

# **Emerging Deep penetrating geophysical technologies for exploring under cover.**

## **Porphyry and Skarn Examples**

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**August 22, 2019**



## **Overview**

- Intro to deep penetrating geophysical technologies**

- Case Examples**

- Bolivar Skarn Mineralisation
  - Deposit delineation and Exploration at Santa Cecilia
  - Charcas 3D Exploration

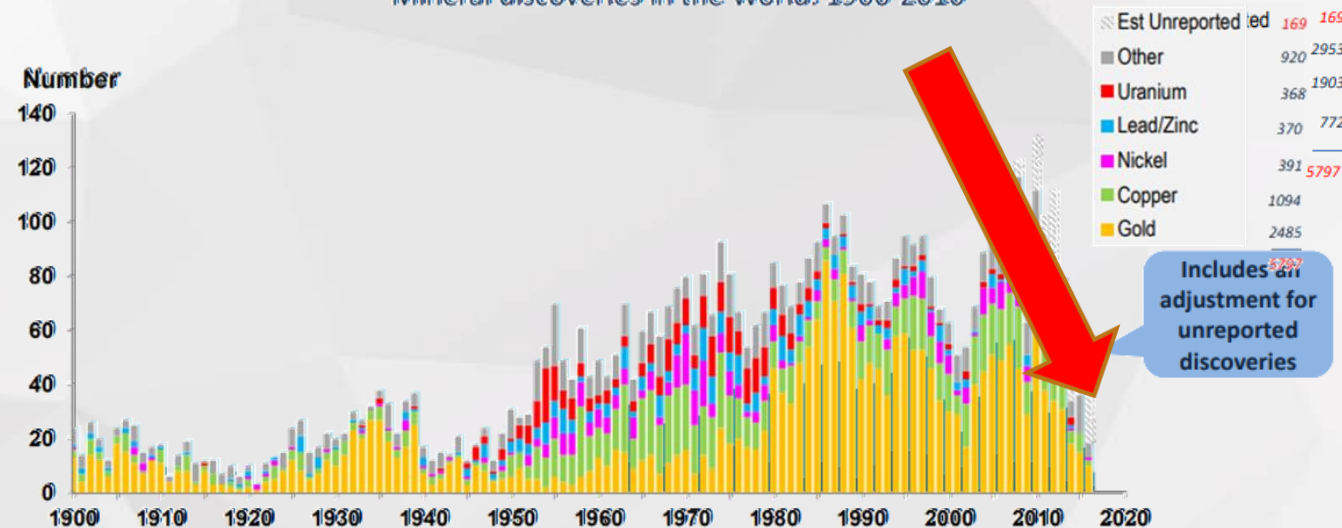
- Conclusions**



## Drivers for deep innovation

### Number of discoveries by commodity type

Mineral discoveries in the World: 1900-2016



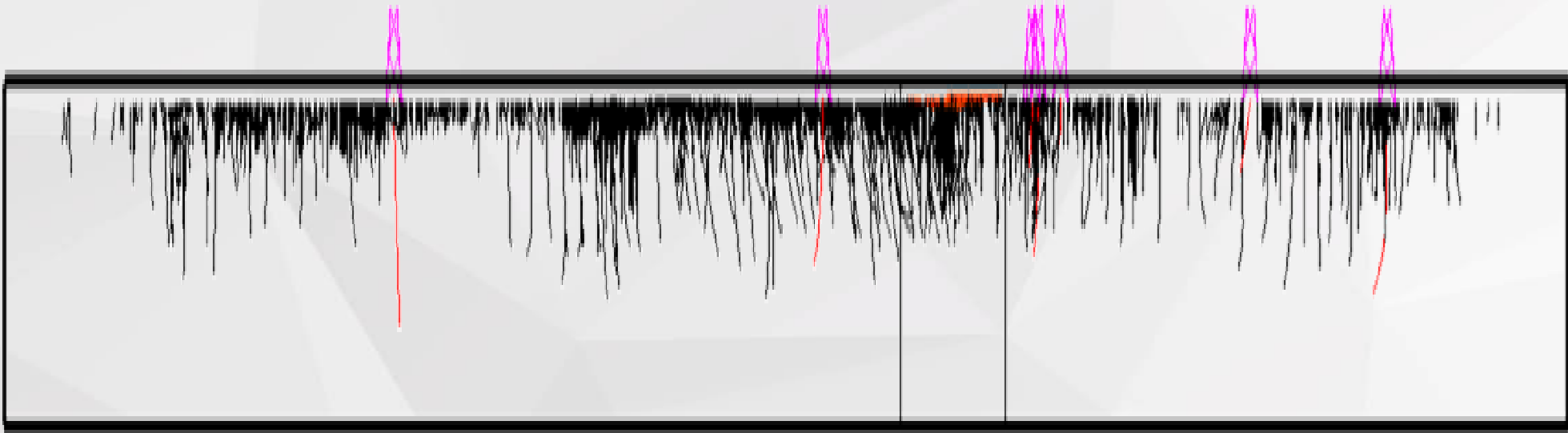
Note: Excludes Bulk Mineral discoveries (i.e. bauxite, potash, phosphate, coal and iron ore)  
 "Moderate" >100koz Au, >10kt Ni, >100kt Cu equiv, 250kt Zn+Pb, >5kt U<sub>3</sub>O<sub>8</sub>  
 "Giant" >6Moz Au, >1Mt Ni, >5Mt Cu equiv, 12Mt Zn+Pb, >125kt U<sub>3</sub>O<sub>8</sub>

Source: MinEx Consulting © October 2017



## Discovery Rates are probably falling because ...

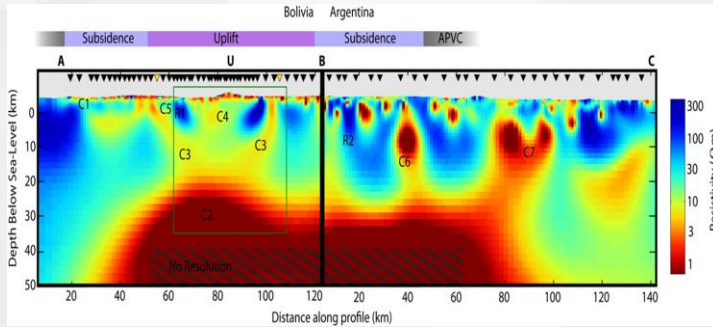
1. The earth is complicated
2. Undiscovered ore bodies are deeper and deeper



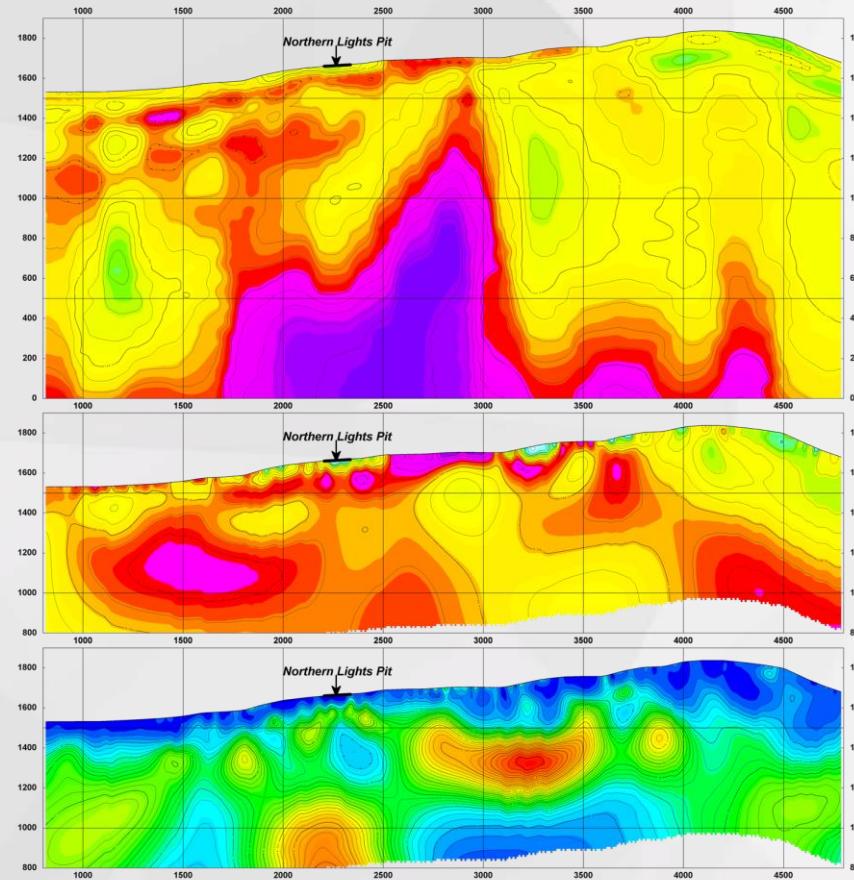
10 years of drilling .... One Orebody .....Guess where??



## Geophysical Imaging started to Advance significantly in 2000



**MT Resistivity – Regional  
Transect across the Andes**



**Top panel: MT Resistivity**

PW 2D inversion;

← Typically 1500 metres

**Middle panel: DC Resistivity**

UBC smooth inversion;

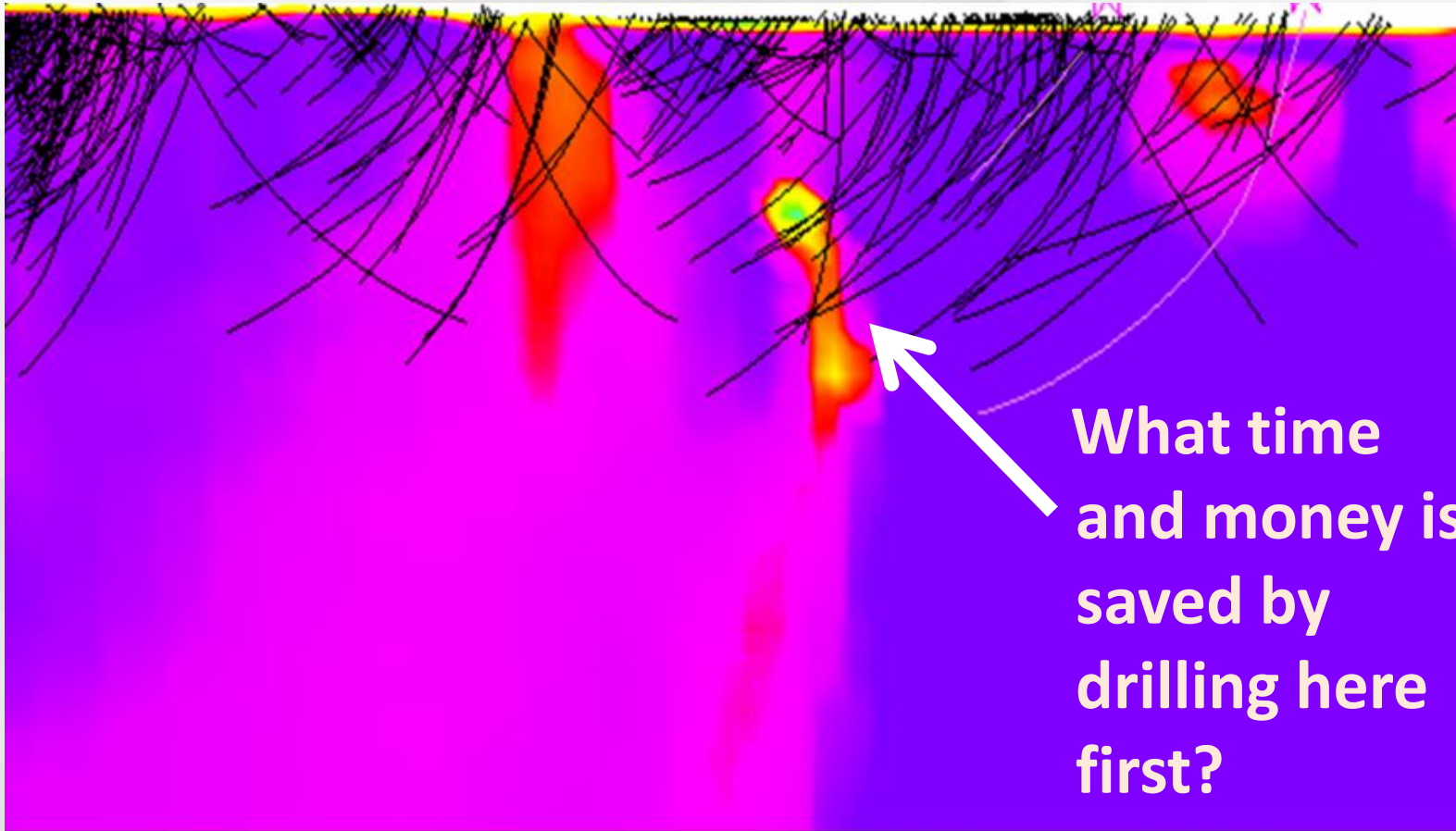
← Typically 500-750 metres

**Bottom panel: Chargeability**

UBC smooth inversion.



**In 2001 The imaging demonstrated how money could be saved**



**But overall adaptation was quite slow**



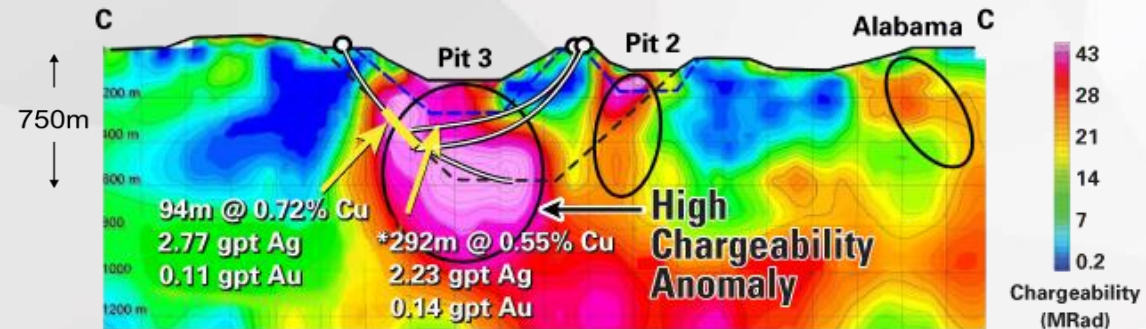


## Early adapters had immediate success

- This image helped the company raise

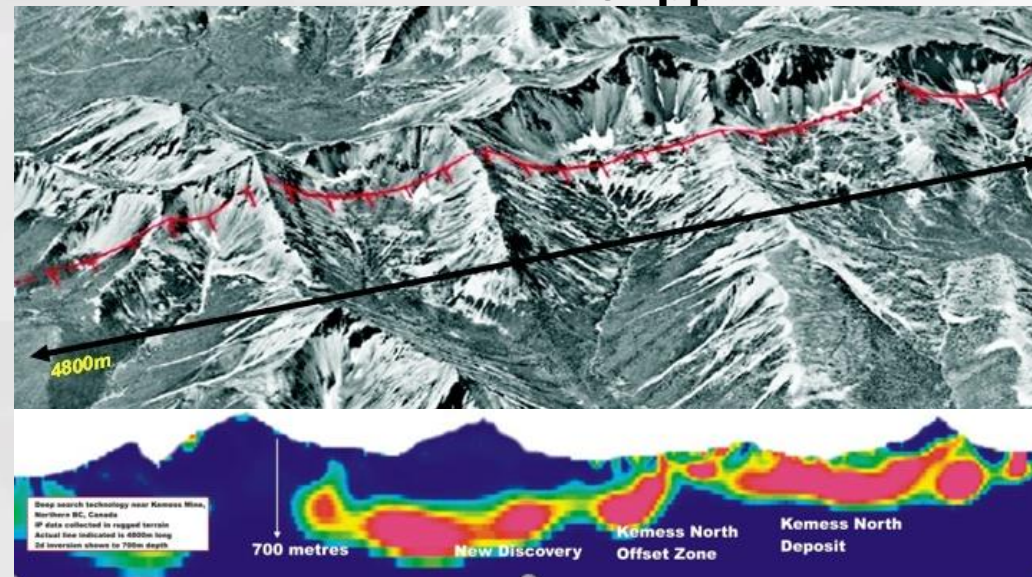
**50 MILLION dollars !**

- Changed mine design



**Copper Mountain**

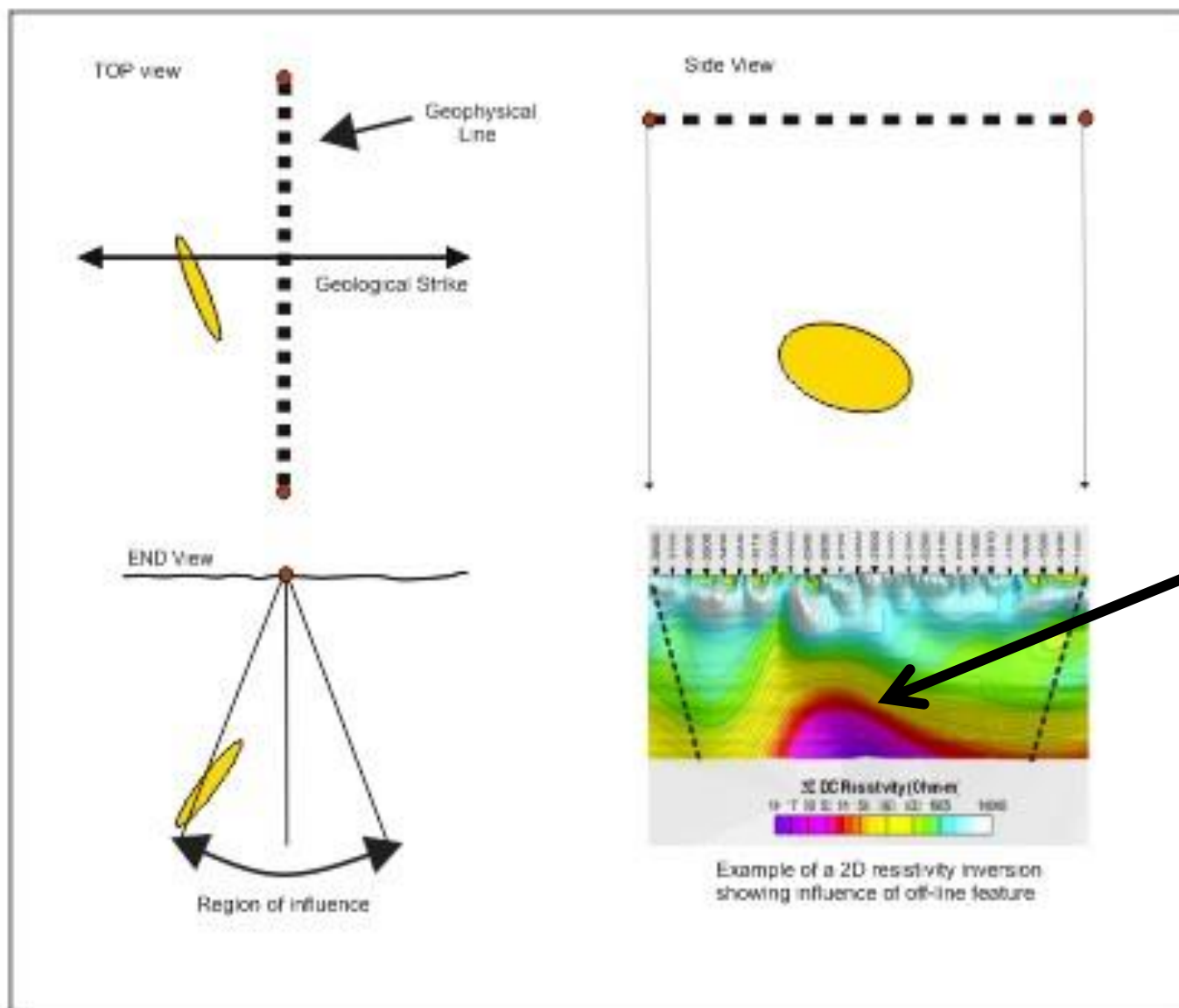
- This image helped Geological team vector to
- New Discovery**



**Kemess**



## 2D Geophysics

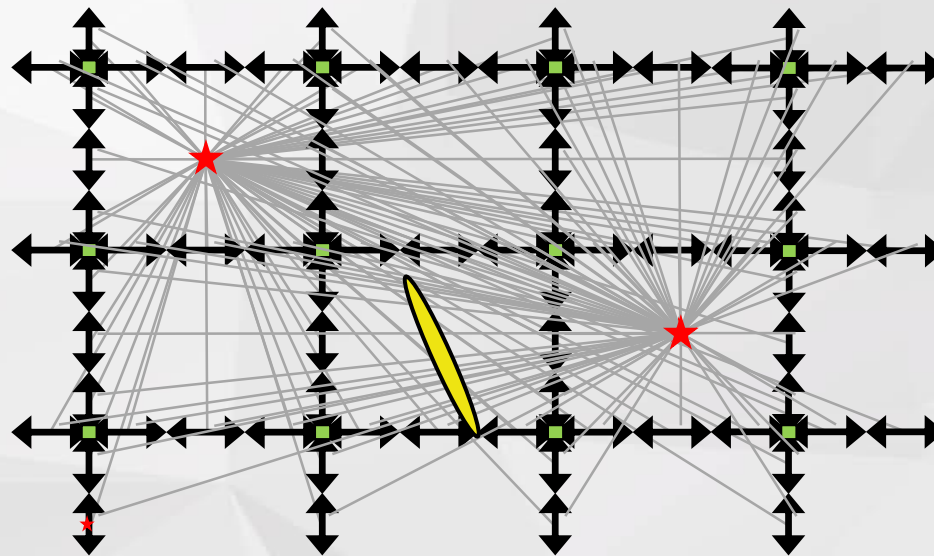






If you drill this..  
you may miss ?





## **TRUE 3D** **Interrogating and imaging in all directions**



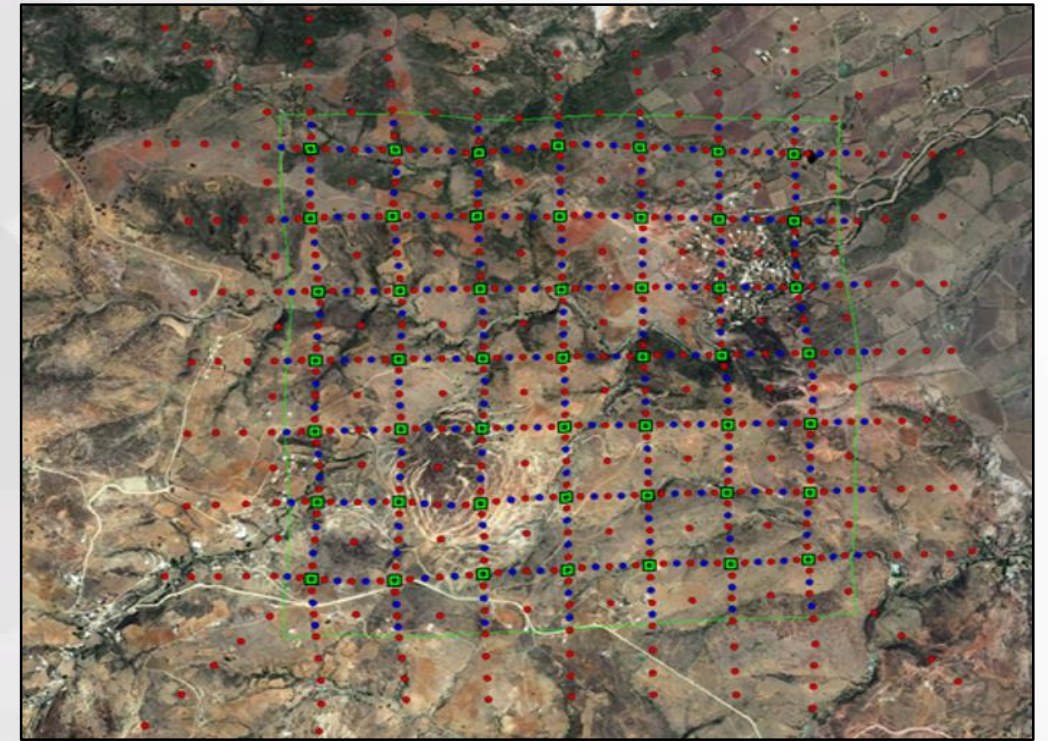
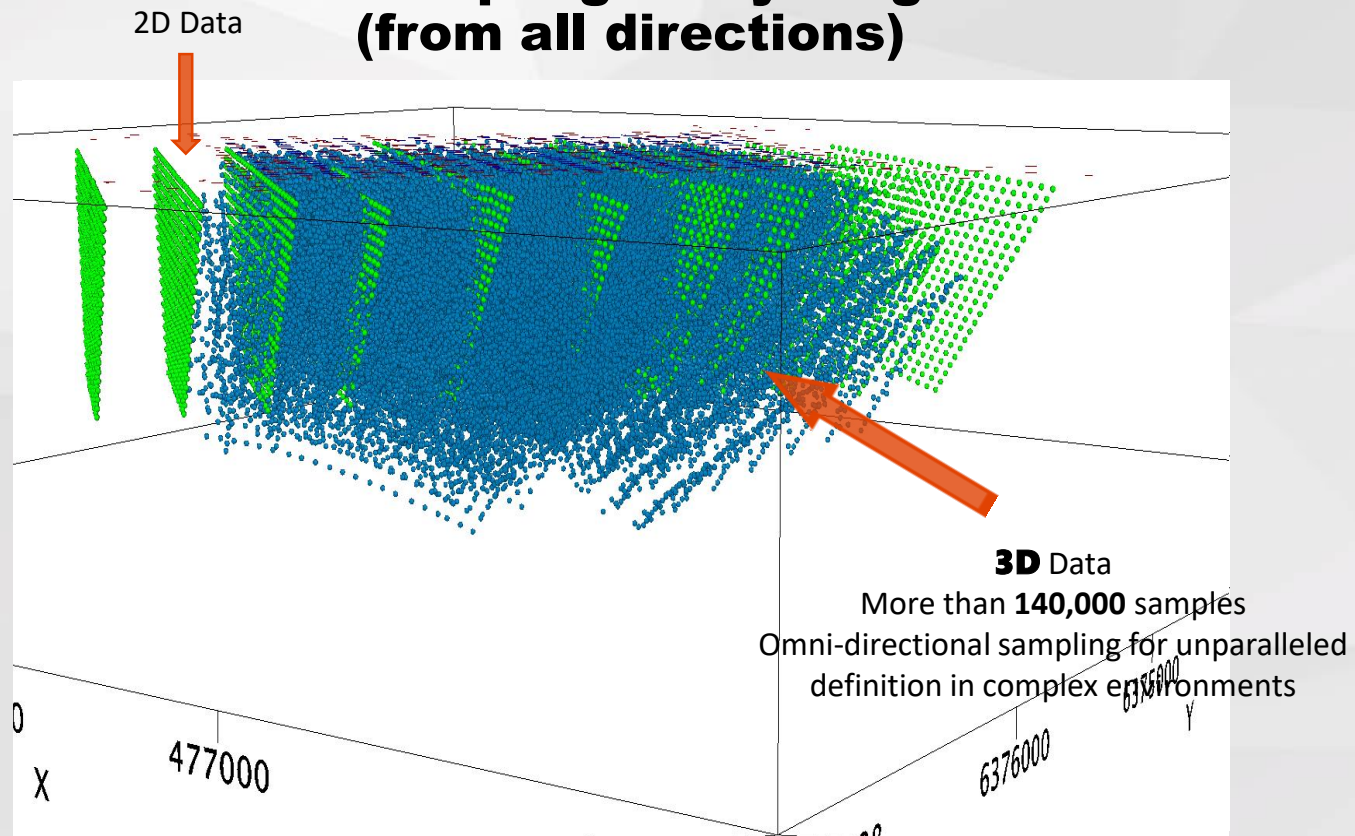
-  Receiver dipole
-  Data recorder
-  Current injection
-  “Conceptual” current path

- True 3D measurement (DCIP)
- Simultaneous receiver sampling
- Omni-directional data free from receiver geometry bias



- ◆ Tx
- Rx
- Data Logger

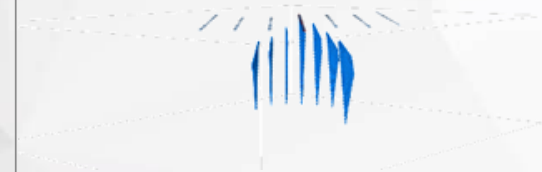
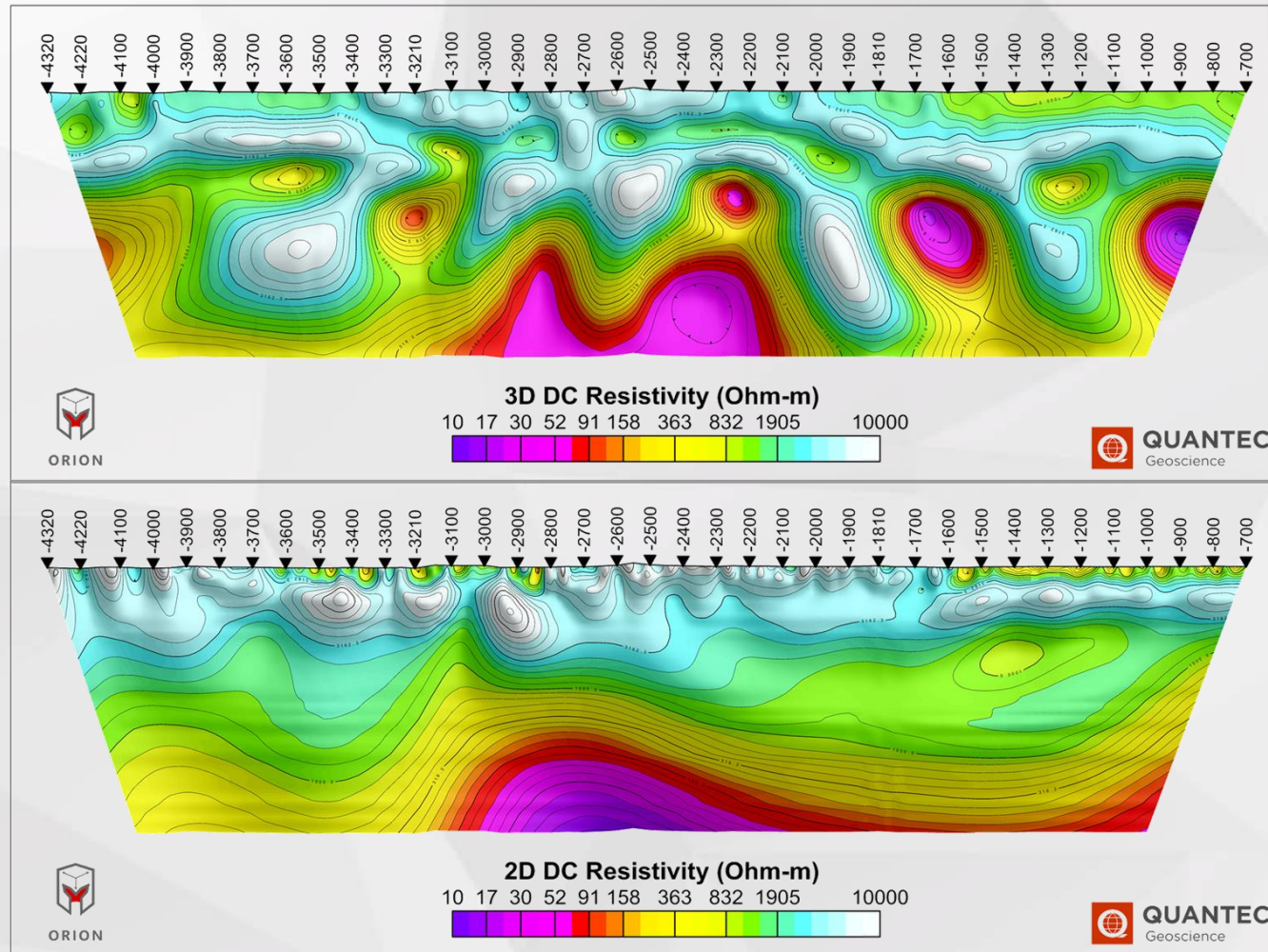
## Sampling everything (from all directions)



## Large Survey footprint (2km x 2km and more)







Resistivity data  
acquisition from  
multiple lines (2D  
slice through a 3D  
inversion)

Resistivity data  
acquisition from 1 line  
(2D Inversion)

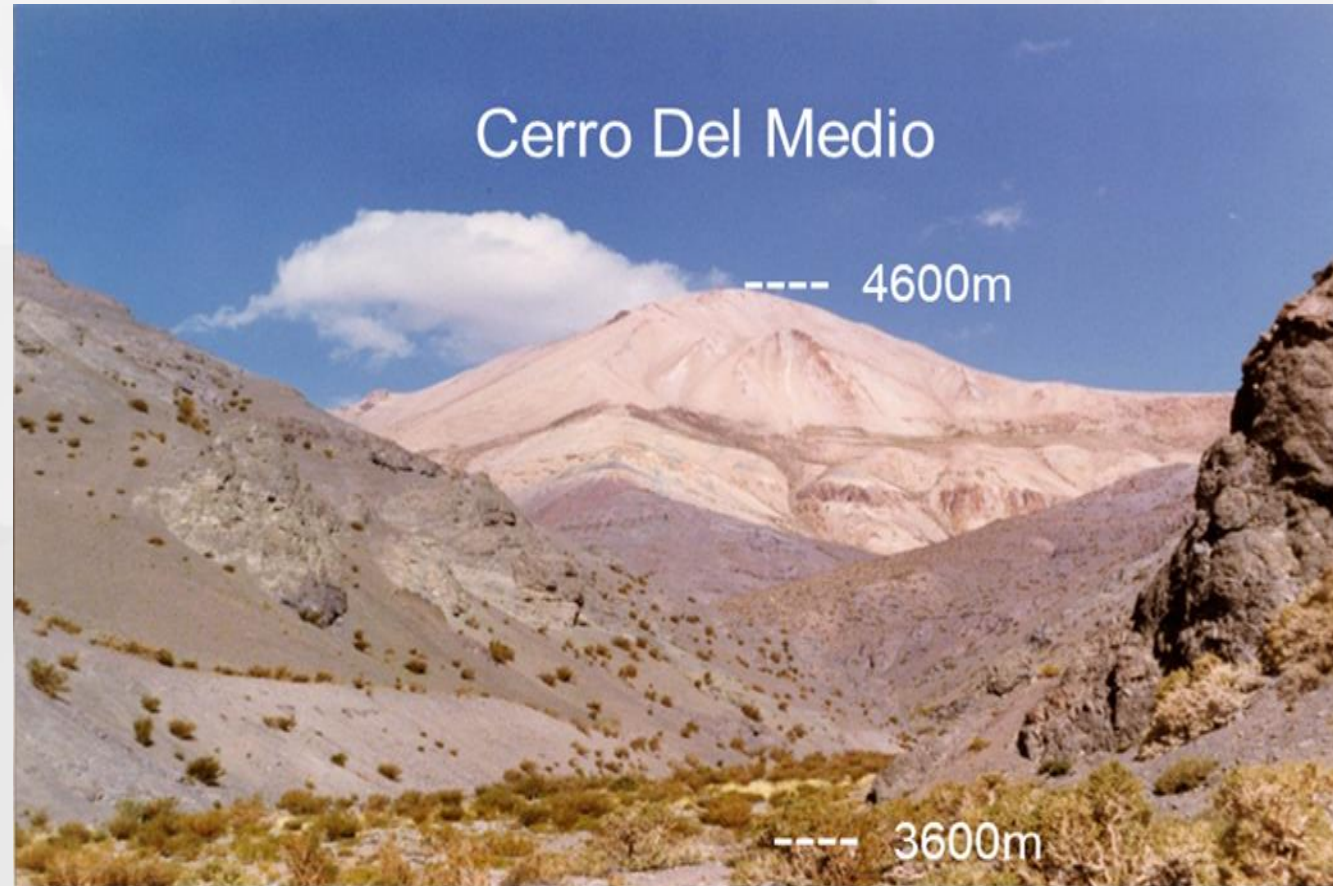


# Recent Exploration Case Examples of Deep Earth Imaging

- ❑ Santa Cecilia, Chile
- ❑ Bolivar Skarn , Mexico
- ❑ Charcas



## **Santa Cecilia, Chile**



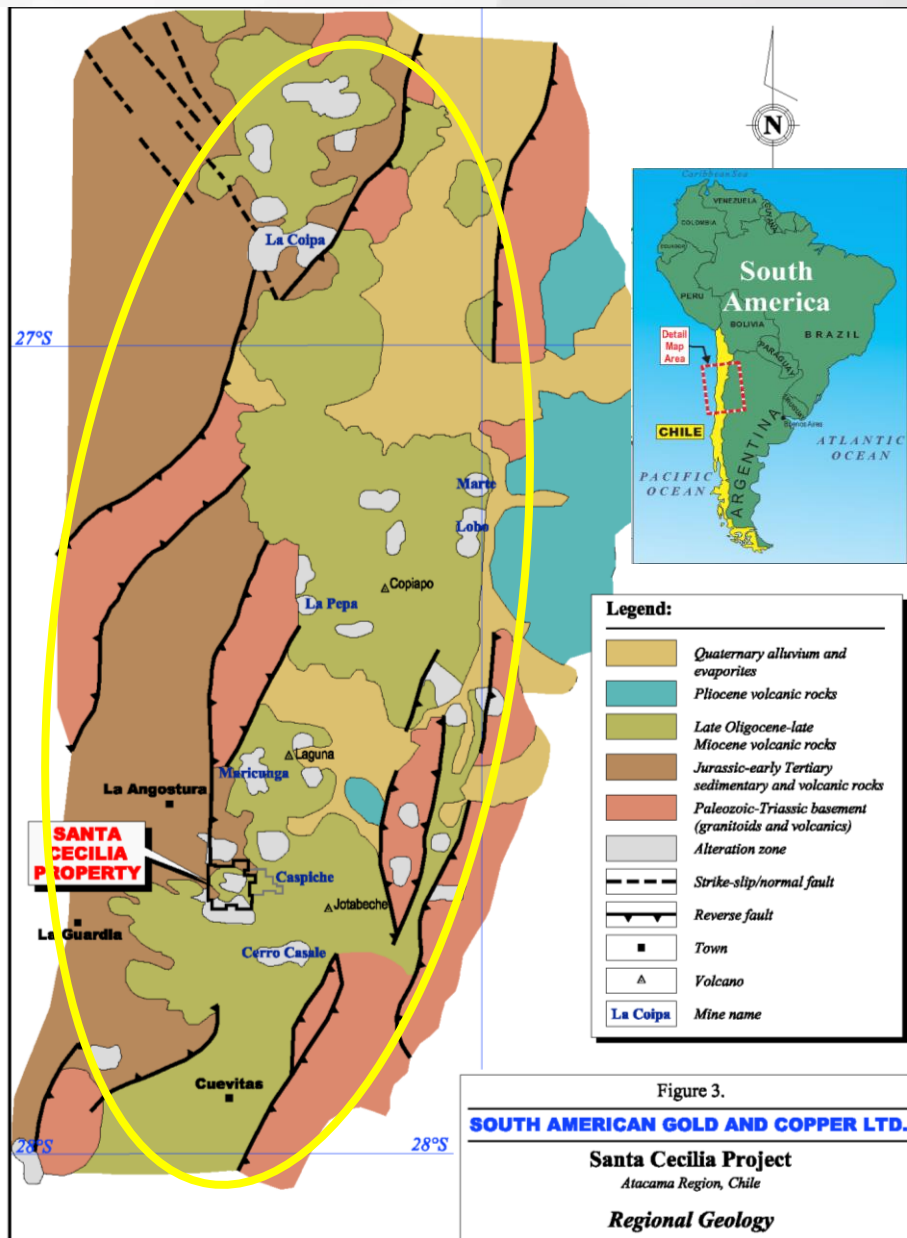


# History

- ❑ 1983- Helicopter-borne reconnaissance by M. Hernandez and D. Thomson
- ❑ 1984-1990- Anglo American Chile
- ❑ 2009- Ground magnetic survey
- ❑ 2010- CSAMT and Mobile Metal Ion (MMI)
- ❑
- ❑ 2011-2012- CSAMT coverage and drilling
- ❑ 2012- QUANTEC ORION 3D DCIP/MT



# Regional Settings



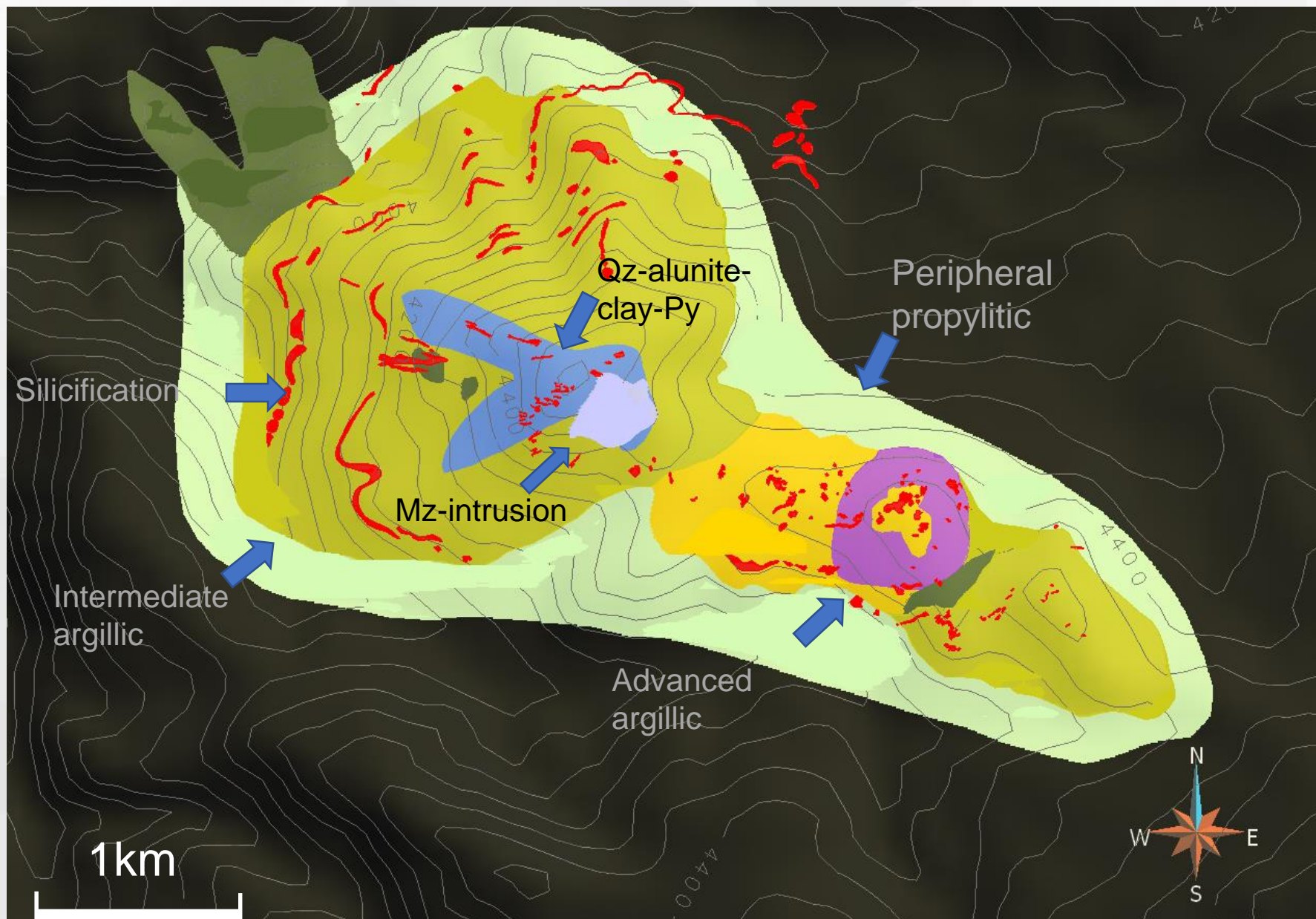
- Maricunga Mining Belt (Mining District)
- Folded Formations of Upper Triassic Caspiche
- Oligocene to Lower Miocene Aguas Blancas and Rio Nevado Formations
- Porphyry intrusives, diorites and Qz-diorites & alteration zones

## Cordillera Belt



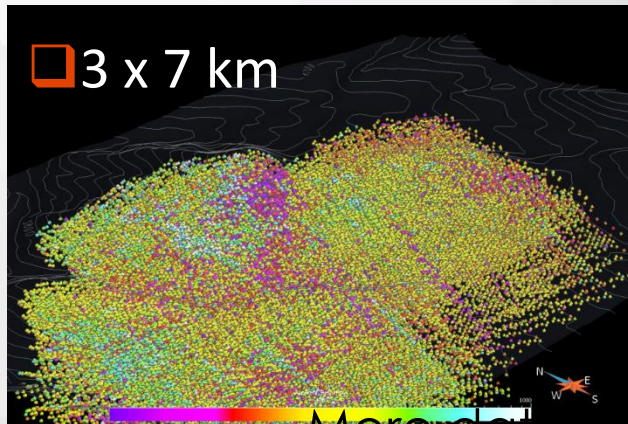


# Intense Hydrothermal Alteration

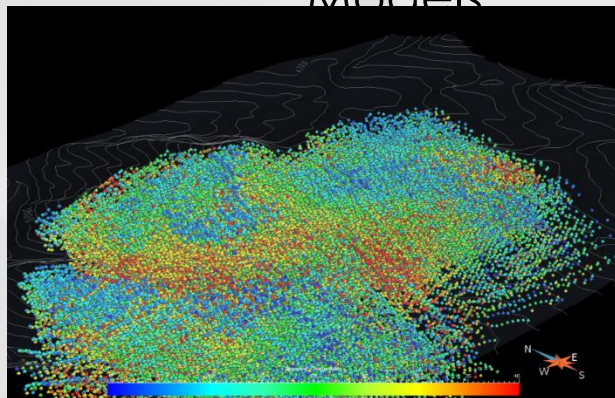




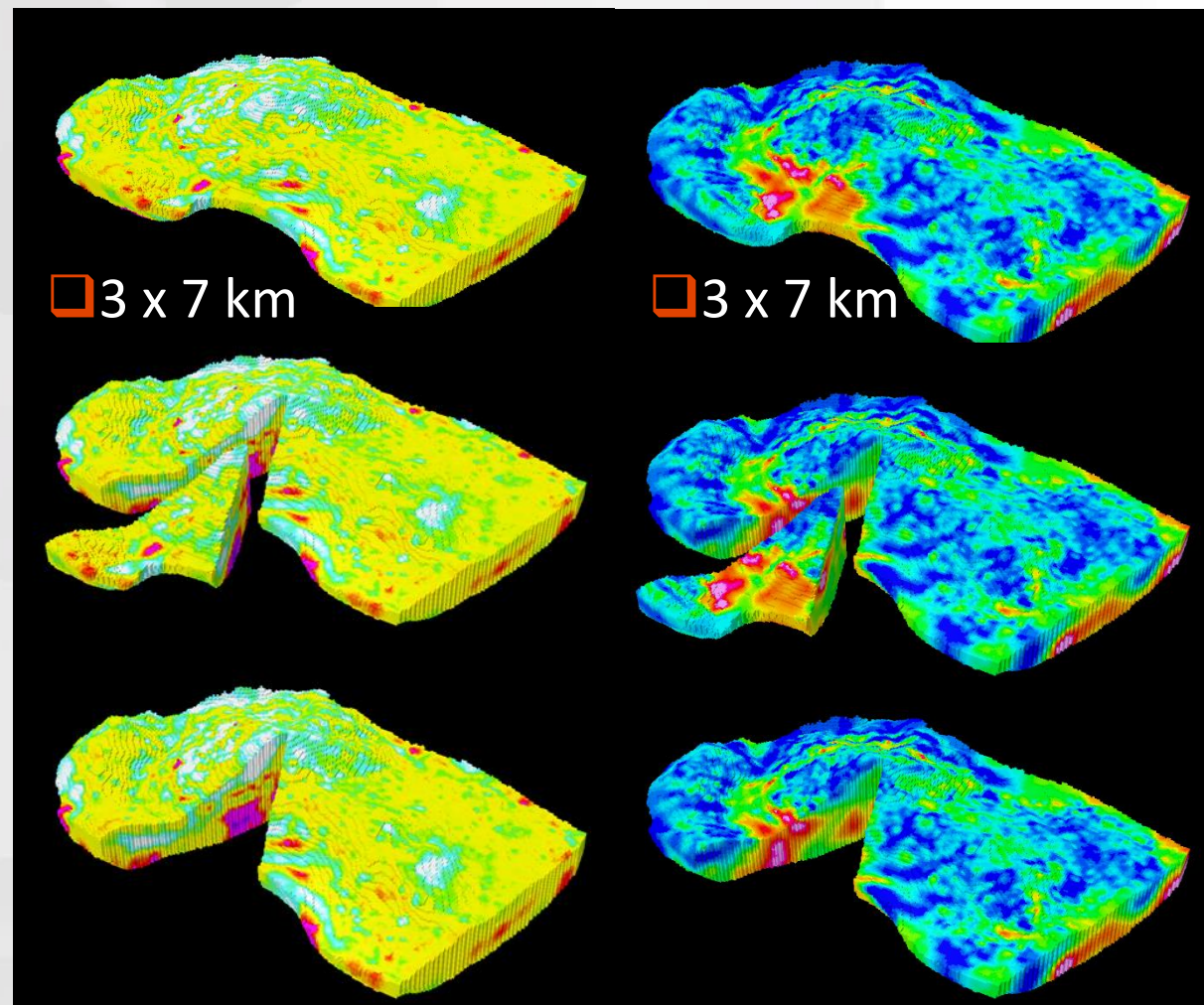
## High volumes of data collected



More data – Accurate Models

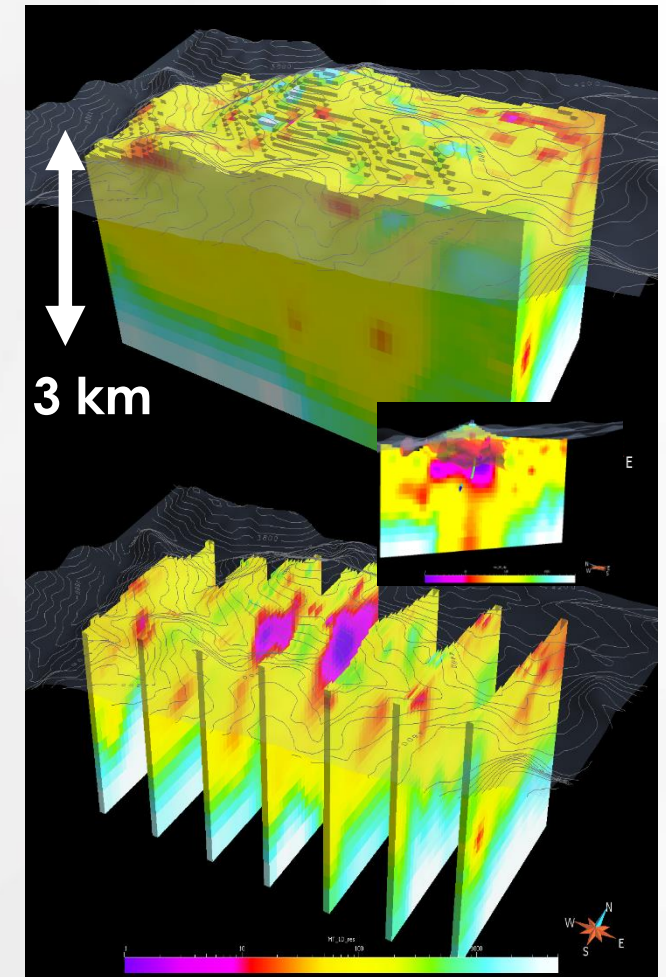
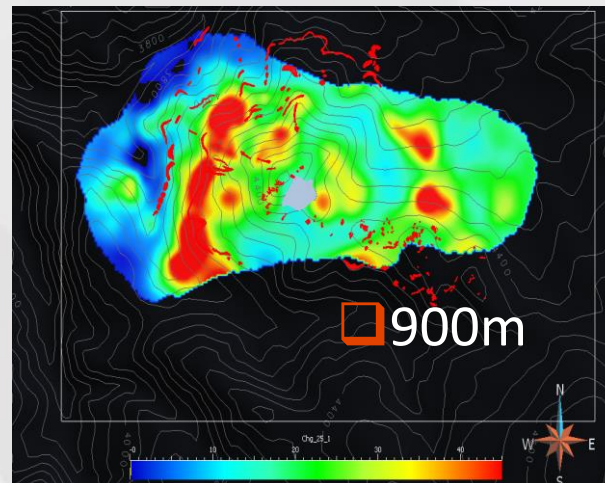
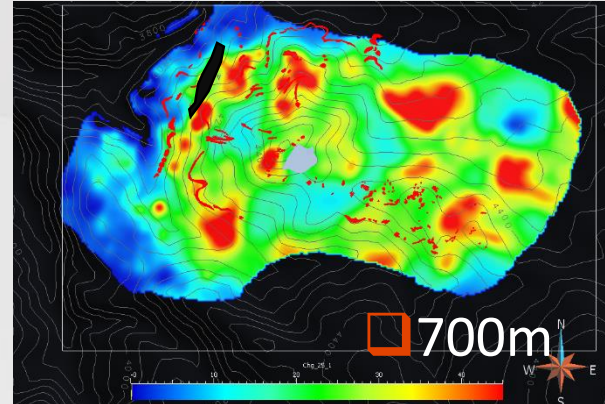


## Broad exploration areas



## Deep IP Information

- ❑ 3D inversions of 3D data
- ❑ Accurate representation of subsurface
- ❑ High resolution



## Deep MT Resistivity





# BOLIVAR PROJECT

## Exploration Objectives

- ☐ Use TITAN 24 DC/IP & MT to help delineate the Bolivar deposit for drill targeting.
- ☐ Map and delineate near-surface zones associated with Skarn mineralization.
- ☐ Map and delineate deep-seated alteration zones that could control or host mineralization.
- ☐ Focus drilling thereby reducing overall drilling costs.
- ☐ Mine Planning



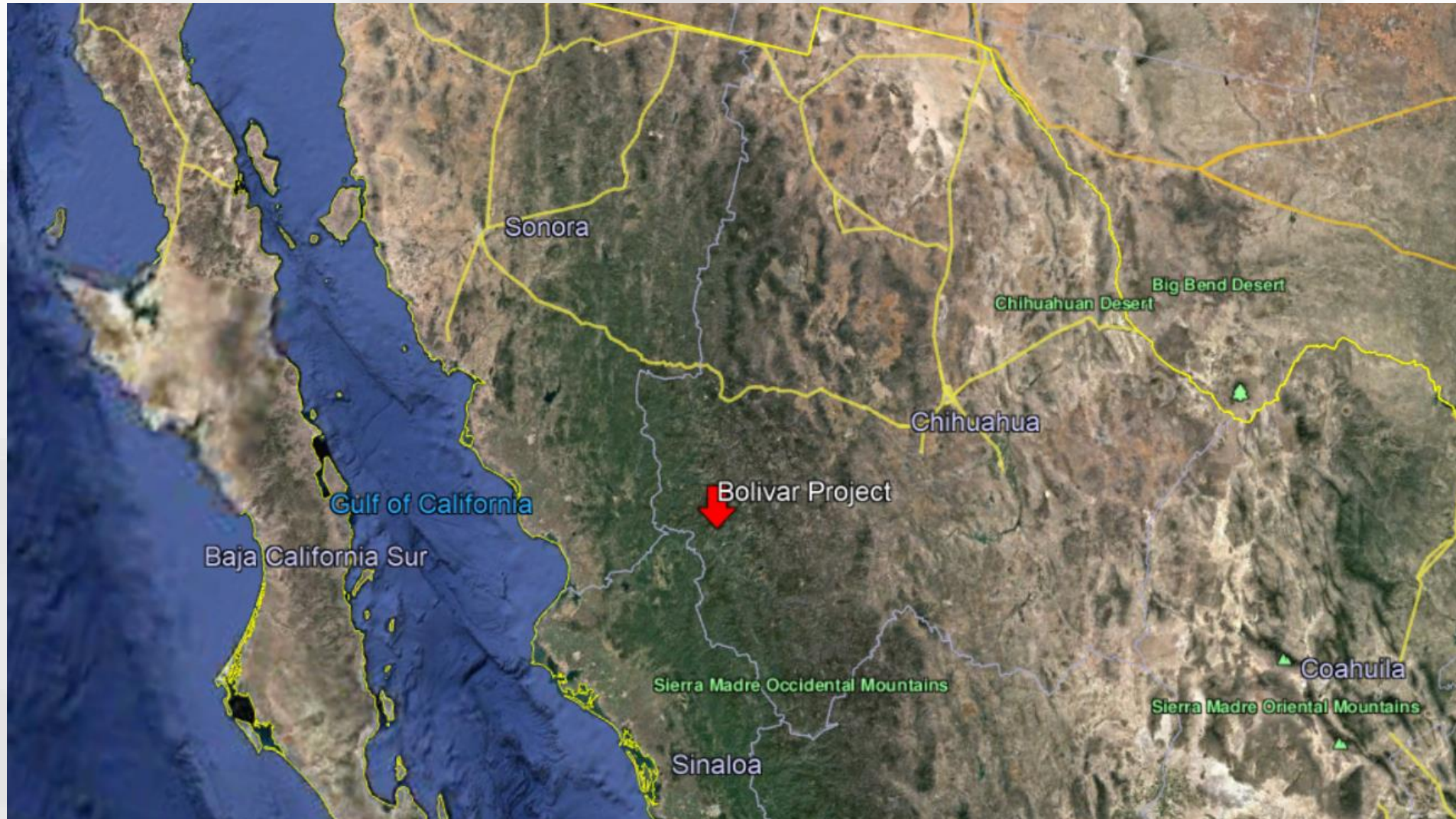
# Exploration History

- ❑ Small-scale mining was conducted during the Spanish Colonial days
- ❑ An estimated 300,000 tonnes of mineralized material was reportedly mined from 1998 to 2000, while the Bolívar Mine was under the control of Bencomo Family
- ❑ Minera Frisco conducted a mapping and exploratory drilling program from 1968 to 1970
- ❑ Between 2003 and 2012, Dia Bras carried out an exploration program and the results have shown presence a polymetallic skarn mineralization within the Bolívar
- ❑ **In 2010 was conducted the first Titan24 DC-IP Survey**
- ❑ In 2014, underground drilling expanded the copper-gold-silver mineralization
- ❑ **In 2017 was conducted the second Titan24 Survey , but this time include MT (Titan24 DC-IP/MT)**
- ❑ In 2017 – 2018 drilling expanded the copper-gold-silver mineralization. New discovery

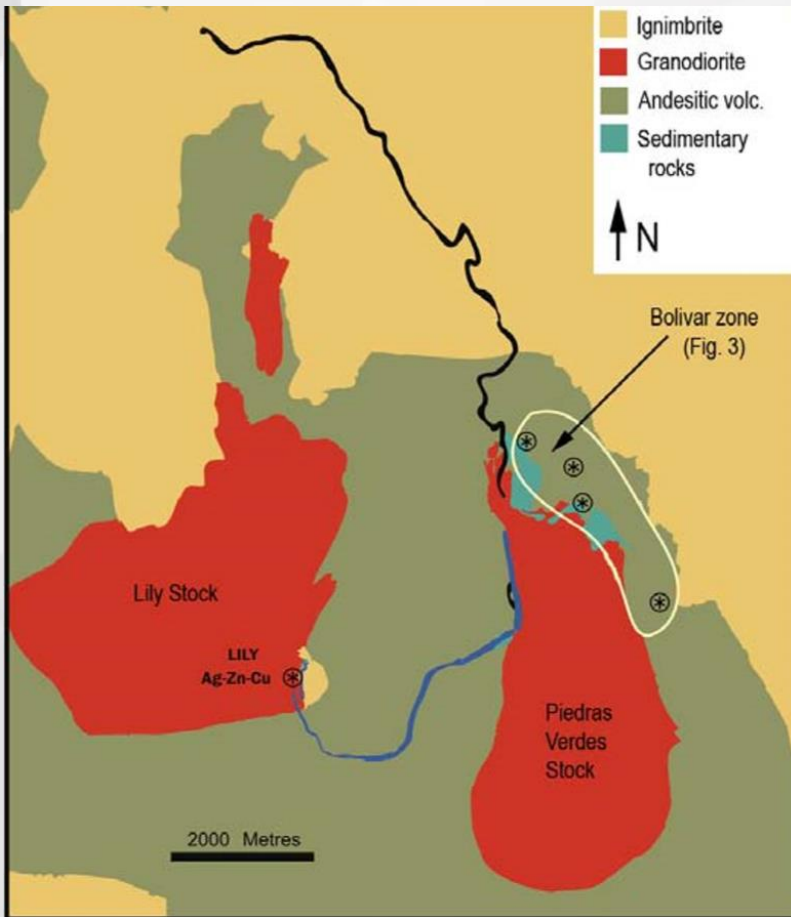




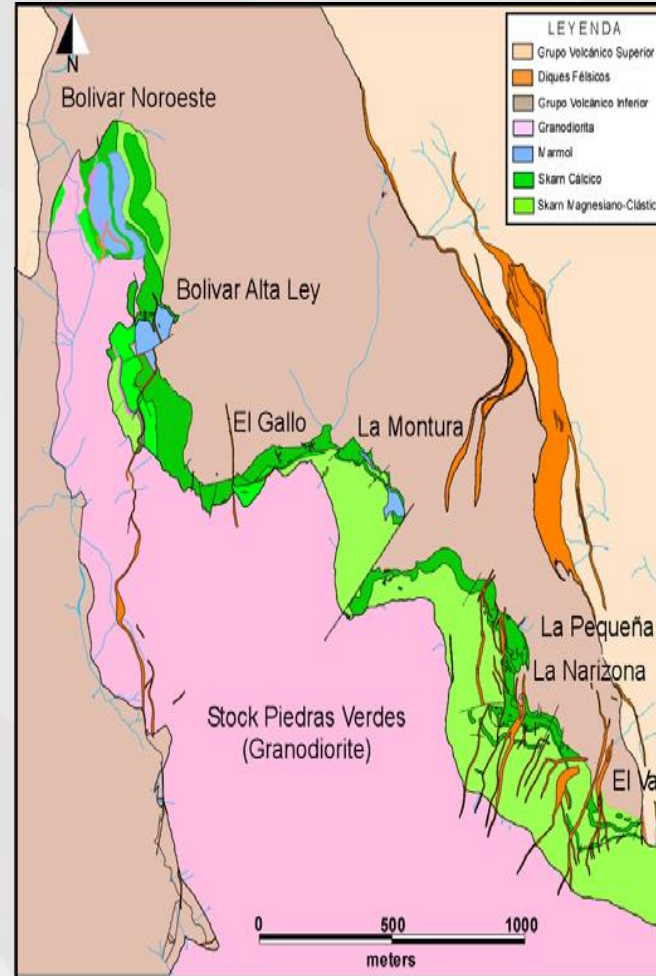
# Location



# Geologic Setting



Regional Geologic setting of the Bolivar district



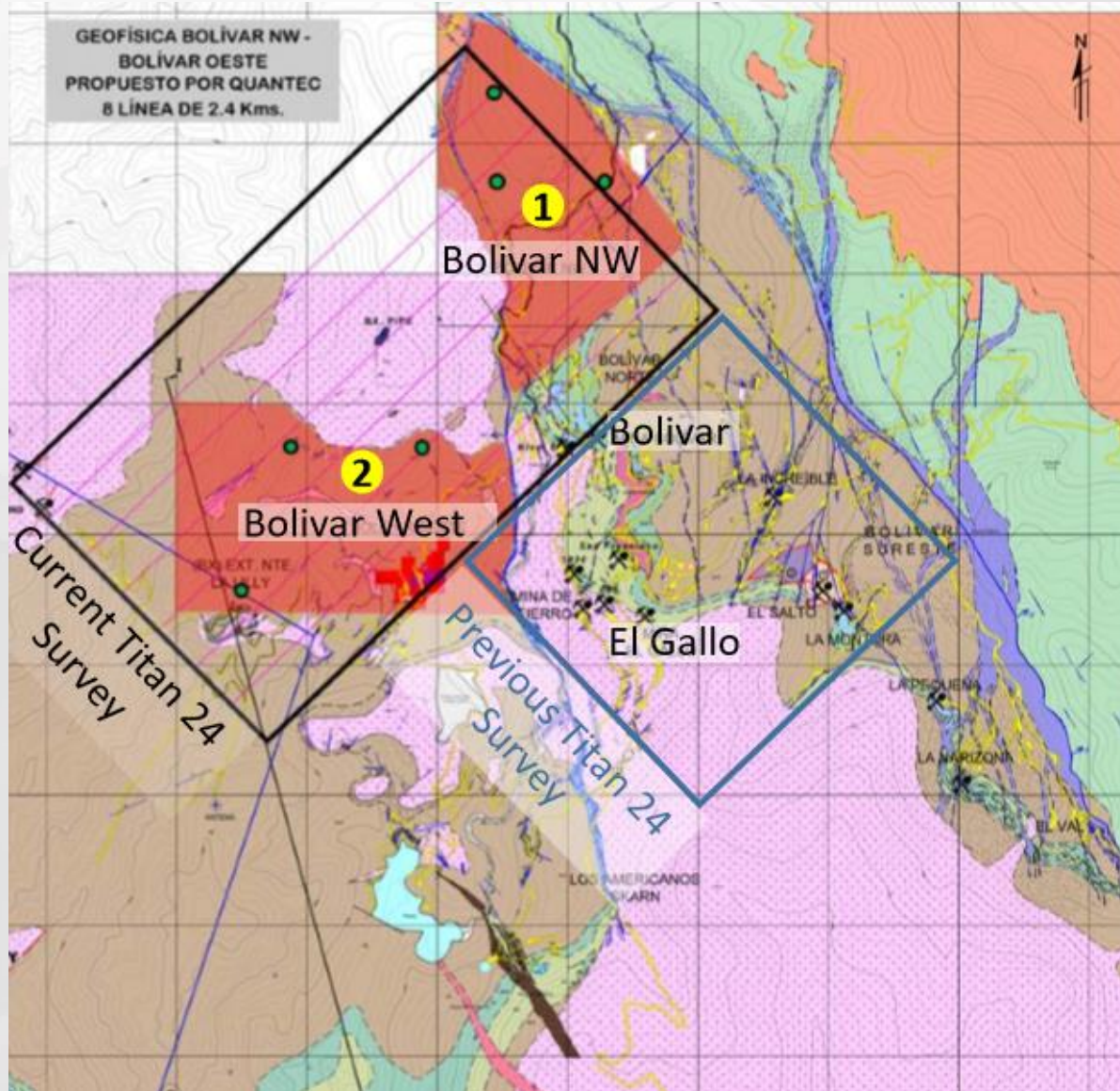
Local Geologic setting of the Bolivar district

- ❑ Guerrero composite terrane, western Mexico
- ❑ Consists of submarine and lesser subaerial volcanic and sedimentary sequences ranging from Upper Jurassic to middle Upper Cretaceous in age. Urique Group
- ❑ The Bolivar deposit is one of many precious and base metal occurrences in the Sierra Madre precious metals belt.





## Bolivar mineralization



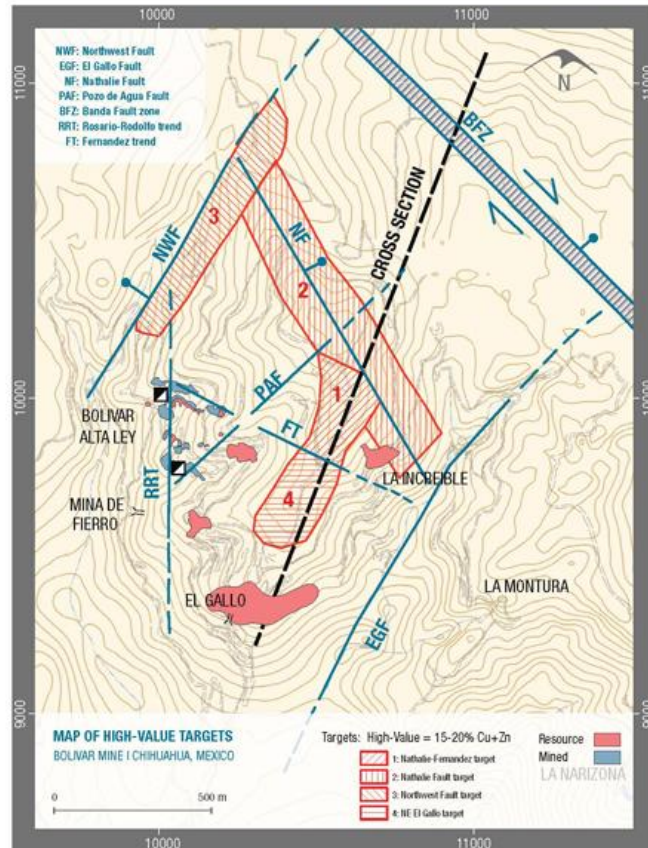
- ☐ Skarn alteration and mineralization
- ☐ hosted primarily in Late Cretaceous – Early Cenozoic sedimentary and volcanic rocks
- ☐ Skarn-type Cu-Zn-Ag-Au mineralization in the Bolivar area is structurally controlled and forms mineralized zones that are close to structures
- ☐ The mineralization is generally flat-lying mantos replacement or skarn with a high sulphide component.
- ☐ Chimneys and feeders are the exception and have a steeper dip



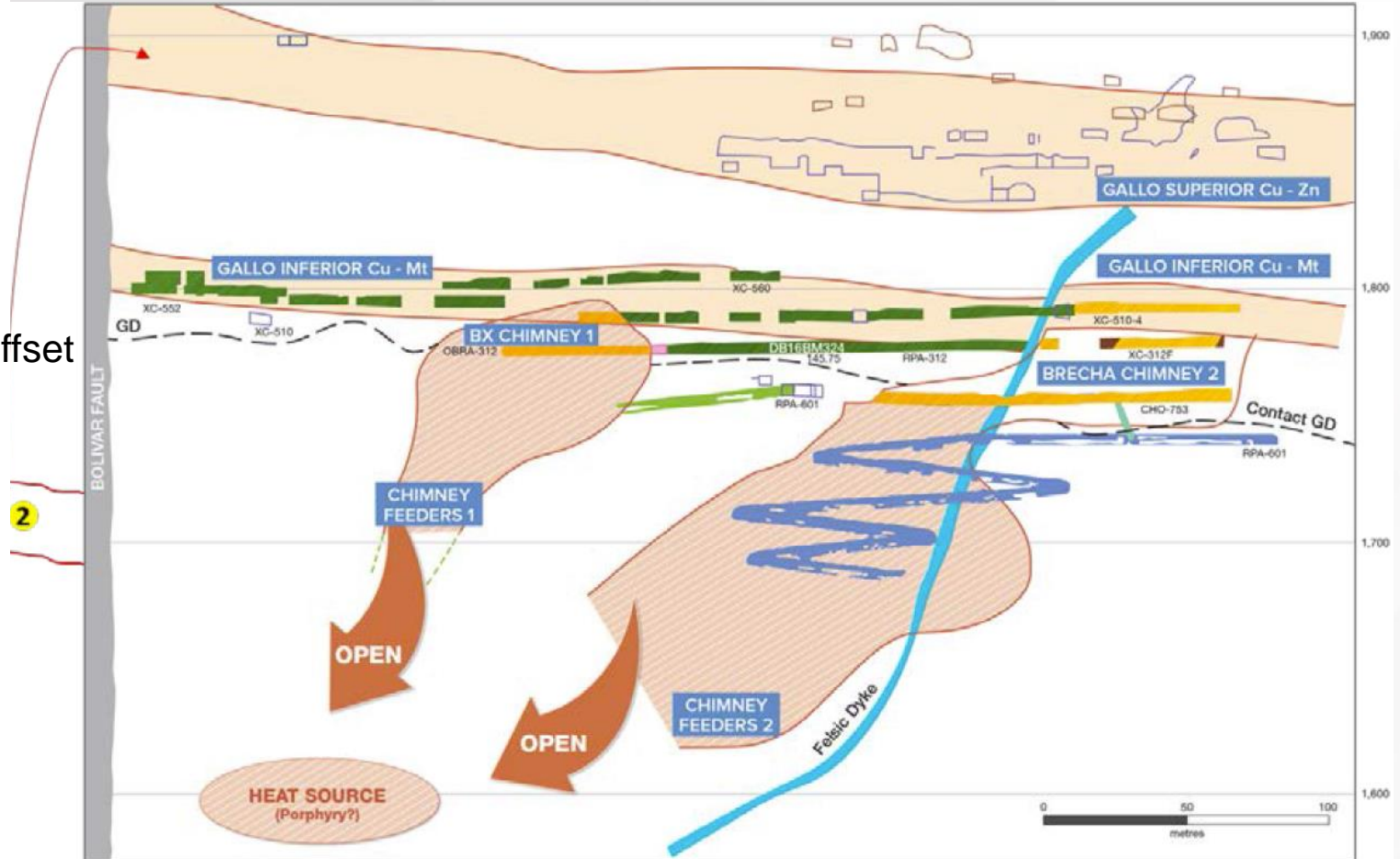


# Target Map

Bolivar Mine High-Priority Target Map

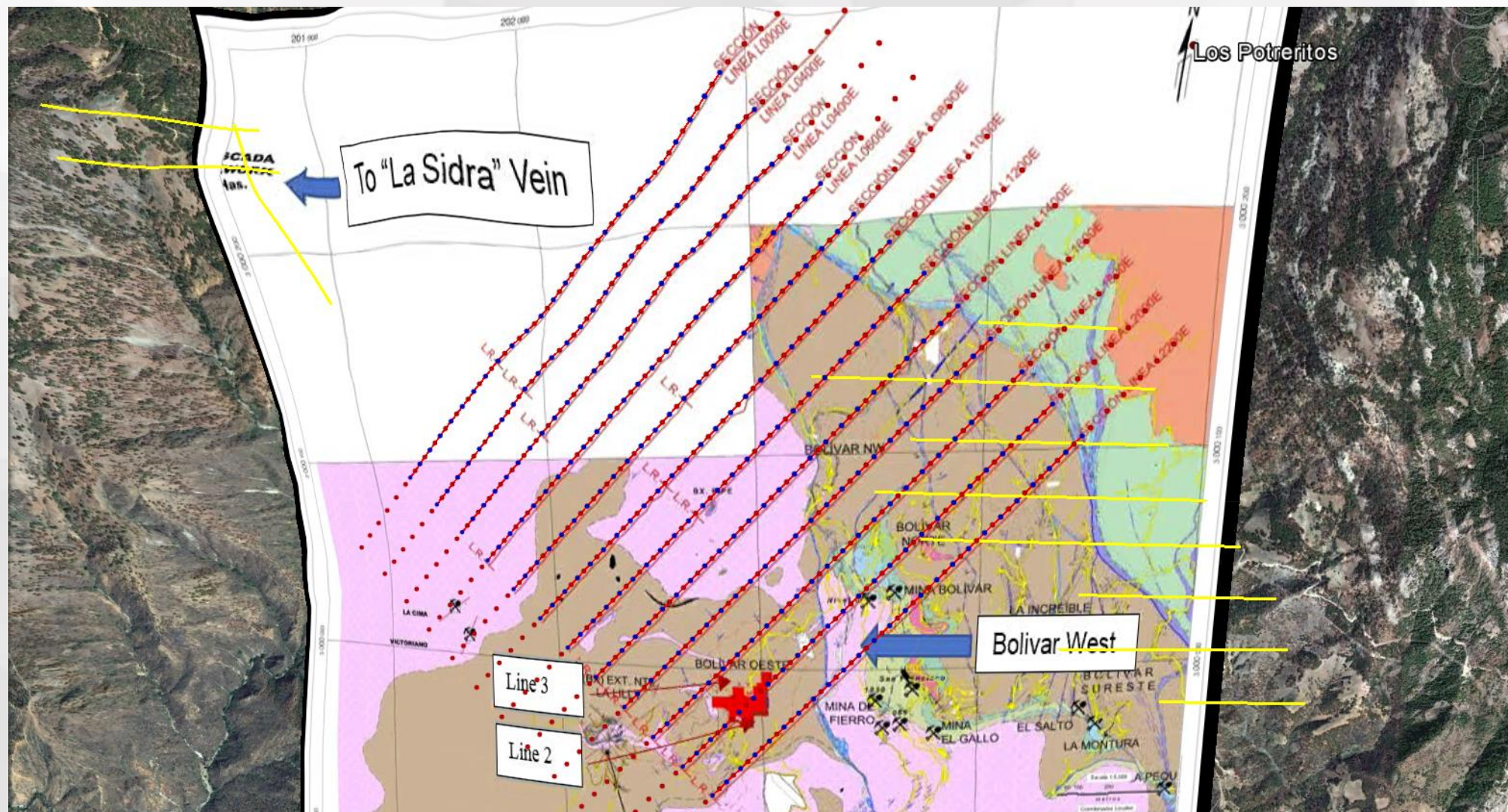


offset





# Titan 24 surveys

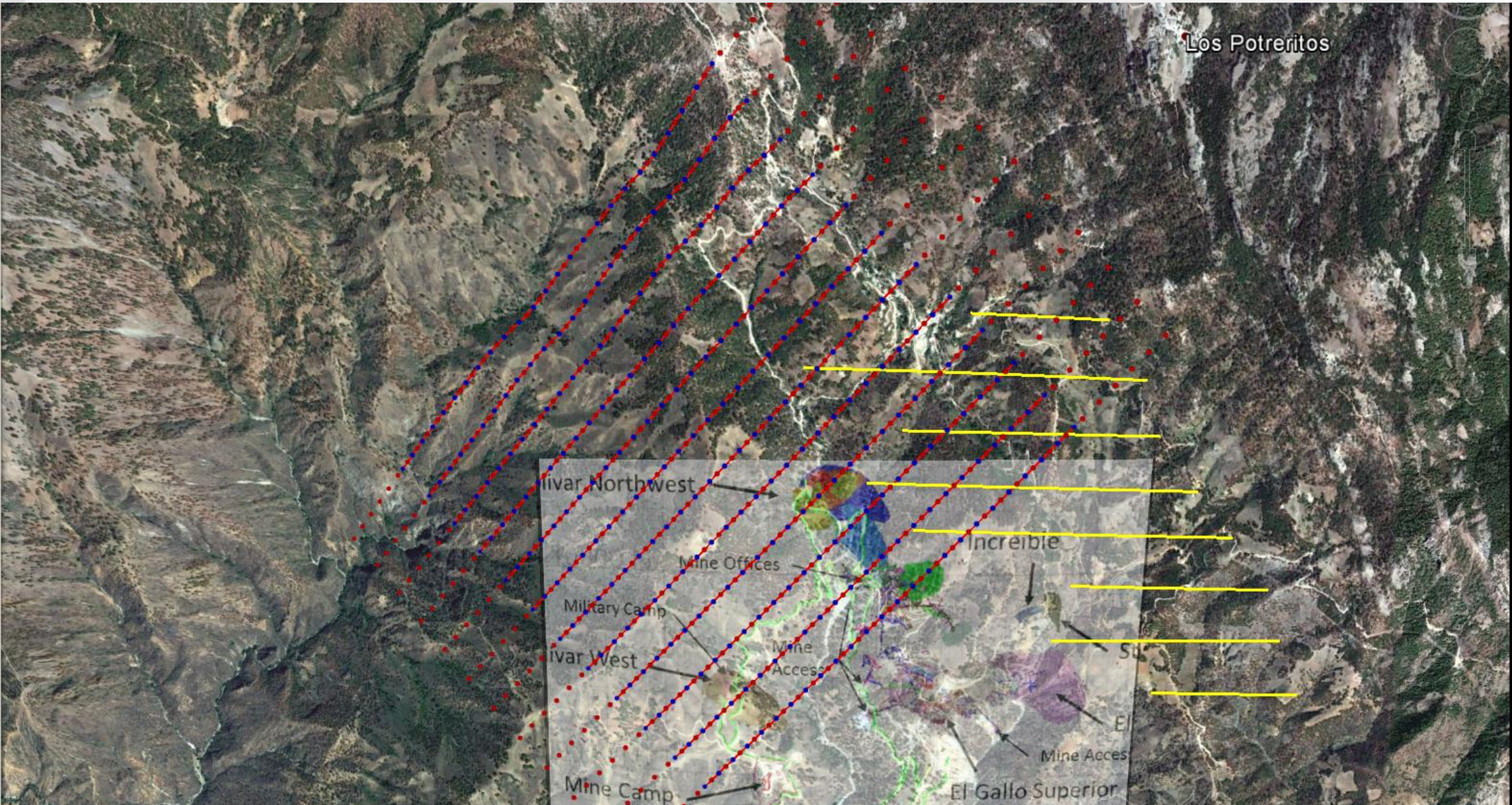


2010 DCIP-only shown in yellow





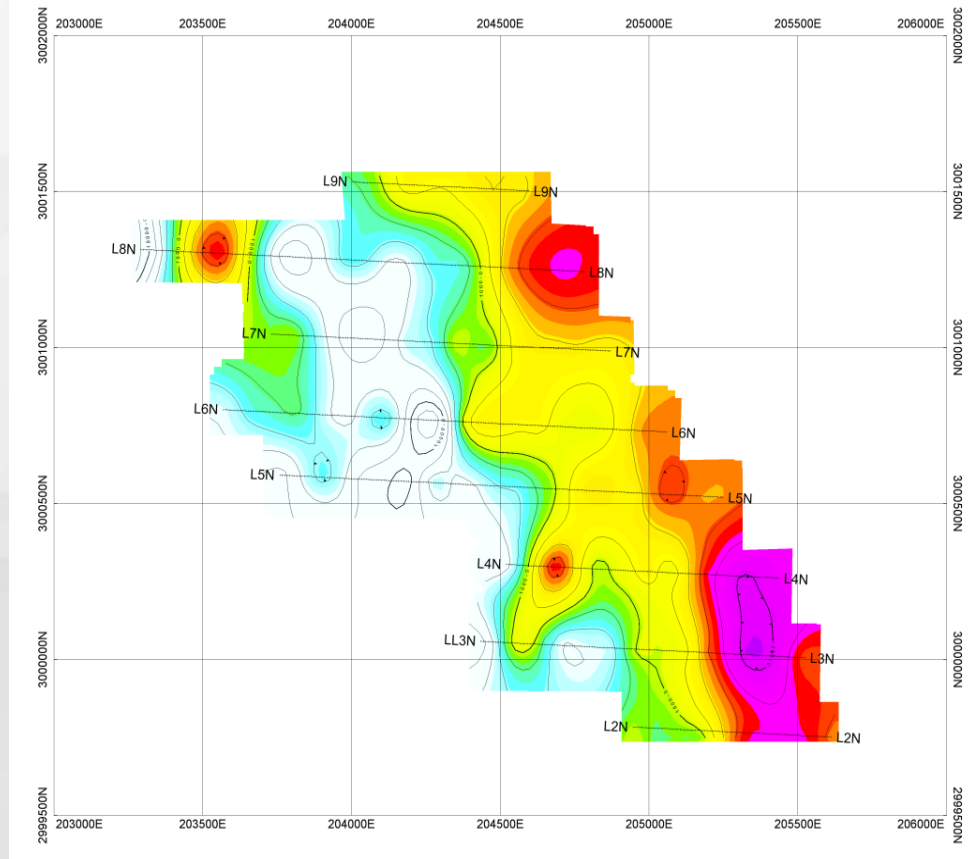
# 2017 re-orient the survey grid and add the MT



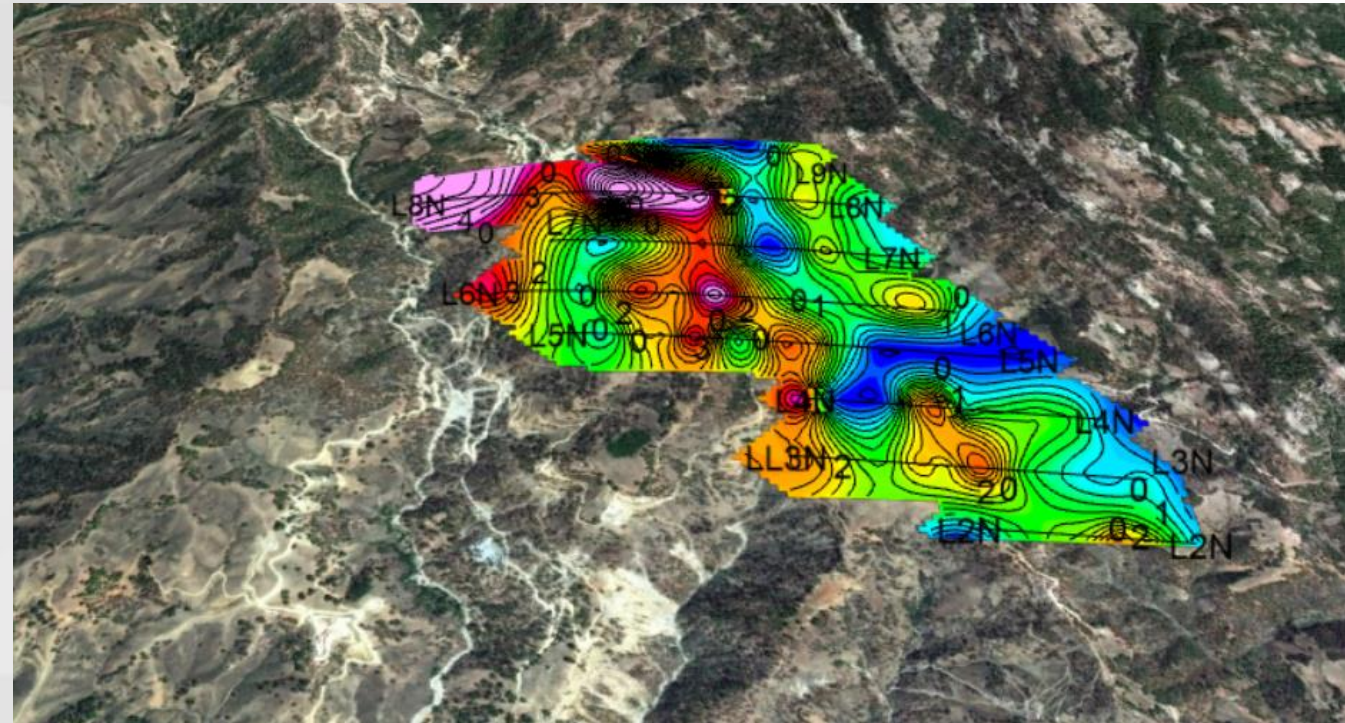


# 2010 Titan24 DC-IP Survey Results

## 2D DC (200 m) INVERSION



## 2D IP (200 m) INVERSION

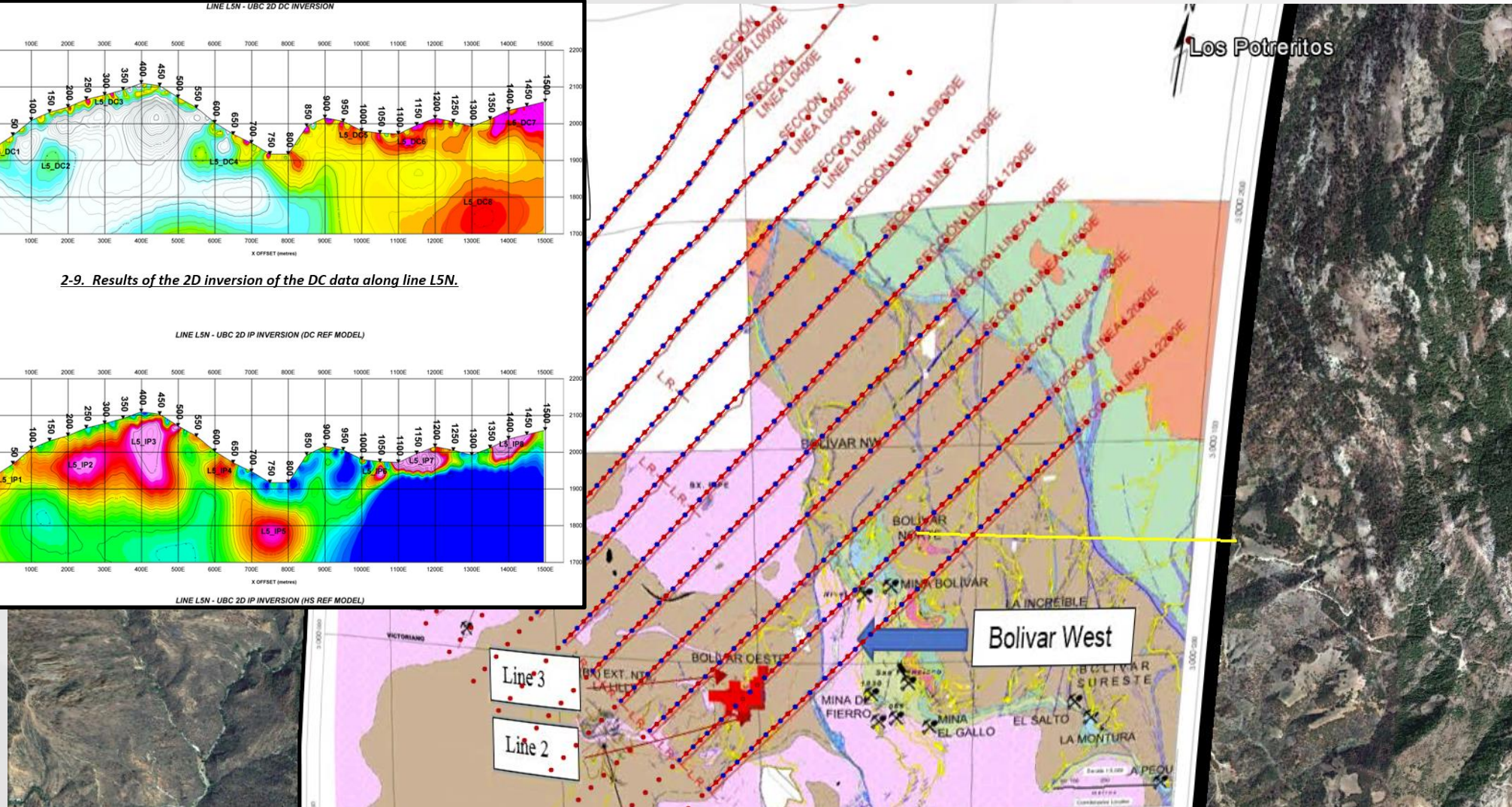
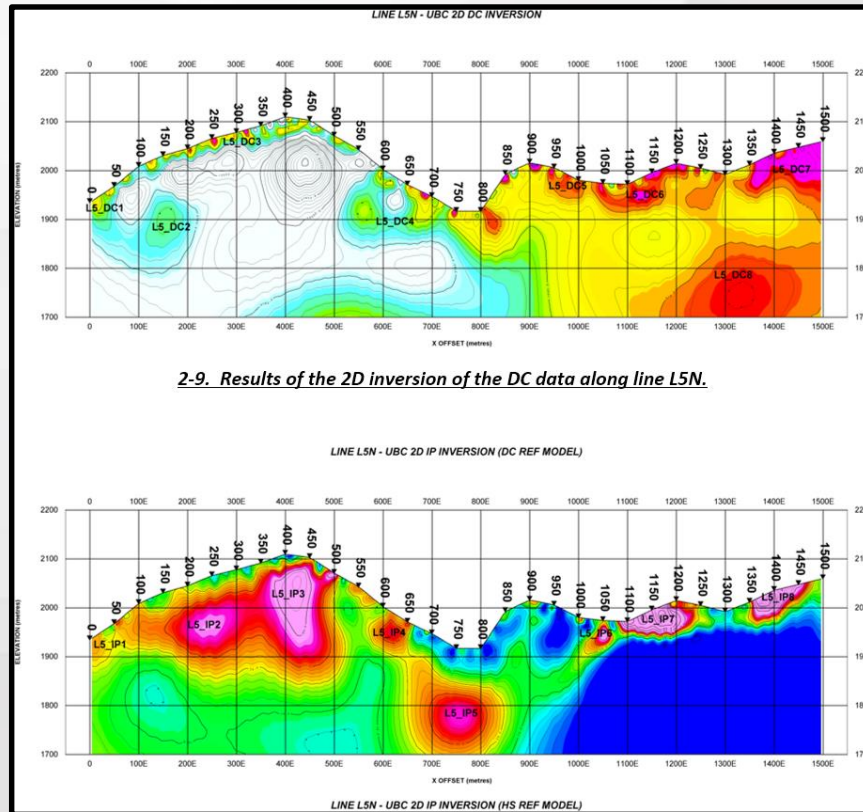


A total of 39 potential targets with different priority levels have been identified by the Titan 24 2D DCIP survey conducted in 2010





# 2010 L5; Resistivity maps the Geology

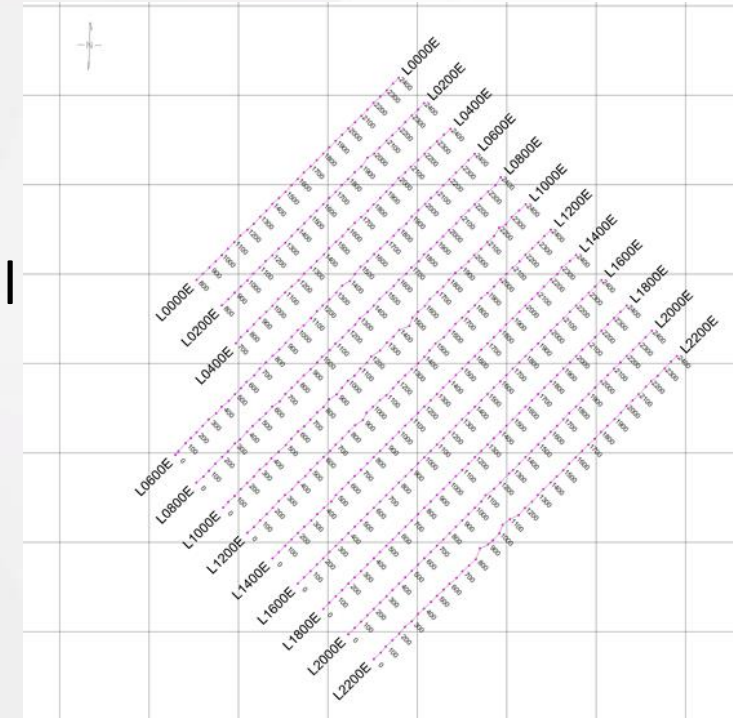


IP shows strong association to mineralization

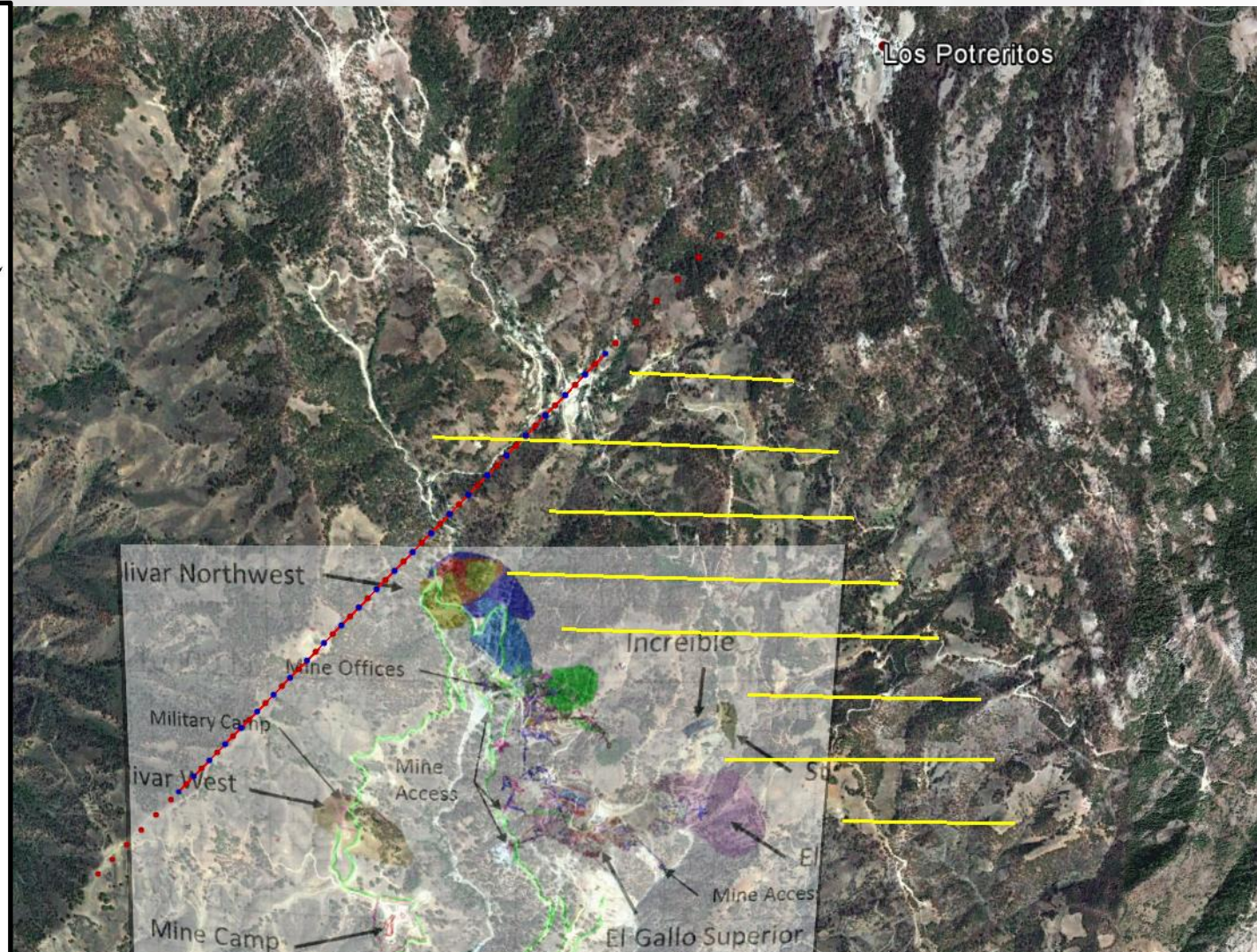
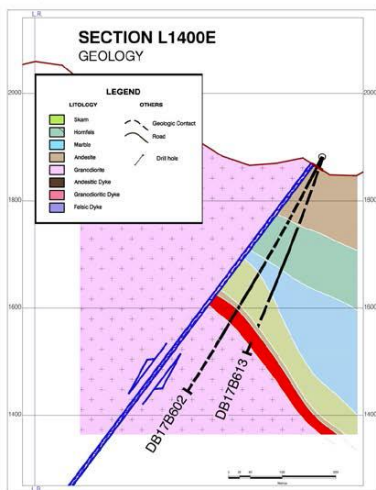
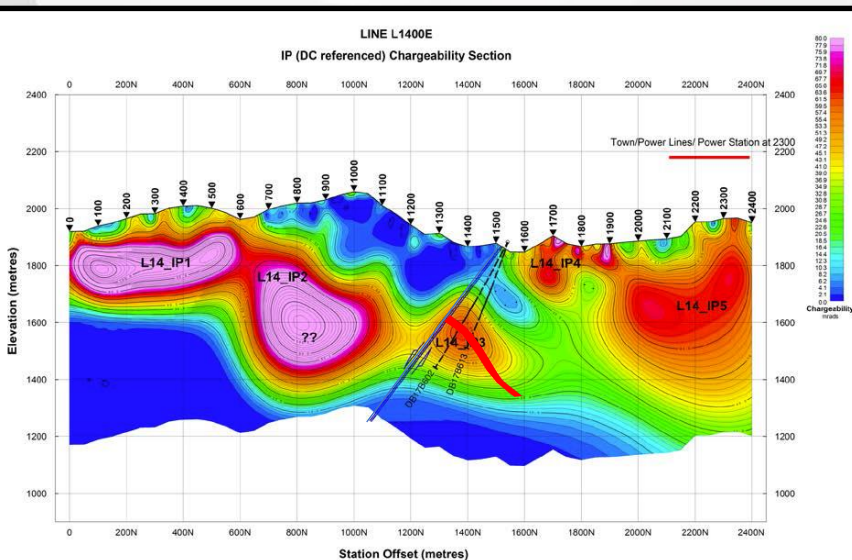


## 2017 Titan 24 deployment

- ❑ A Titan 24 geophysical survey was carried out to assist in mapping the extent of mantos replacement and structures containing copper and copper / zinc skarn mineralization
- ❑ In 2017, the survey was re-oriented and MT was added for drill targeting in the immediate vicinity of the Bolivar mine.
- ❑ The Bolivar survey grid consisted of a total of 12 lines which were 26.5 km in length.
- ❑ Each line had a 100 m dipole spacing and was located 200 m from the line adjacent.
- ❑ The survey covers an area of approximately 2.4 km by 2.2 km.
- ❑ The Titan 24 geophysical survey was planned and integrated with several phases and scales of geological mapping including
  - ❖ 25,000 scale regional geology and stream sediment sampling,
  - ❖ 1,000 scale geological mapping chip sampling and
  - ❖ 250 scale geological mapping and panel sampling.





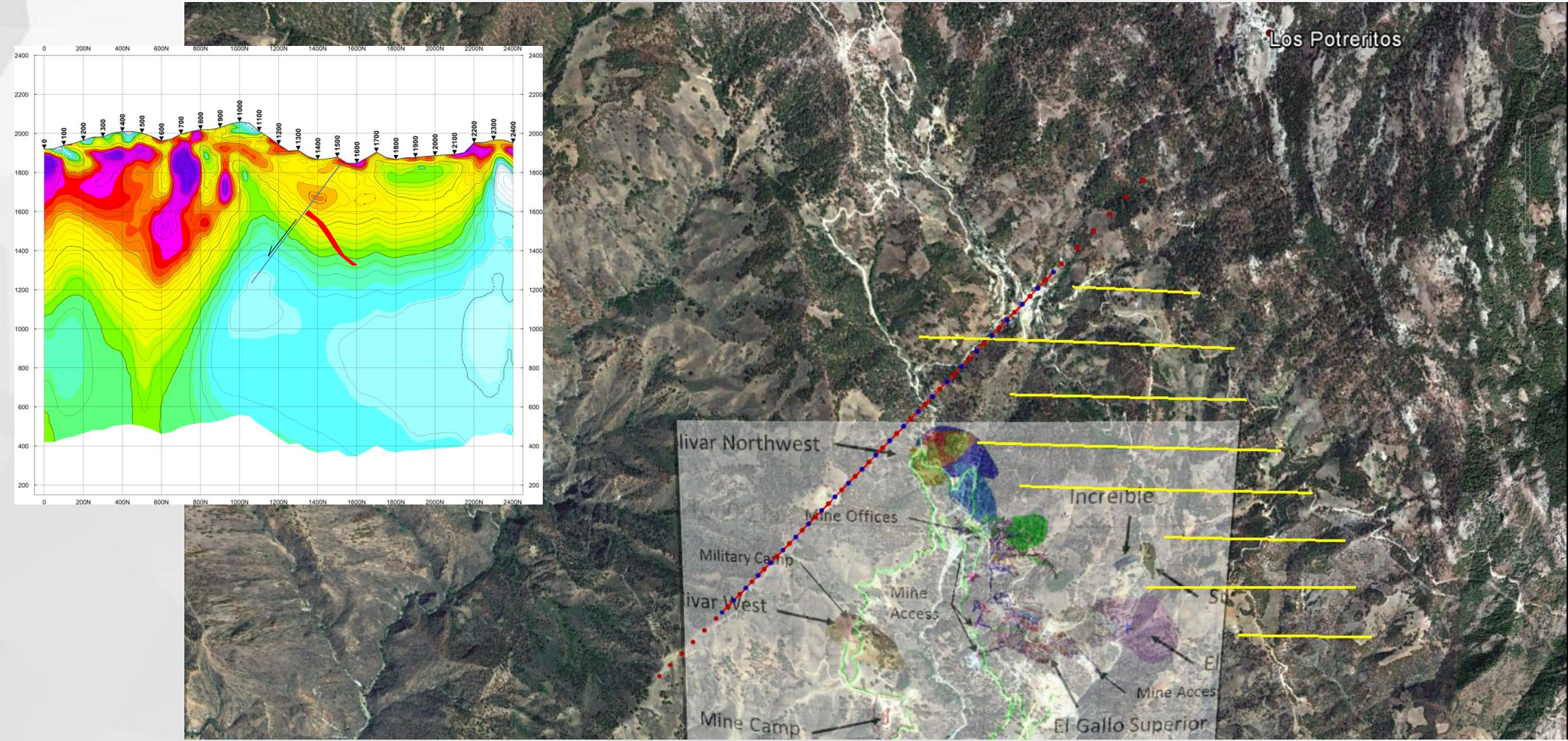


Lines 1400. Note structural changes (dip and faults)





# 2017 Bolivar North-west MT resistivity

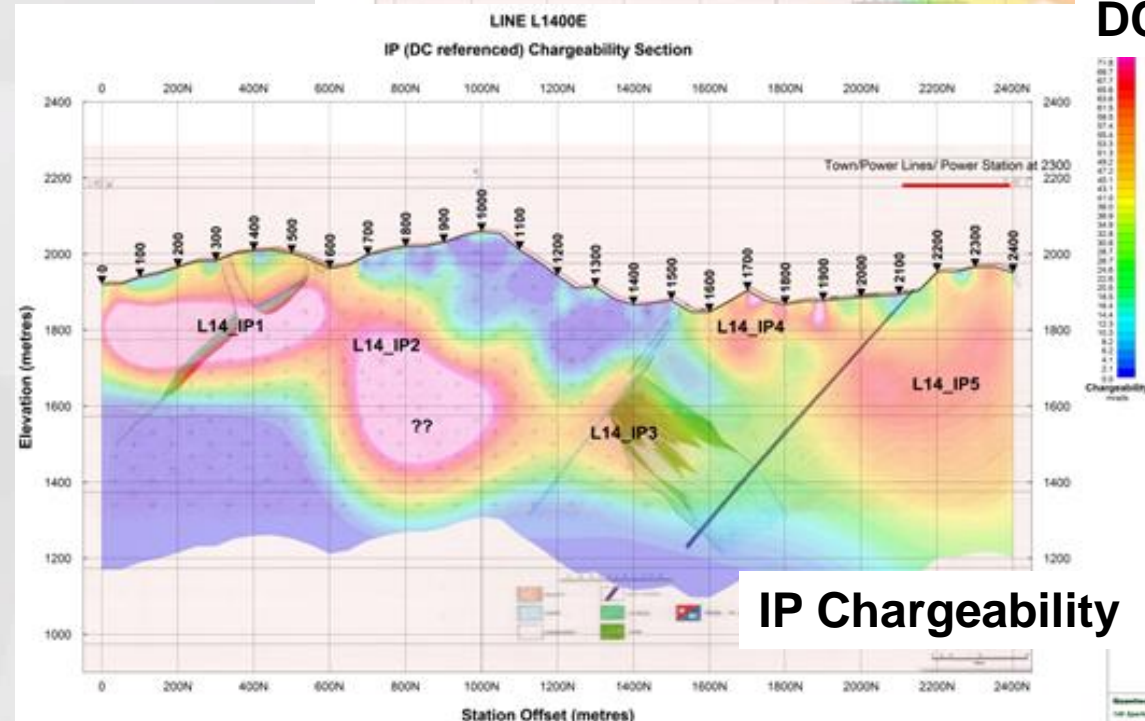
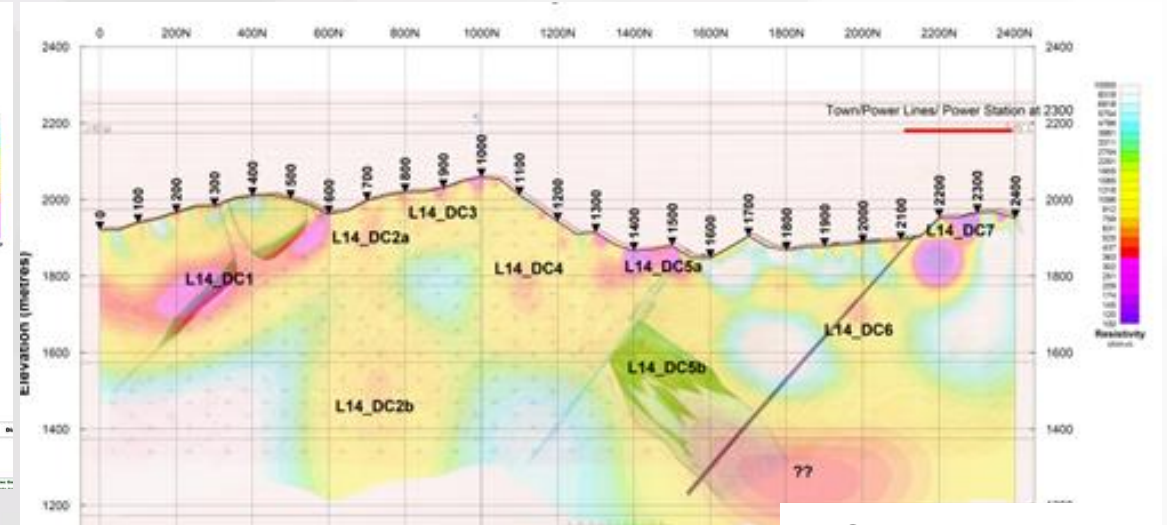
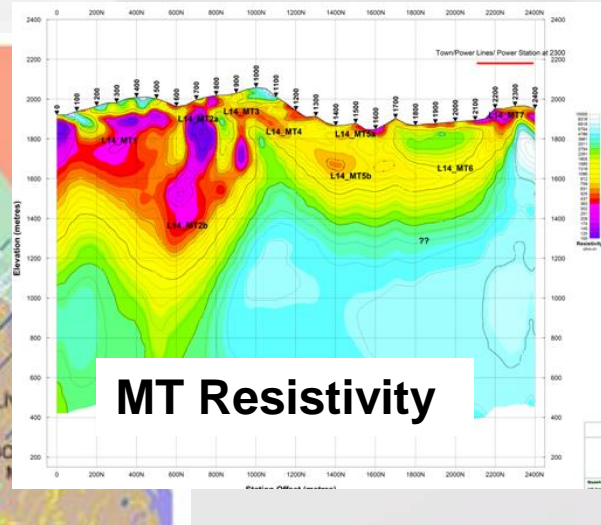
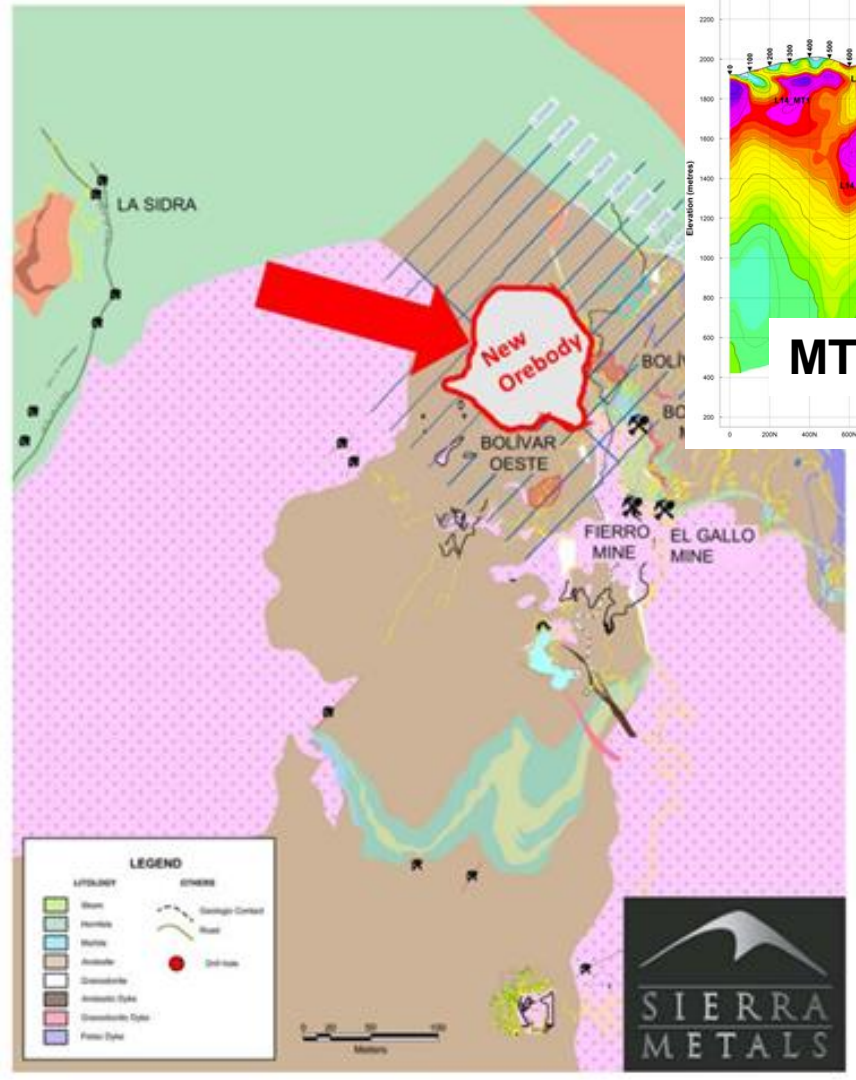


Lines 1400. Note deep correlation with the structure and dip of mineralization





# 2017 Bolivar North-west . Lines 1400

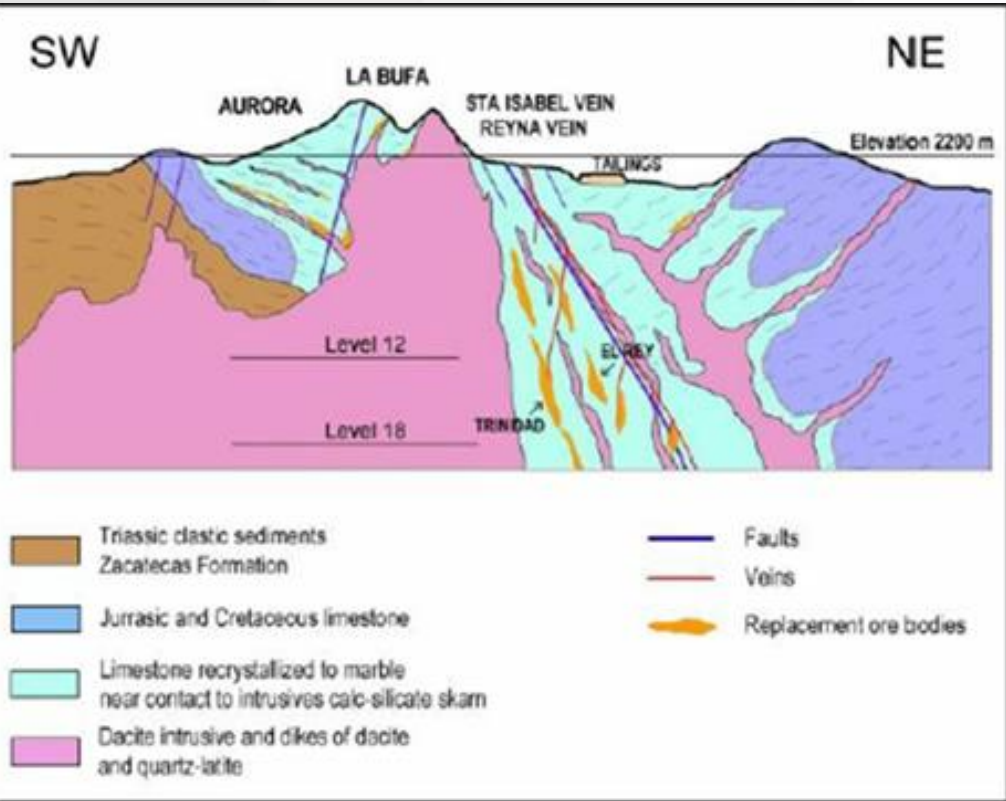




## Bolivar Summary

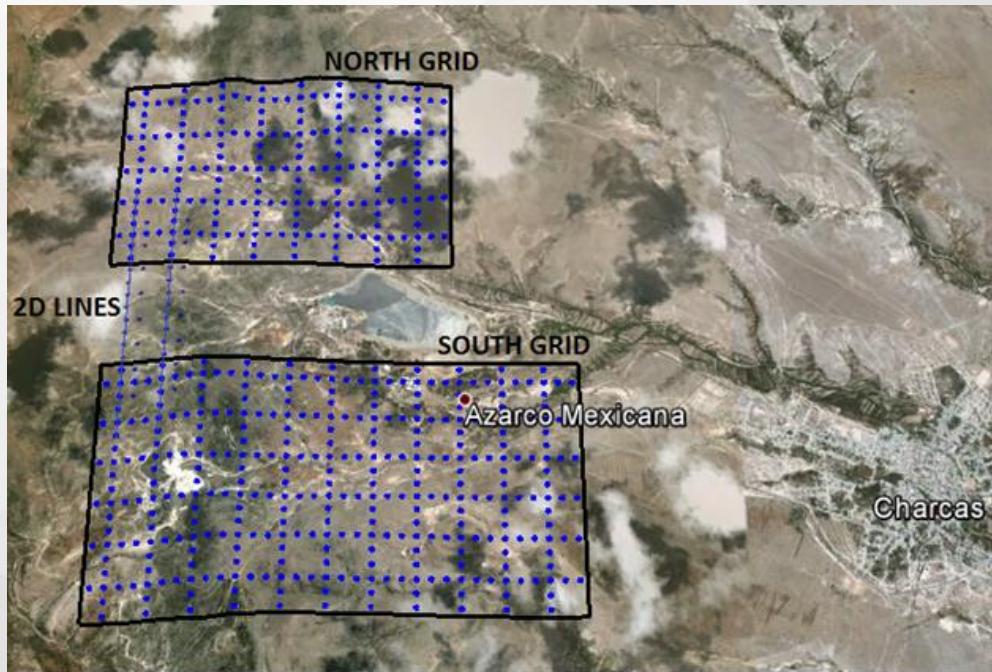
- ❑ Accurate delineation of alteration and mineralization (up to 400) with the TITAN 24 DCIP/MT
- ❑ Accurate Surveying in high noise environments (Bolivar Mine, active mining operations)
- ❑ Subsequent drilling over this region was very successful.
- ❑ 12 drill holes have been executed in the area where a Titan 24 program identified geophysical anomalies
- ❑ Drilling identified a new wide high-grade copper structure which extends the continuity of the Bolivar Northwest structure by an additional 400 meters
- ❑ Average grade of intercepts is 1.37% copper with an average true width of 8.1 meters



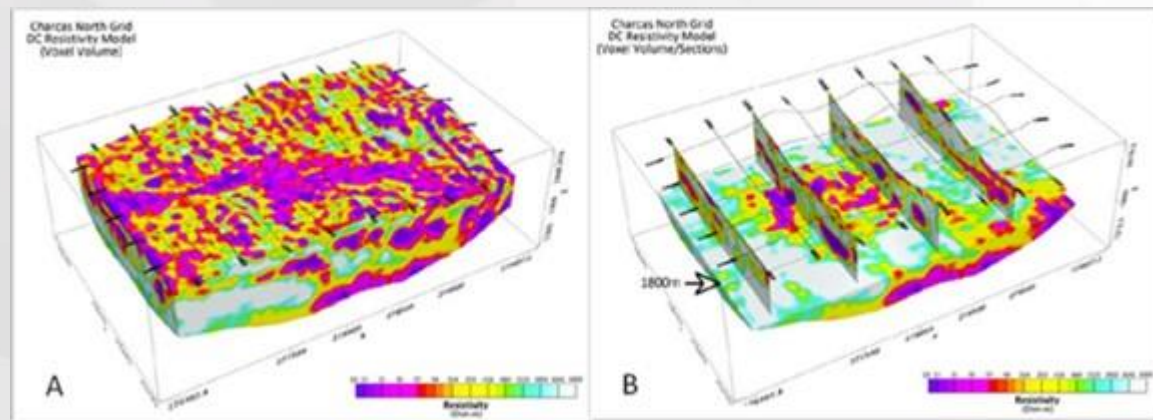


## Cross section at Charcas, Mexico

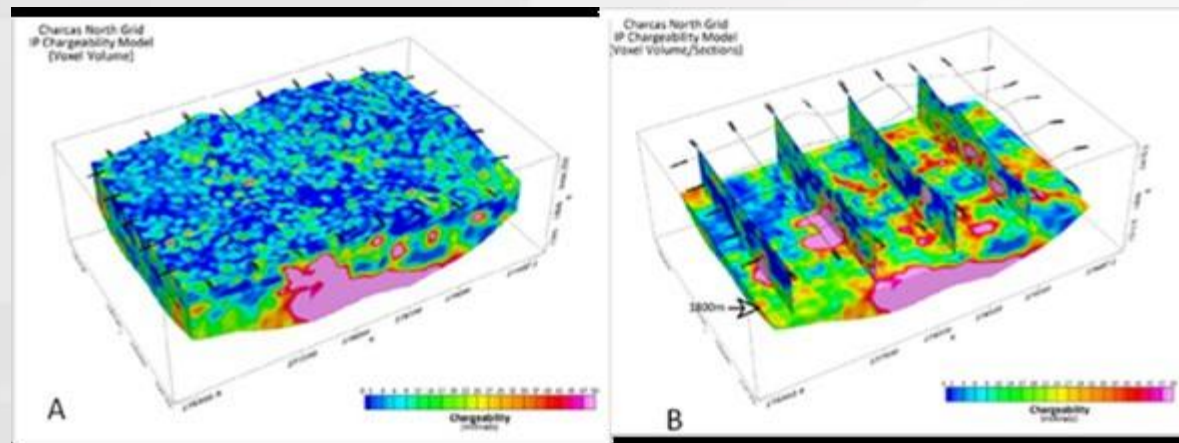




*The design of the ORION 3D study for the Charcas project.*



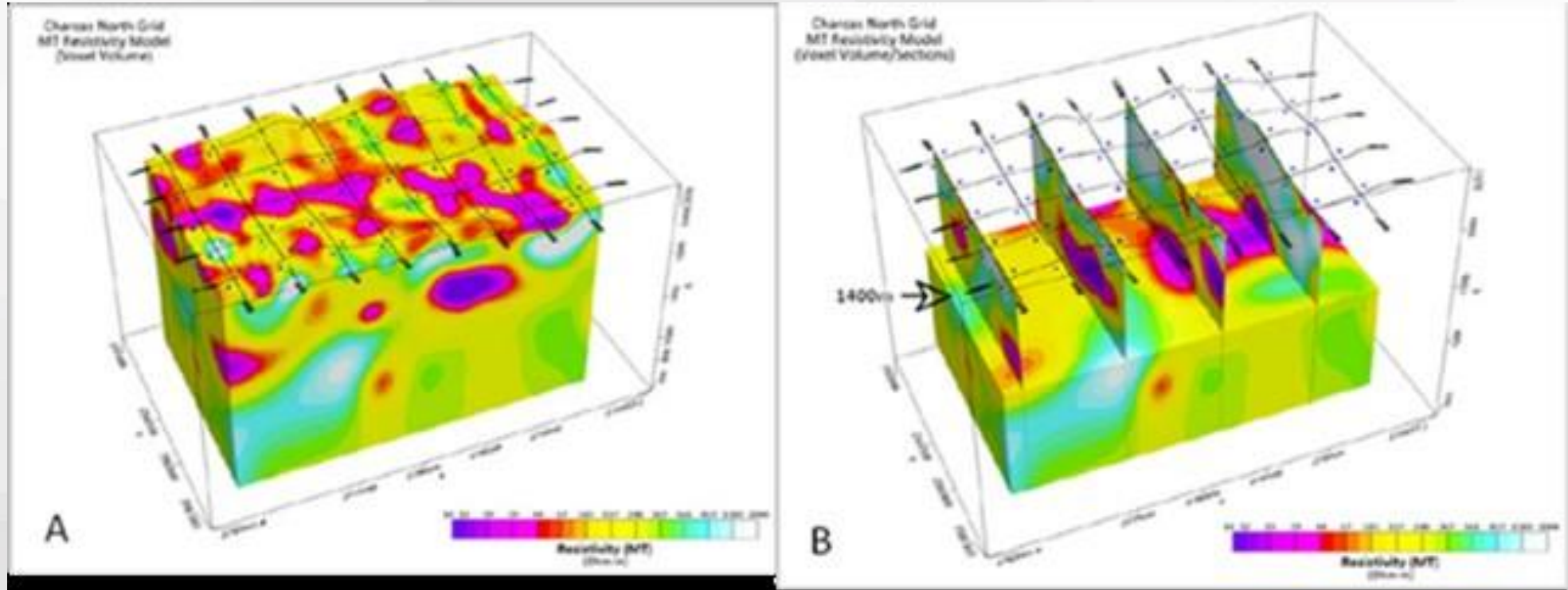
*Resistivity model North Block, left. Level plan in resistivity model shown at 1200m*



*Chargeability model, North Block (left)*







*North Block. A- 3D inversion resistivity MT. B-Plan at 1400m elevation with selected cross sections NS.*



## Charcas Summary

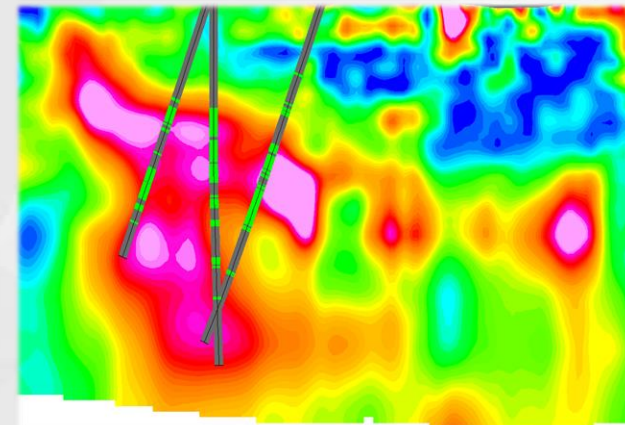
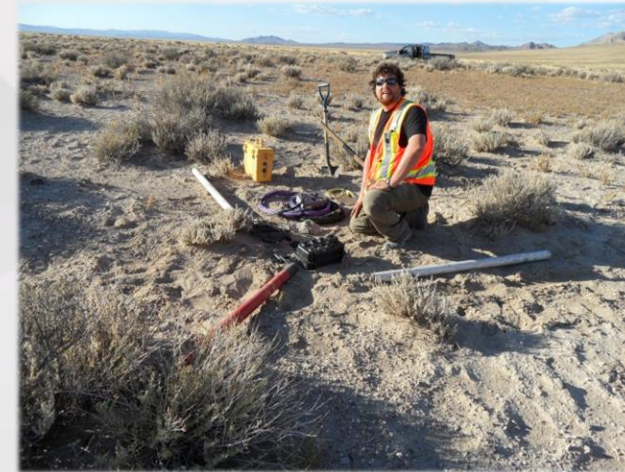
- ❑ Reliable deep and high resolution data obtained in extremely noisy Charcas mine environment
- ❑ Good correlation between geophysical data obtained and available drill information
- ❑ Main geological and structural features located and delimited at distance of 2 km around mine
- ❑ 76 new drill targets identified by survey





## Conclusions

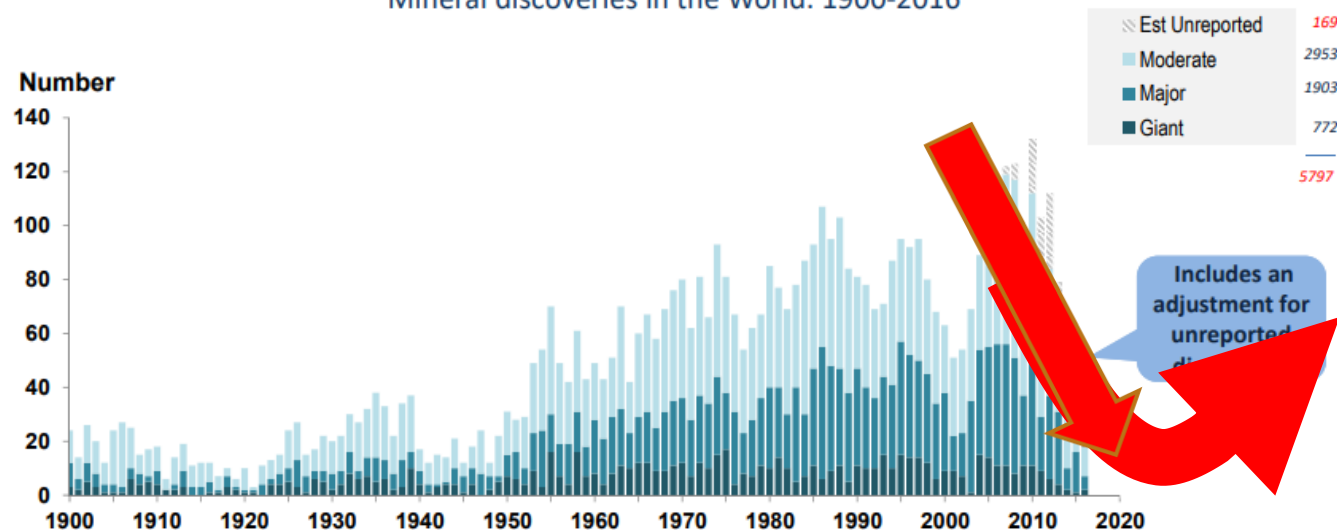
- ❑ Deep imaging helps explore deeper terrains
- ❑ Mapping key parameters accurately to depth, such as resistivity and chargeability provides improved targeting and a thorough approach to exploration
- ❑ More companies are finding exploration success by incorporating these technologies earlier into their process and planning
- ❑ Large areas can be explored cost effectively



## Technology for Discovery

### Number of discoveries by size

Mineral discoveries in the World: 1900-2016



Note: Excludes Bulk Mineral discoveries (i.e. bauxite, potash, phosphate, coal and iron ore)

"Moderate" >100koz Au, >10kt Ni, >100Kt Cu equiv, 250kt Zn+Pb, >5kt U<sub>3</sub>O<sub>8</sub>

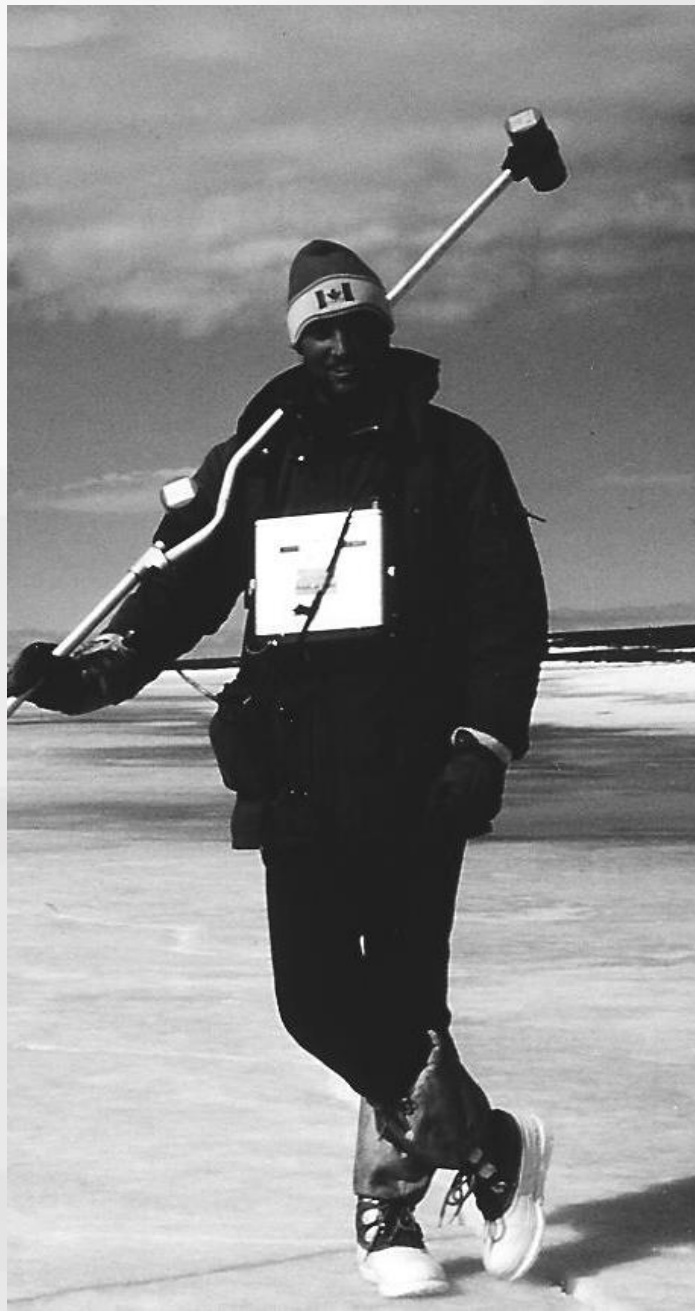
"Major" >1Moz Au, >100kt Ni, >1Mt Cu equiv, 2.5Mt Zn+Pb, >25kt U<sub>3</sub>O<sub>8</sub>

"Giant" >6Moz Au, >1Mt Ni, >5Mt Cu equiv, 12Mt Zn+Pb, >125kt U<sub>3</sub>O<sub>8</sub>

Source: MinEx Consulting © October 2017







## **Acknowledgements**

**Sierra Metals  
Grupo Mexico  
CMG**

# **Thank you !**

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