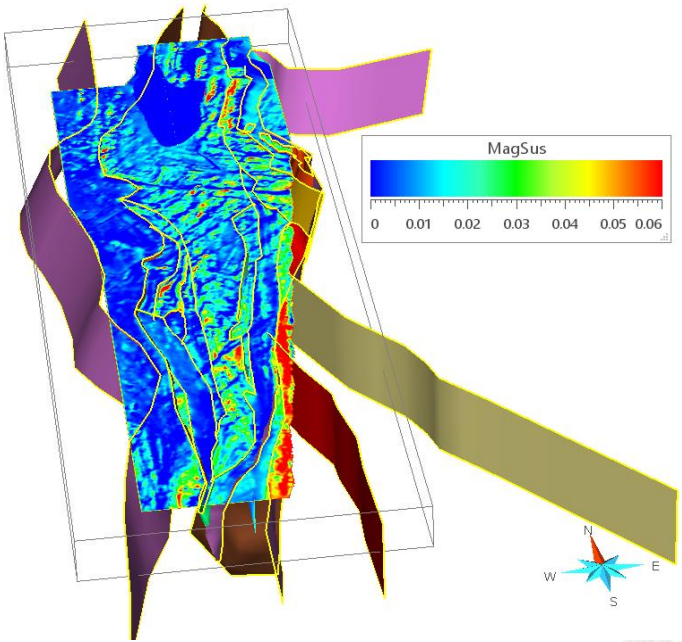
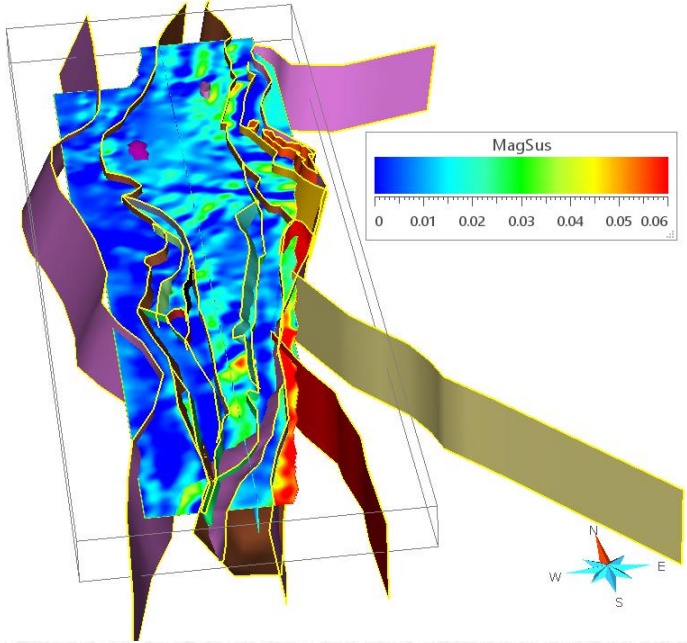
Densities relative to 2.67 g/cc

3D Magnetic modelling – heterogeneous-unit inversion

RL +250 m



RL -750 m



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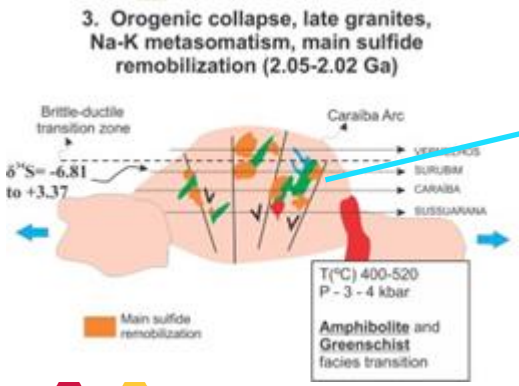
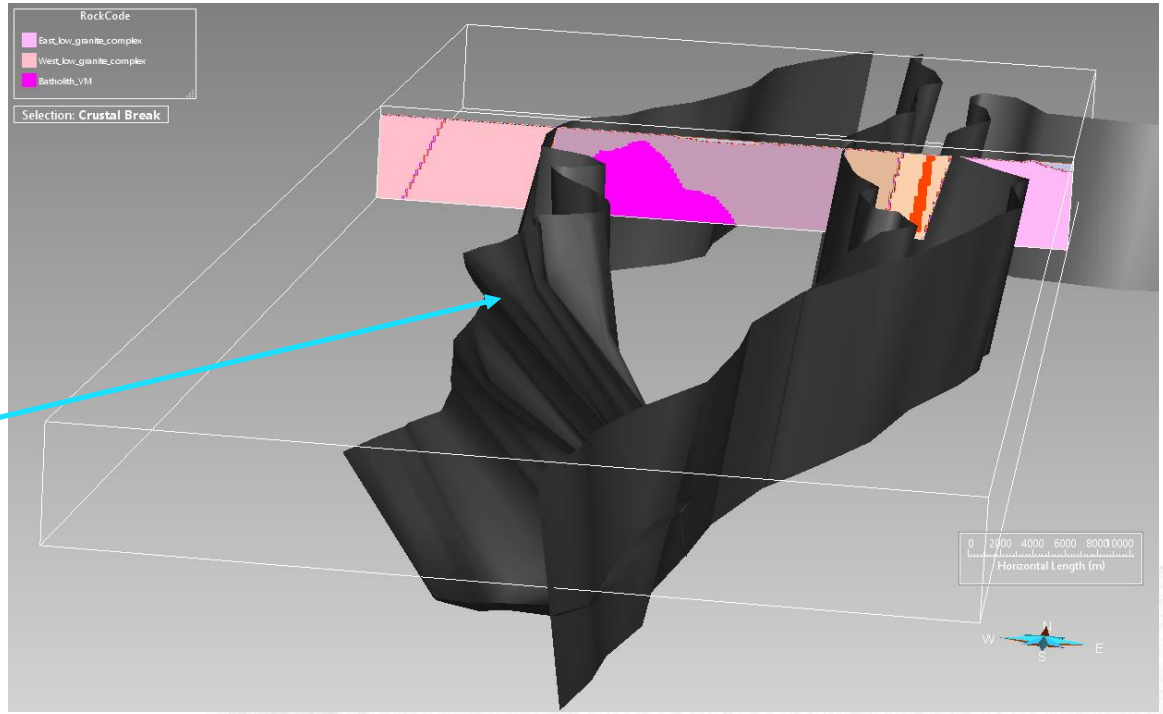
Crustal scale features

Tying the interpreted model to the exploration story





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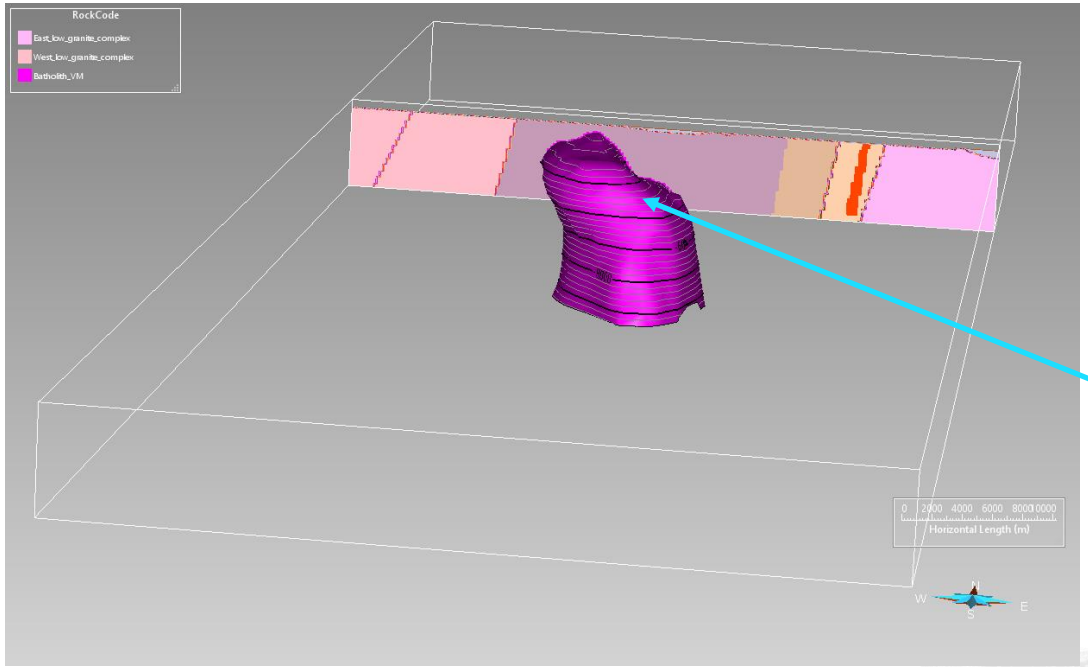
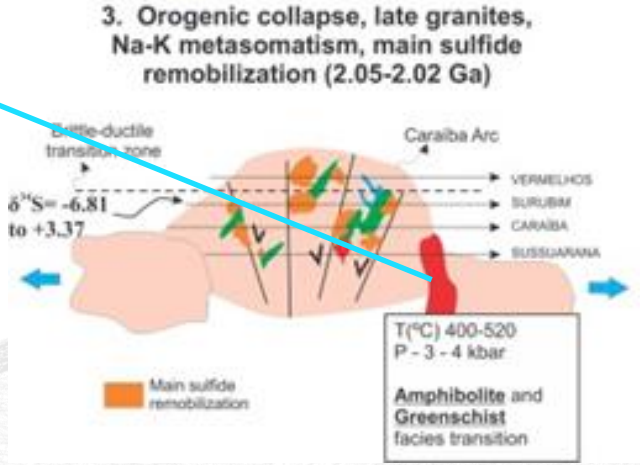
Granitic to syenitic intrusive features



Tying the interpreted model to the exploration story



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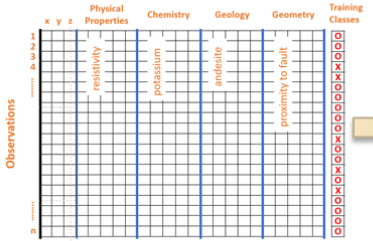
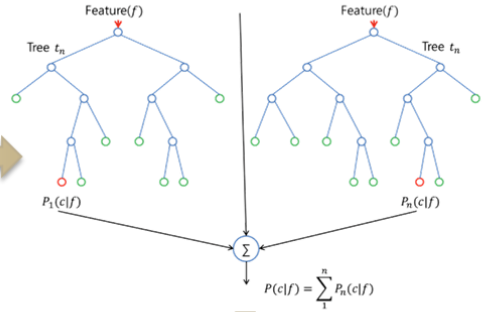
Mineral Prospectivity Index using Random Forest

Learning Set:

Know mineral occurences

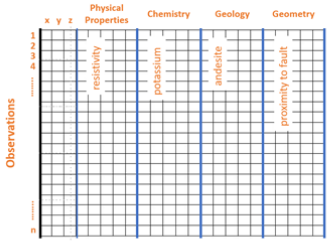


Classification Algorithm



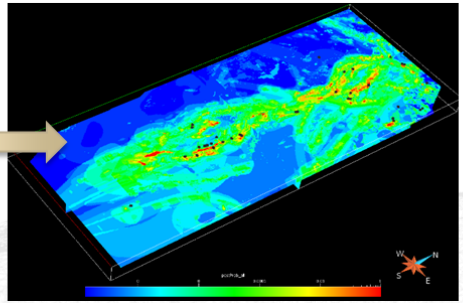
Application Set:

Untested targeting model



Mineralization Predictive Model

Prospectivity Model



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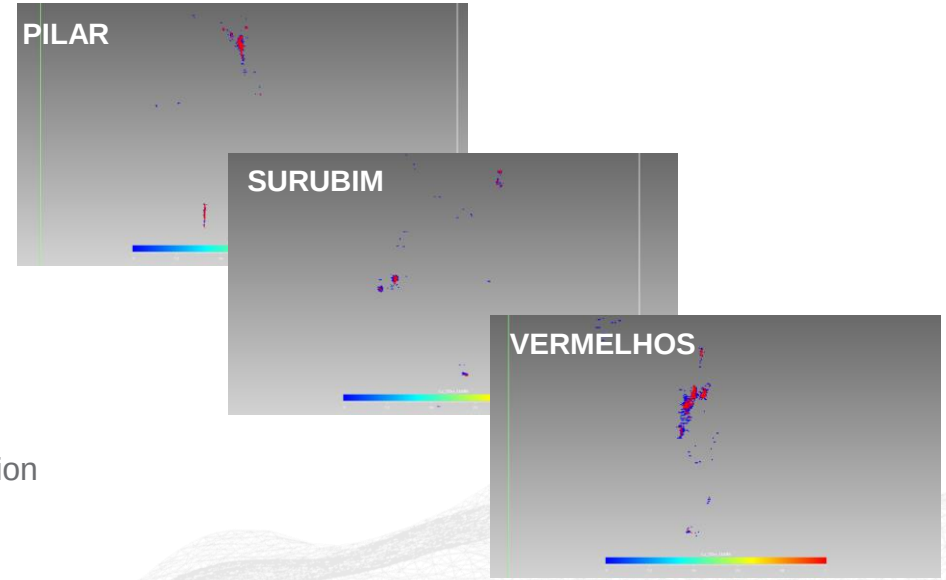
MPI Learning Scenarios

Learning labels creation:
Assign Cu values to the 2D voxet. Positive to negative examples are generated using a threshold of 0.1% Cu

Learning Labels:
1. Pilar (306 negatives and 250 positives)
2. Surubim (201 negatives and 109 positives)
3. Vermelhos (324 negatives and 210 positives)

Learning Features:
1. Full data coverage (75 features)
2. Gravity data coverage (5 features)
3. Magnetic data coverage (17 features)

Random Forest modelling approach
1. Predictive model optimized to the accuracy metric.
2. 10 iterations of learning/prediction were run and averaged to a final score including standard deviation
3. All predictions combined in global score through a weighted average



Positive learning examples (red) and negative examples (blue)

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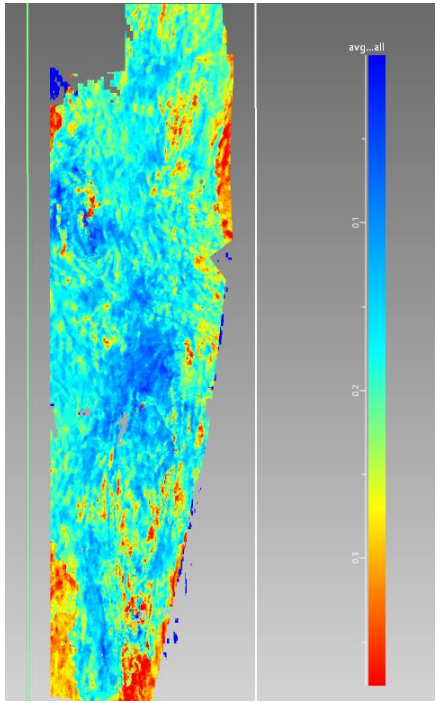
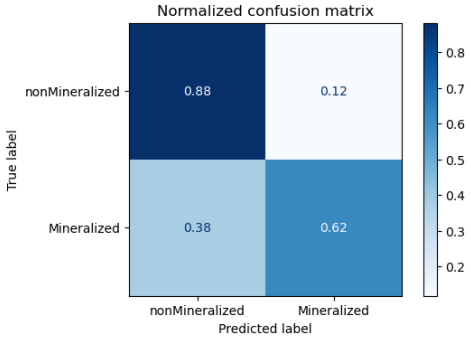
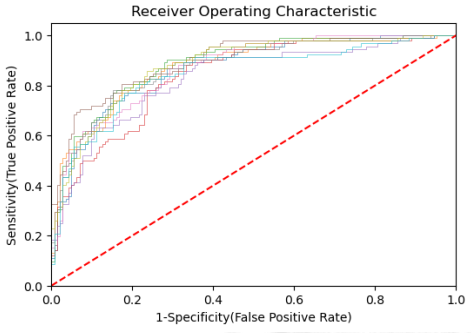
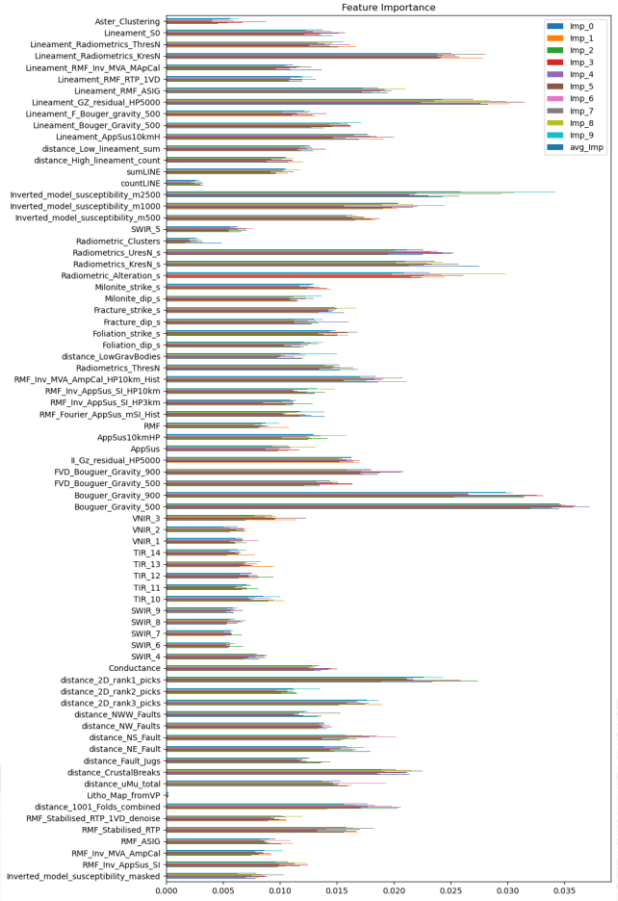
MPI Performance Metrics

Learning on all examples using all feature coverage









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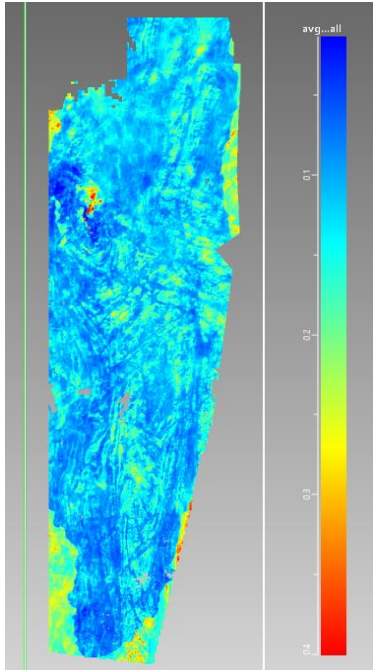
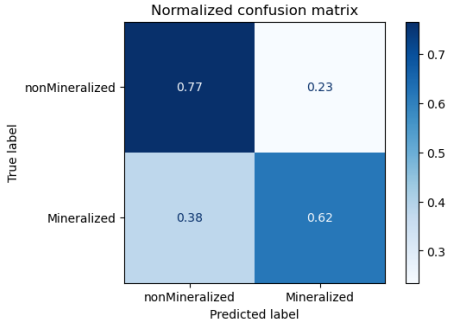
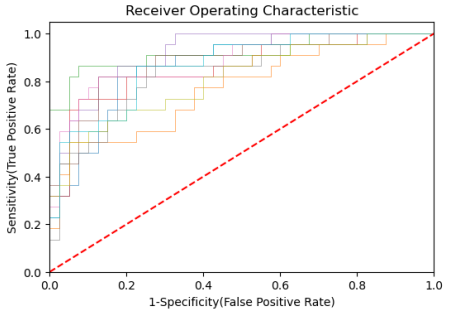
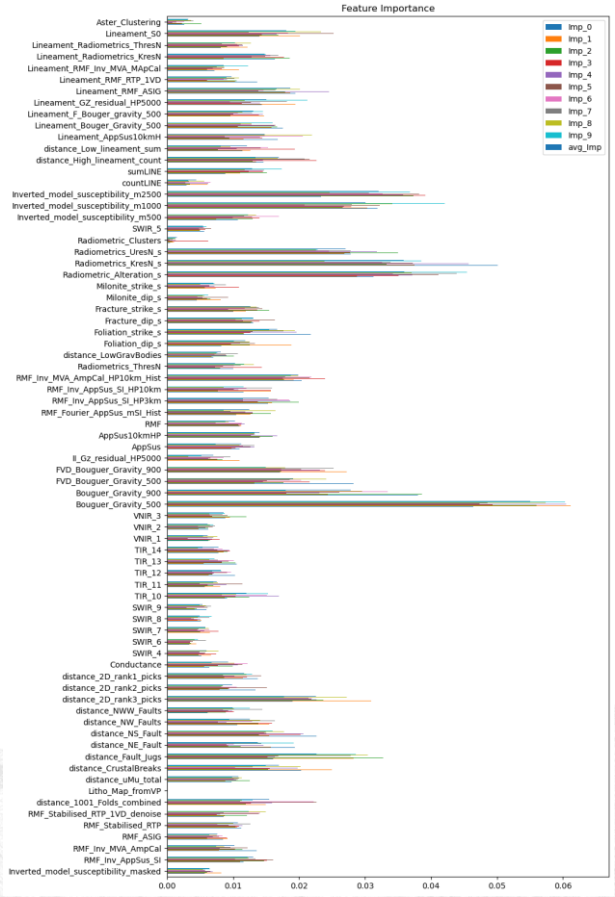
MPI Performance metrics

Learning on Vermelhos examples using all feature coverage









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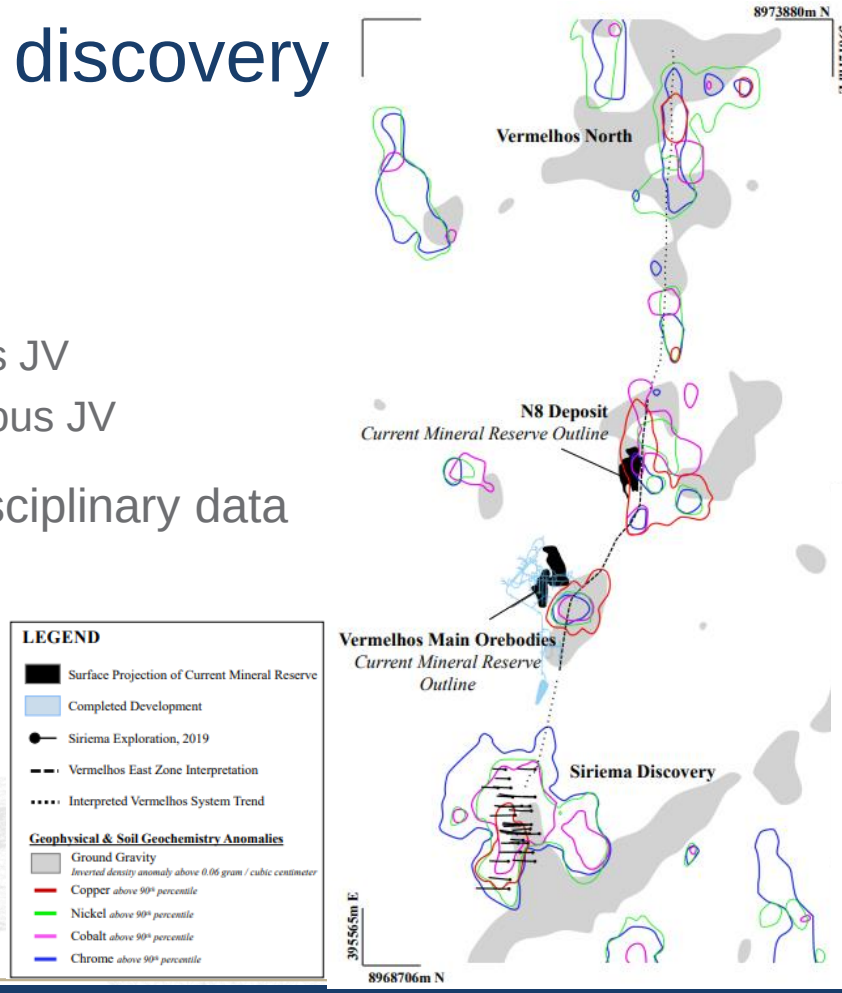
Siriema – a multidisciplinary discovery

Exploration History

- On trend with Vermelhos
- Soil Geochem anomaly
- A few holes drilled from the west by previous JV
- Some intersections but abandoned by previous JV

ERO 2018/19 drill target on basis of multidisciplinary data

- New re-leveled soil geochemistry
- Weak IP response
- Gravity high
- Weak-moderate SkyTEM response
- Drilled from east



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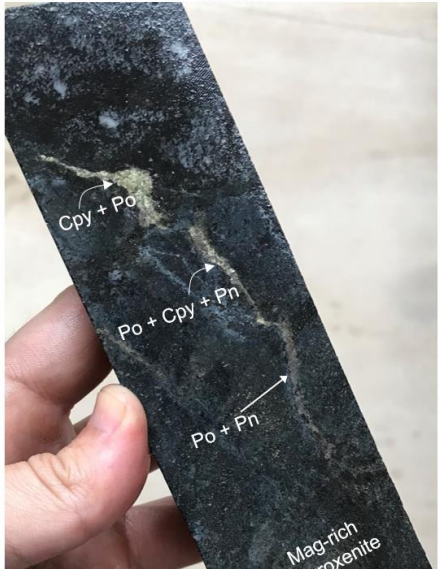
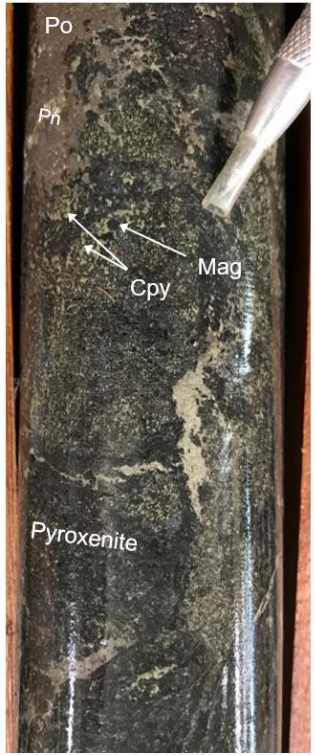
Siriema deposit overview

Sulfide minerals:
Pyrrhotite, chalcopyrite and pentlandite

Textures:

Semi-massive to Veins





Siriema (2020 Technical Report):

Resources Classification*	Tonnage *(000 tonnes)*	Grade *(Cu %)*	Cu Contained *(000 tonnes)*
Measured	-	-	-
Indicated	2,956	0.92	27.1
Measured & Indicated	**2,956**	**0.92**	**27.1**
Inferred	187	0.99	1.9

* Effective date of the resources: July 4, 2020.
Mineral resources are stated inclusive of mineral reserves.
Mineral resources that are not mineral reserves do not have demonstrated economic viability.
2020 Technical Report for the Vale do Curaçá Property (https://www.sedar.com).

Conclusions

Geophysical surveys have more potential than direct detection of mineral deposits

More information can be derived from proper geologically-supported integrated interpretation

By combining the different sources of information, it is possible to build a comprehensive 3D model suited for mineral exploration

The end result of the geophysical data modelling needs to be usable for the exploration geologist

Only possible through collaborative and iterative integrated interpretation of the data

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Shameless Plugs

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What's new in EM inversion?

Geoscience ANALYST Pro Geophysics Virtual Lecture

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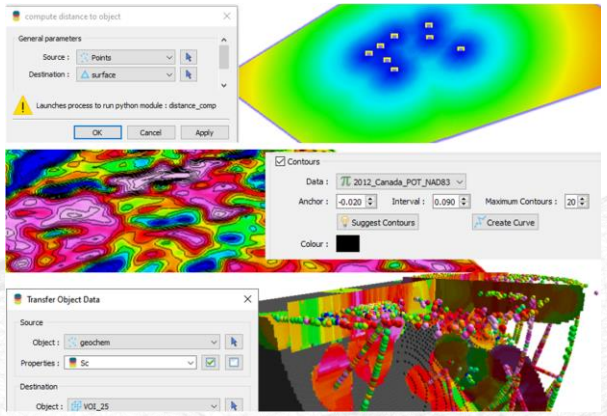
Geoscience ANALYST



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