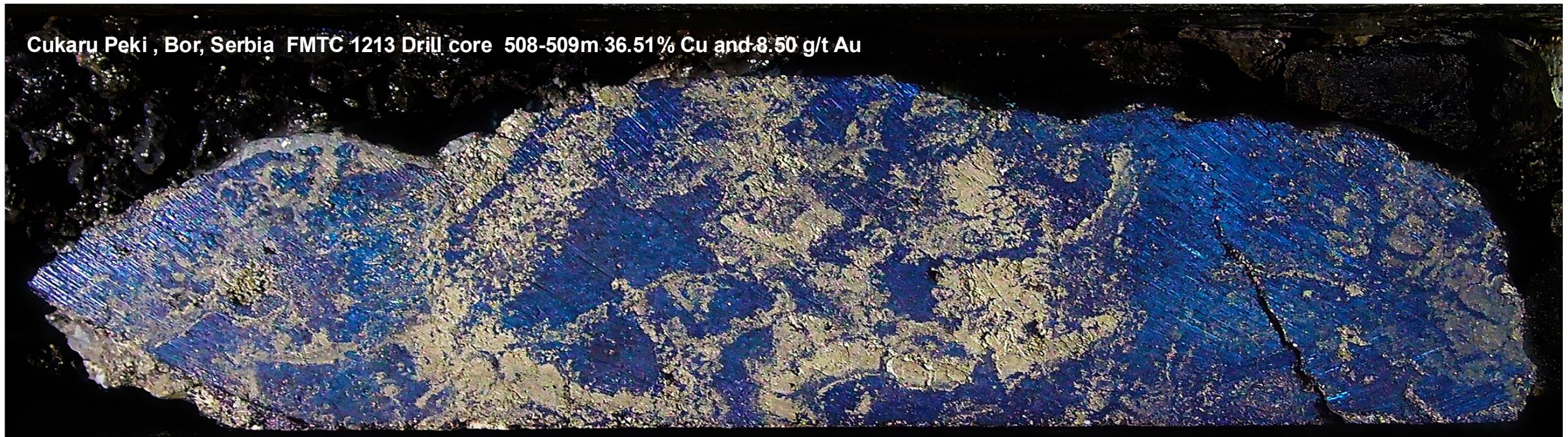
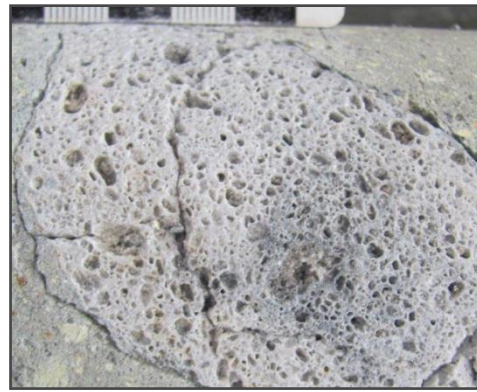
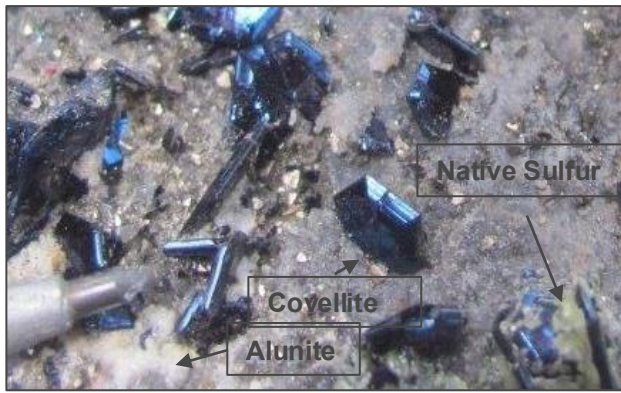




Cukaru Peki , Bor, Serbia FMTC 1213 Drill core 508-509m 36.51% Cu and 8.50 g/t Au

Porphyry exploration techniques in the lithocap environment

OUTLINE

- Definitions and broad characteristics of Lithocaps
 - Formation and Telescoping
- Case study of Onto deposit in Sumbawa, Indonesia
- Other examples to show full range of lithocap-hosted deposit characteristics
- Lessons for successful lithocap exploration
 - Geological environment / level of erosion
 - Alteration and HS mineral zonation
 - Geochemistry and Geophysical signatures

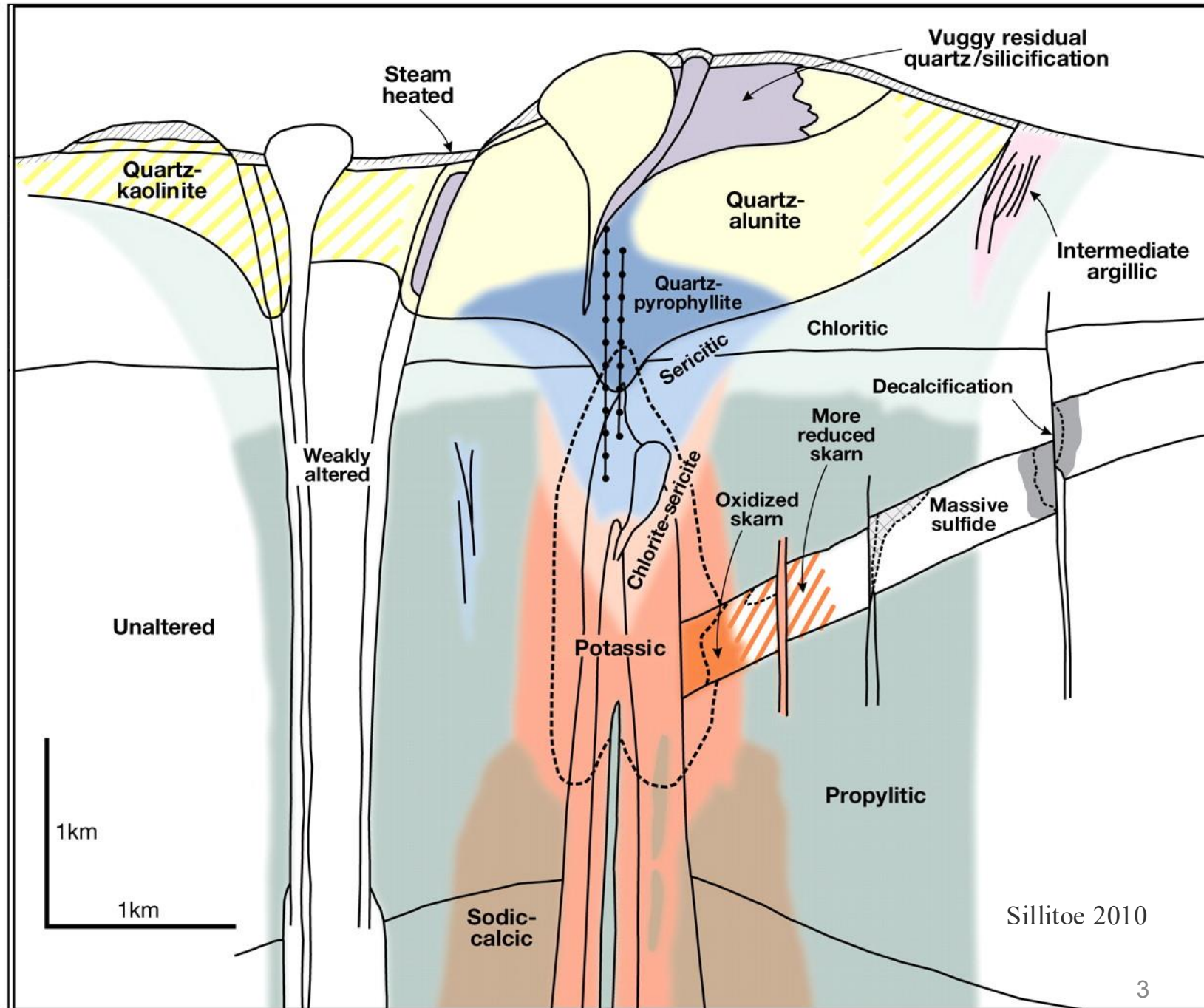
Geological Symposium, Ulaanbaatar, Mongolia September 18th, 2026



Contemporaneous Lithocap & Porphyry Formation

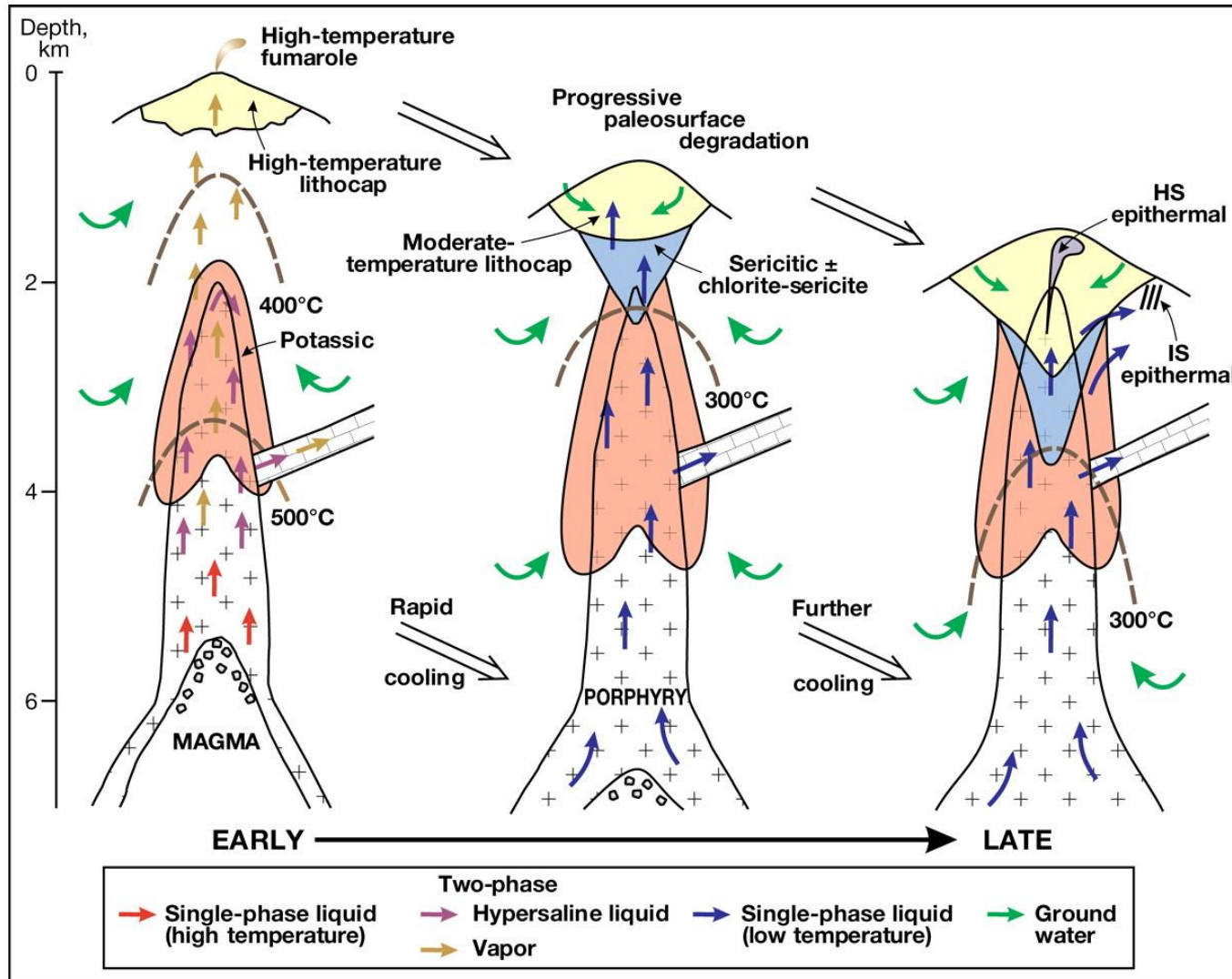
At shallow depths ($\leq 4\text{km}$) intrusions exsolve two-phase fluid, comprising a

1. small fraction of hypersaline liquid (brine) $\rightarrow$ potassic alteration and associated quartz veinlet stockwork with copper-gold $\pm$ molybdenum ore shell
 2. a much larger volume of low-density vapor that rises and forms contemporaneous advanced argillic alteration in laterally-extensive lithocap above / marginal to porphyry intrusions
- Acidic volatile species SO_2 , H_2S , CO_2 , HCl and HF partition to the vapor along with some metals (As, Sb, Hg, Te, Bi and B)



Lithocaps

Porphyry-Lithocap Telescoping

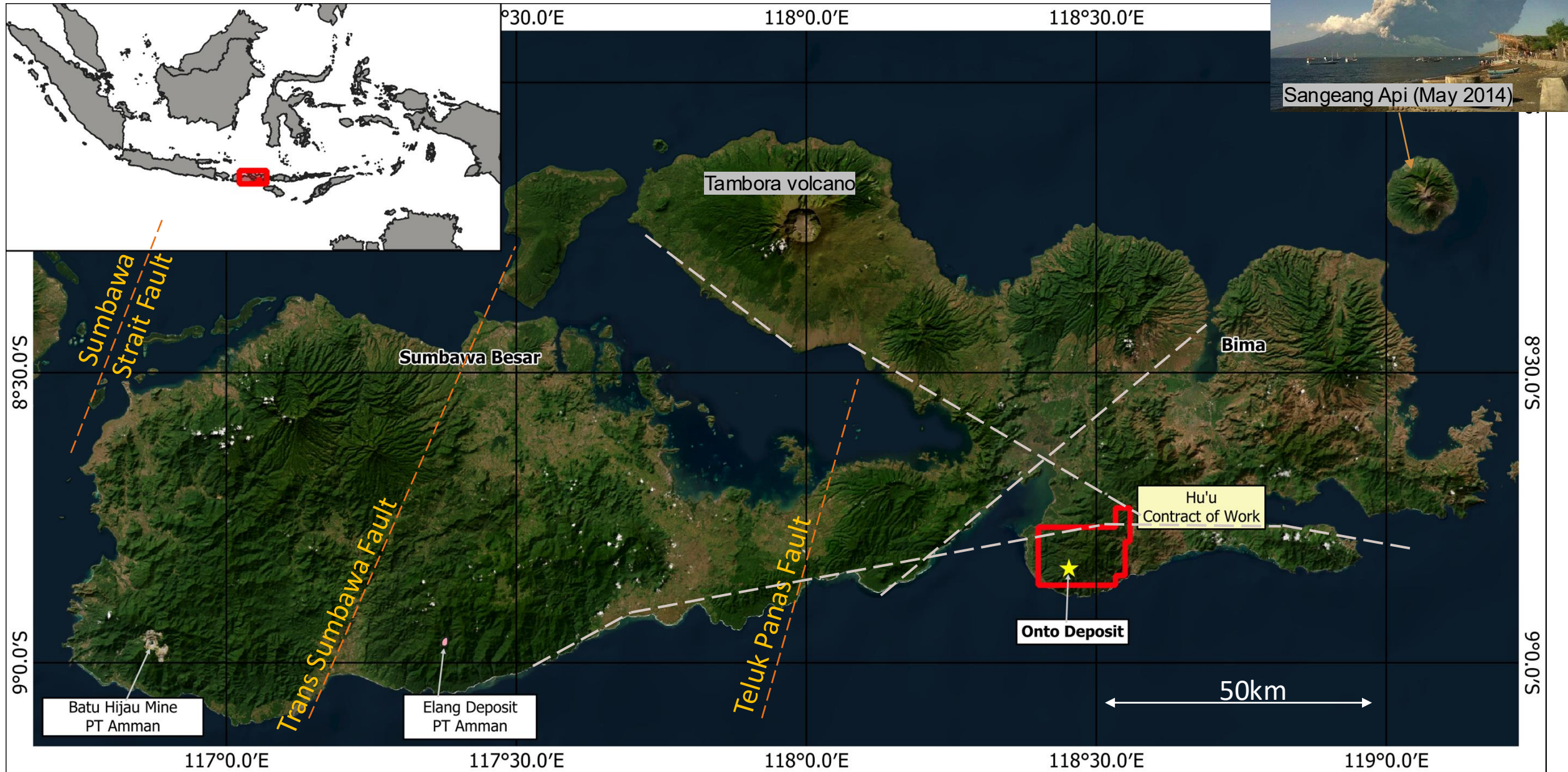


Early-stage separation of hypersaline liquid and vapor as magmatic critical fluids intersect solvus

- Liquid → deep potassic alteration
- Buoyant vapor → ascends toward surface
- Gases HCl, SO₂ etc. fractionate to vapor → condense into groundwater to form acidic fluids leaching and HS assemblage

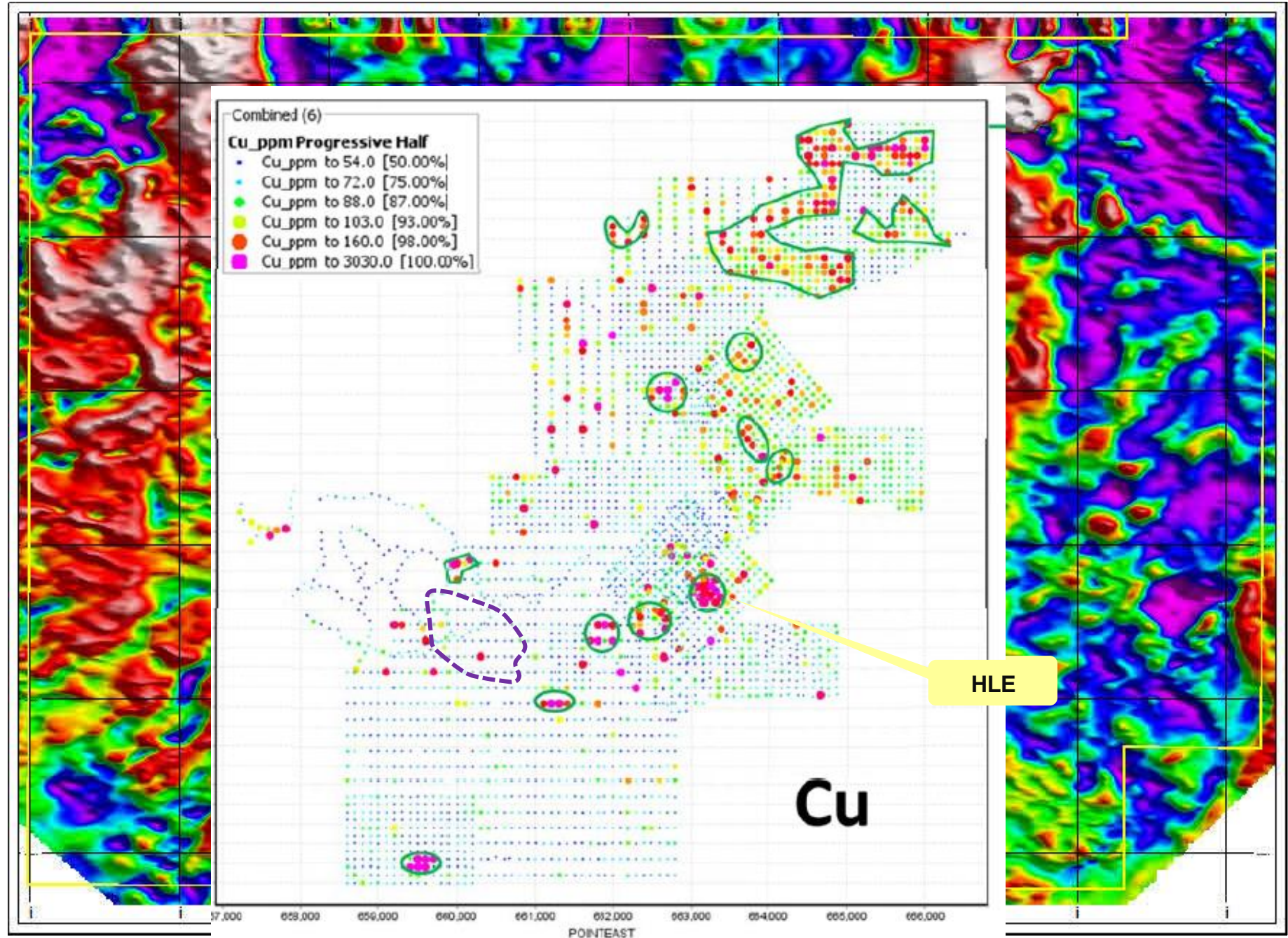
1. AA lithocap forms during initial stage of porphyry formation
2. Phyllic-stage lower salinity; deposits high sulphidation mineralization (*Lepanto*) and overprint porphyry-level mineralization (FSE)
 - Thermal regimes collapse and temperature front retreats downwards super-imposing low temperature mineralization on early formed types
 - Telescoping more extreme with
 - I. Rapid syn-hydrothermal erosion under high uplift, pluvial or glacial conditions
 - II. Gravity-induced sector collapse

Onto Location



Hu'u Targeting

- Airborne magnetic surveys (1996 fixed wing & later 2012 Vale helicopter-borne)
- Extensive soil surveys completed with coincident Cu, Mo & Au anomalies identified
- Vale targeted geochem & coincident magnetic anomaly at HLE
- VHD001: 414m at 0.45% Cu & 0.26 g/t Au at 138m
- Drilled-off small HLE resource (21 holes for 15,062m): 50Mt at 0.5% Cu & 0.5 g/t Au (1.2-1.0Ma)

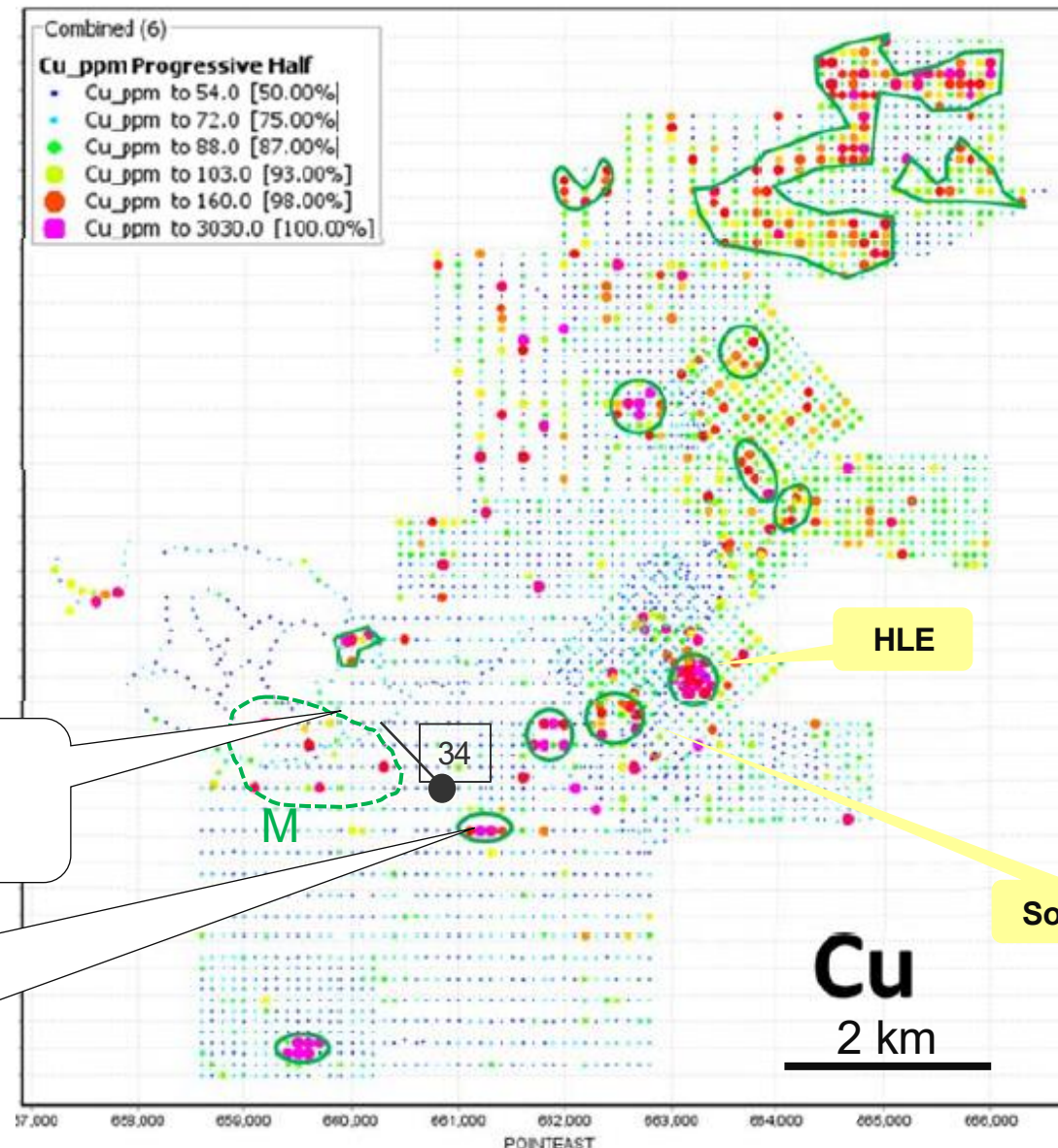


Hu'u Onto Discovery Program

- Reassessment of soil geochemistry
- Progressed to SW through Sori Hiu with 800 m holes – low grade porphyry mineralization
- Sited VHD034 based on weak magnetic high, increasing AA alteration and the breccia
- **Discovery**

Phreatic Breccia with covellite clasts with up to 0.6% Cu

L. Karaba-Onto Trench
A-veined clasts (0.6% Cu) and diss. sulphides in phreatic breccia matrix (0.2-0.3 % Cu)



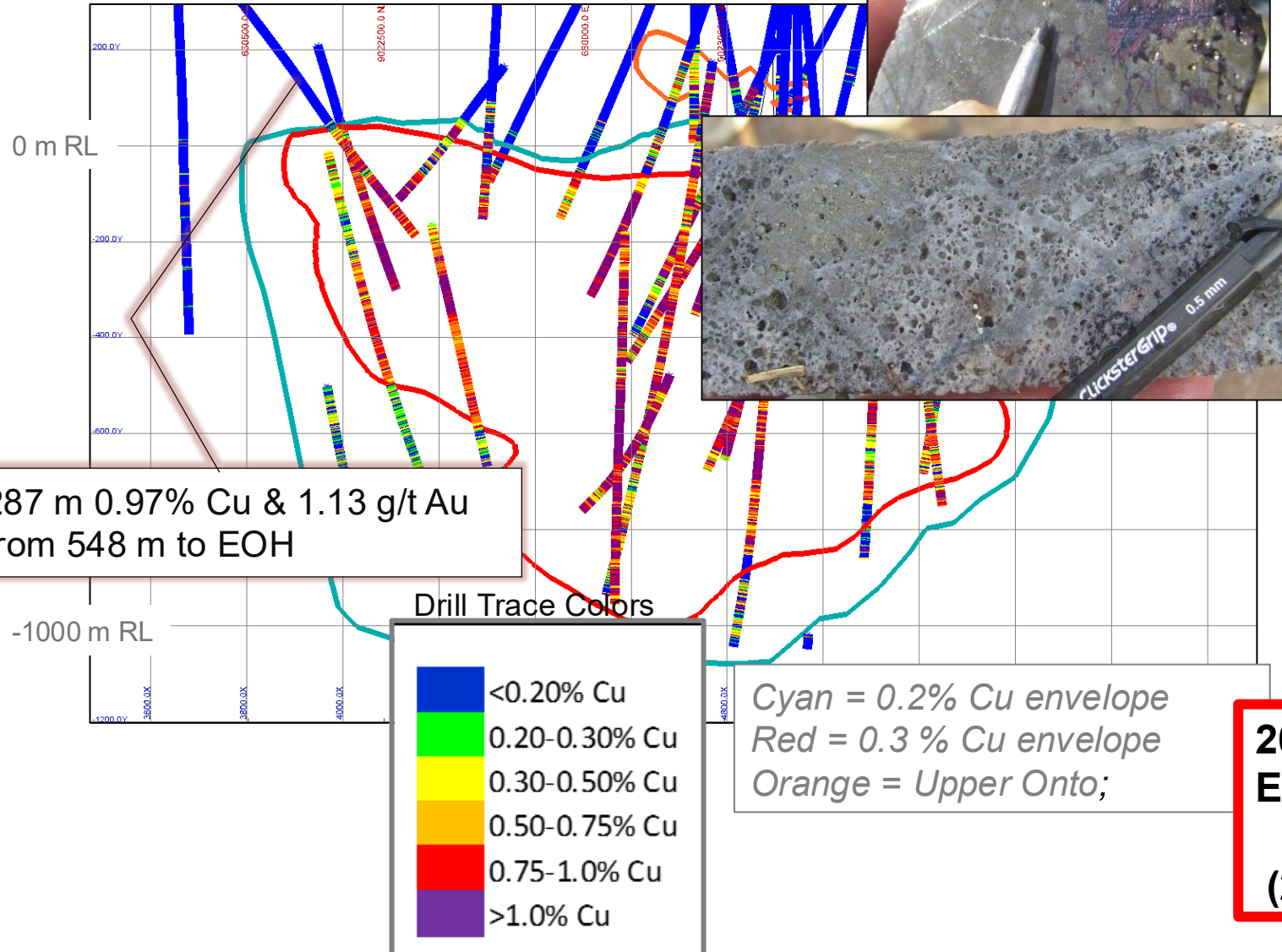
Geochem Anomalies

- Primary (A-H)
- Secondary (I to L)
- Tertiary (M & N)

“M” Anomaly
100-160 ppm Cu only anomalies that only stood out after taking out lithological effects with Cu-Co regression

(Winterburn June 2013)

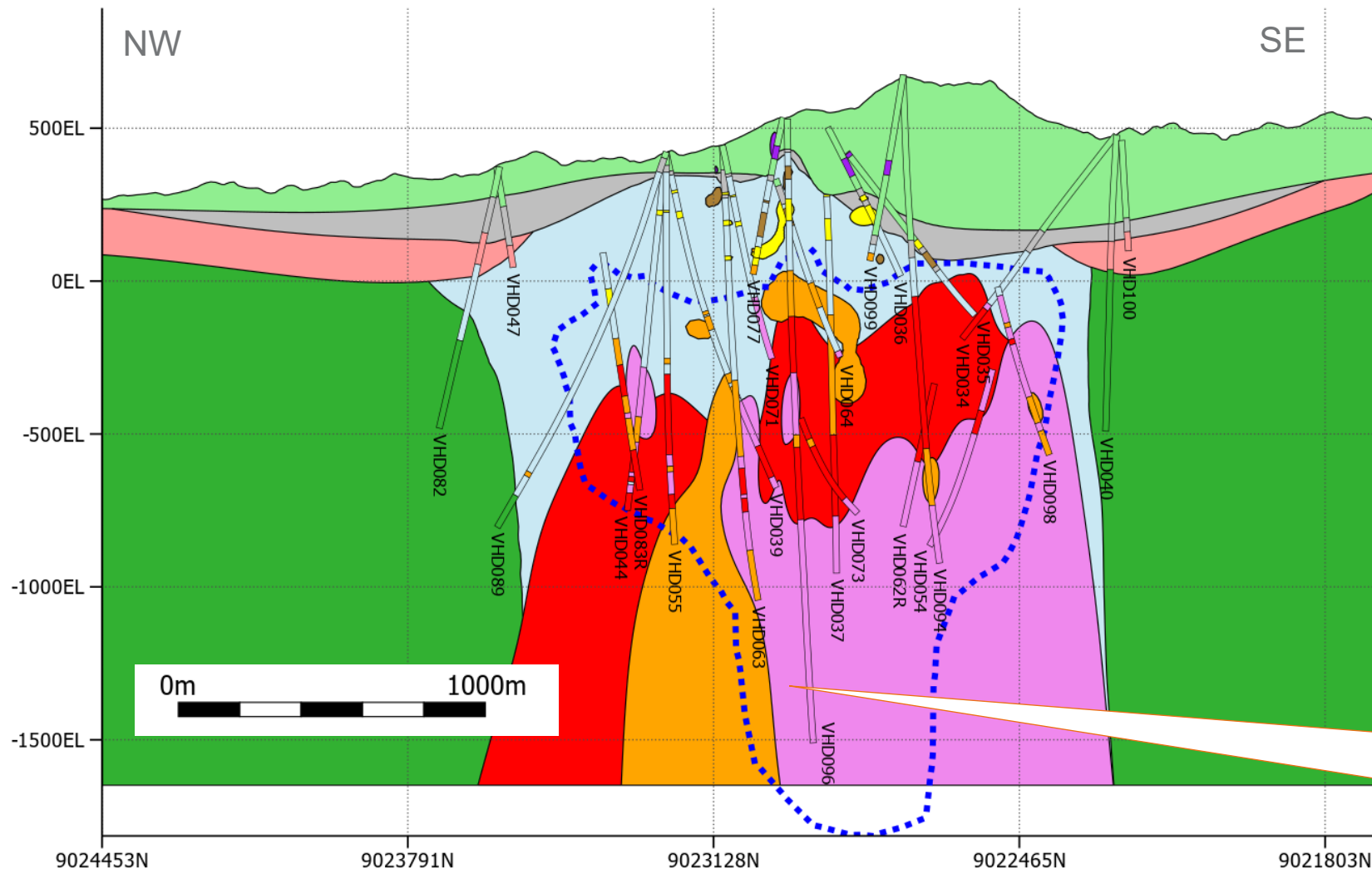
Onto 0.2 % and 0.3 % Copper Envelopes SE-NW oblique long section



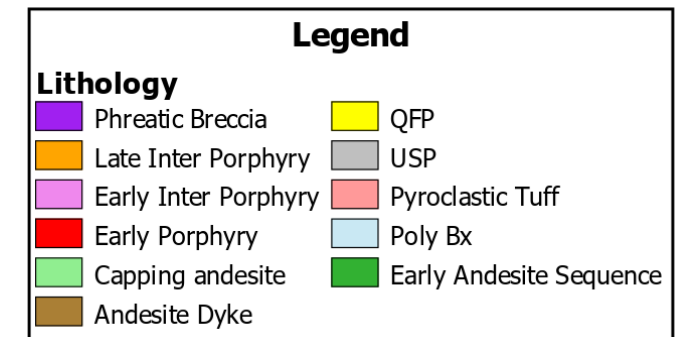
Drill hole	From (m)	To (m)	Interval Length (m)	Cu (%)	Au (g/t)	As (ppm)
VHD034	548	835 (EOH)	287	0.97	1.13	503
VHD037	536	1484 (EOH)	948	1.26	0.7	435
VHD039	498	1165 (EOH)	667	0.97	0.51	376
VHD044	424	1201 (EOH)	777	0.97	0.55	553
VHD045	640	1501 (EOH)	861	0.95	0.41	445
VHD048	522	1523 (EOH)	1001	0.75	0.57	219
VHD054	492	1500 (EOH)	1008	0.66	0.47	263
VHD055	402	1168	766	0.99	0.5	677
VHD058	322	376	54	1.66	0.08	784
	650	1500 (EOH)	850	1.08	0.51	324
VHD060	312	1451 (EOH)	1139	1.02	0.55	312
VHD062R	622	1499 (EOH)	877	0.77	0.69	163
VHD063	408	432	24	6.89	0.42	1834
	486	1304	818	0.93	0.51	321
VHD064	316	408	92	0.52	0.07	399
	586	1466	880	0.97	0.59	184
VHD069	514	1420	906	0.73	0.29	310
VHD071	350	966	616	0.81	0.43	375
	1106	1306	200	0.47	0.1	280
VHD072	358	374	16	12.1	0.12	2153
	499	1396 (EOH)	897	1.06	0.58	457
VHD073	730	1471 (EOH)	741	1.29	0.9	274
	388	422	34	4.71	0.31	1243
VHD076	562	950	388	1.12	0.84	471
	992	1382	390	0.57	0.2	229
VHD078	468	751 (EOH)	283	0.44	0.23	369
VHD079	534	658	123	2.18	1.04	851
	684	1386	702	0.92	0.35	794
VHD080	752	1502	750	0.8	0.3	486

**2025 Indicated and Inferred Resource
Estimate of 3 Bt at 0.72 % Cu & 0.39 g/t Au
(21.7 Mt Cu & 37.4 M oz Au contained)**

Onto Cu-Au Rock Type Longitudinal Section NW to SE



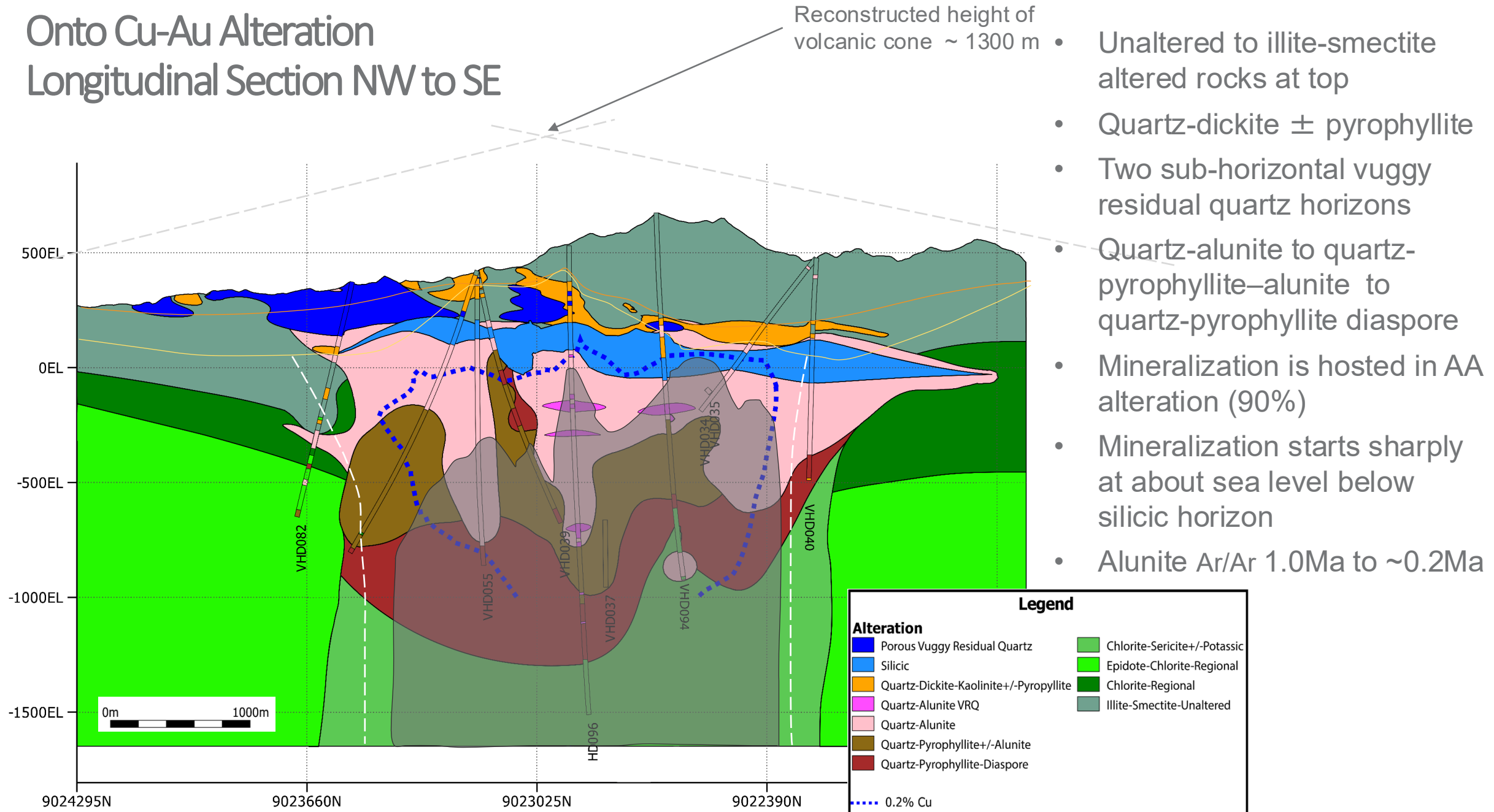
- Early Andesite Sequence (4.7-1.5Ma)
- Diatreme with maar sediments and tuff ring
- Capping Andesite (0.84 Ma)
- Core of coalesced porphyry stocks (0.68 Ma); top out -50EL
- Cu-Au mineralization (0.2% Cu shell) centered on top of porphyry stocks (~0.4 Ma Re-Os on MoS₂)



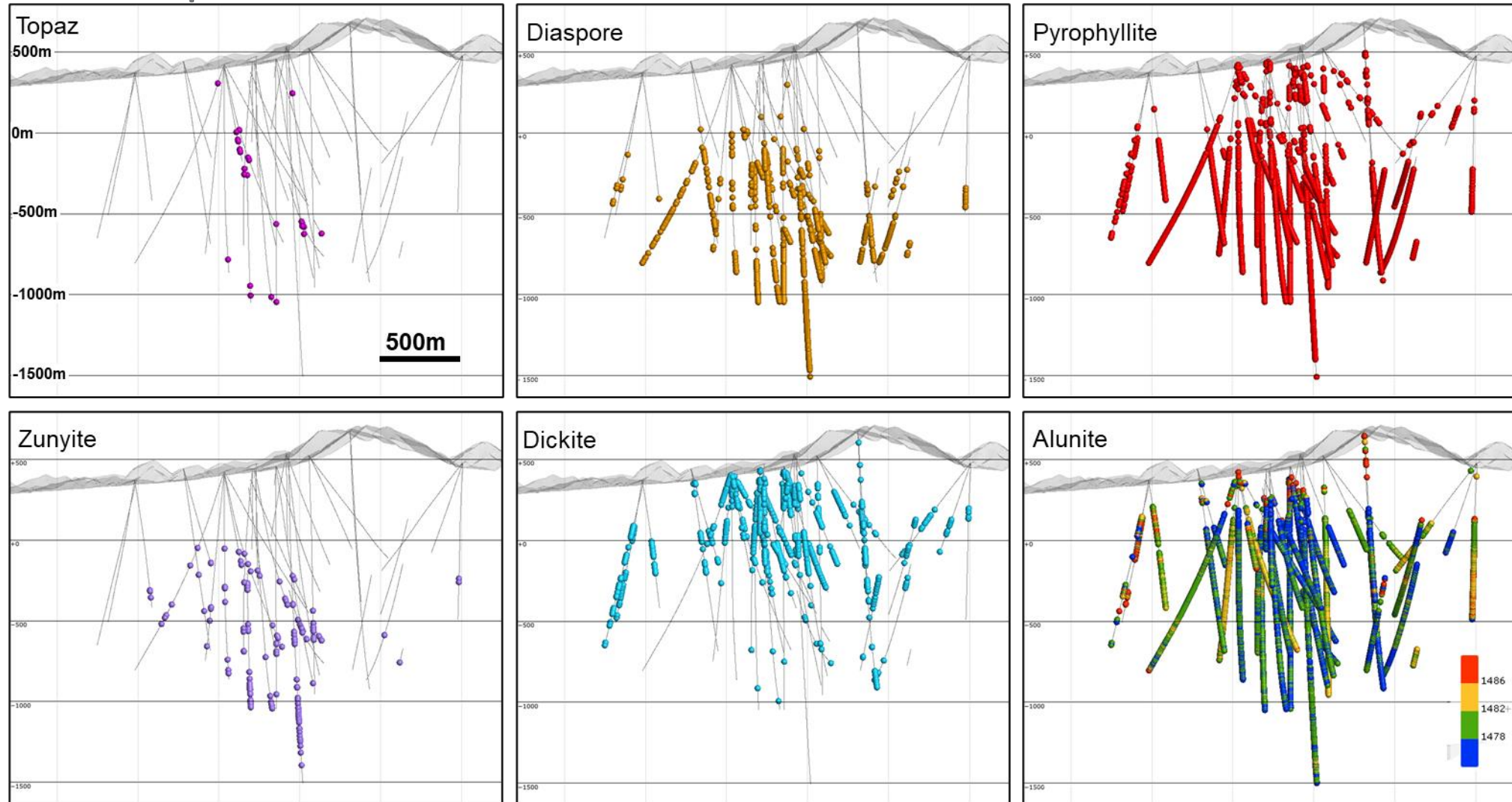
0.2% Cu shell

VHD096 to 2042m intersected 1595m at 1% Cu & 0.4 g/t Au including 100 m at 6% Cu & 1.1 g/t Au

Onto Cu-Au Alteration Longitudinal Section NW to SE



Onto Lithocap



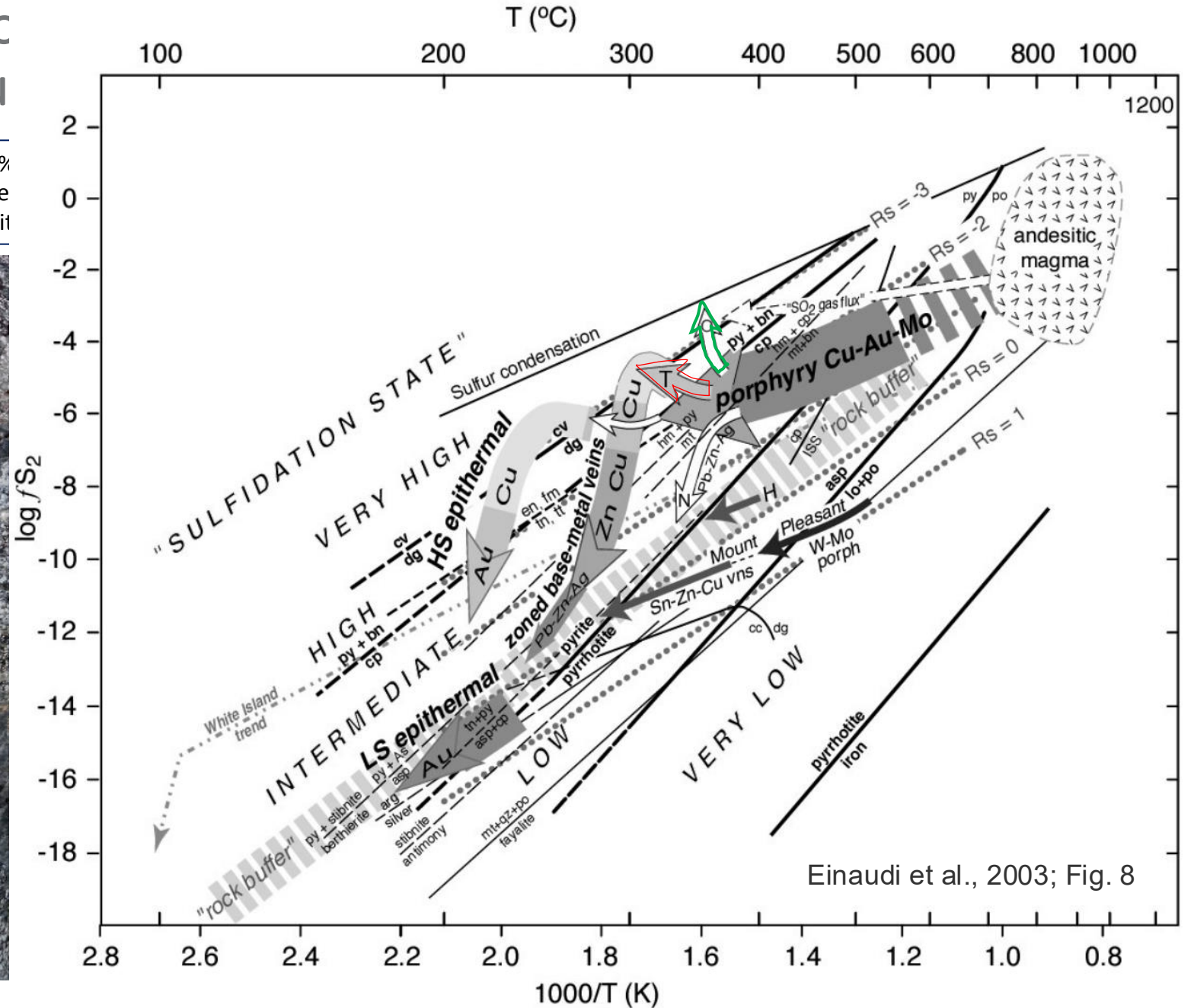
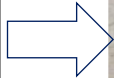
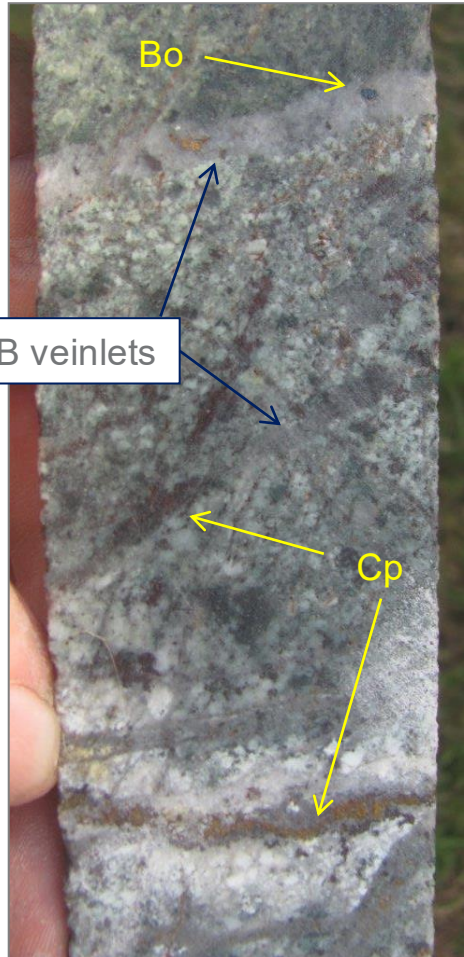
Onto longitudinal section from NW to SE.

Alunite is colored by 1480 nm absorption feature and shows dominance of potassic alunite (<1482 nm), except for higher Na contents in the north-west holes and at shallow depths

Advanced Argillic Alteration Replacement with high su

VHD062R 993m: EP 1.2 % Cu, 3.4 g/t Au. Potassic with chloritic overprint

VHD34 759m: EP 0.8 % g/t Au. Quartz-alunite relict potassic; hematite



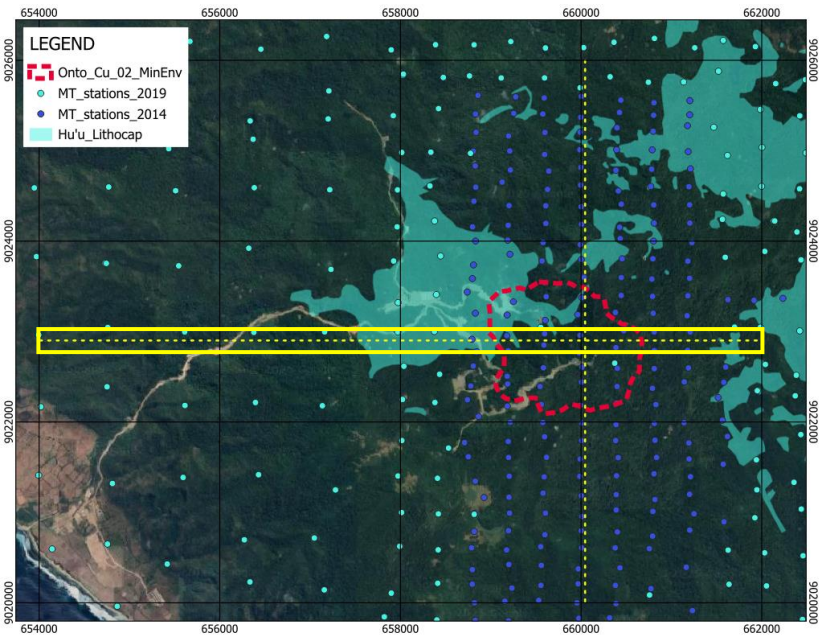
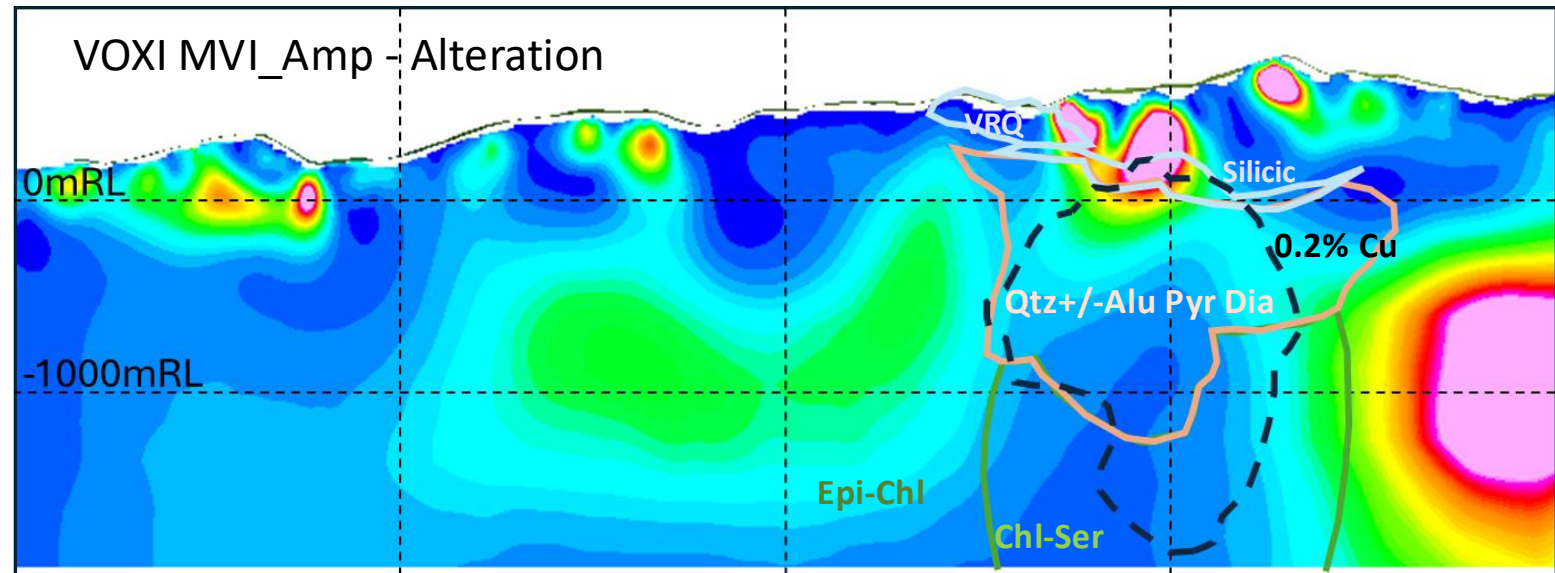
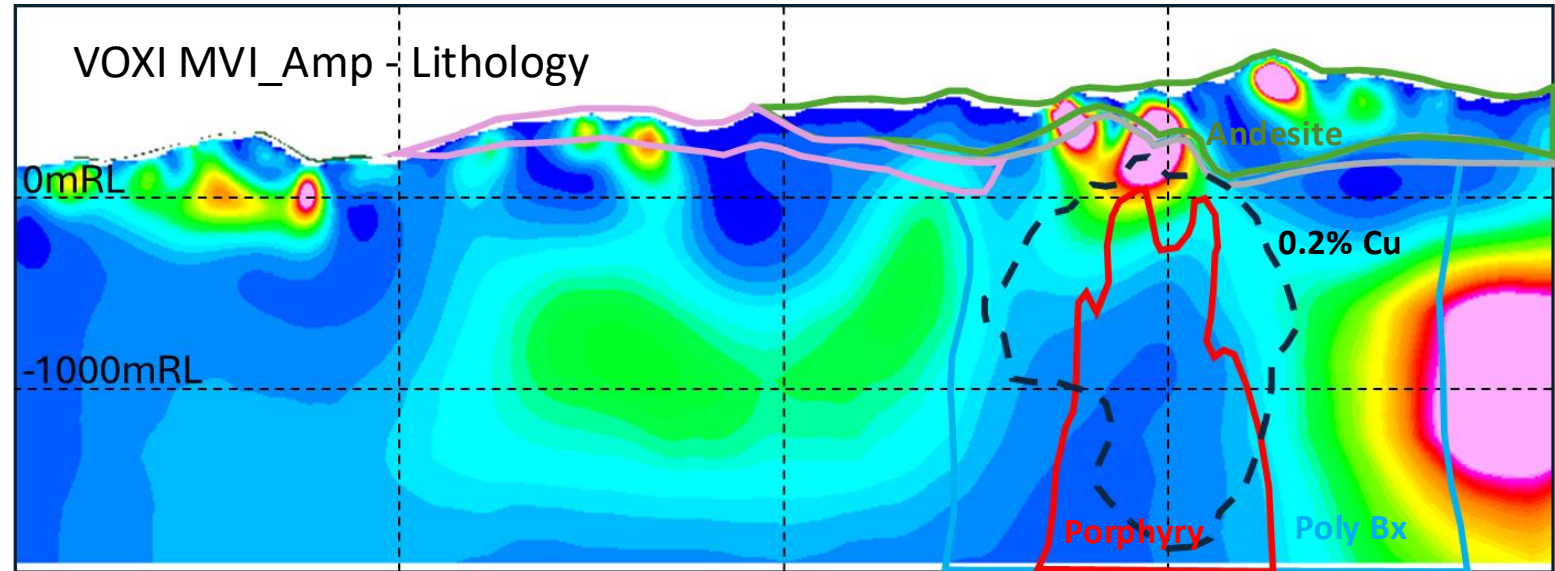
Einaudi et al., 2003; Fig. 8

Onto Magnetics – EW Section

3D modelling

Mineralisation and HS alteration correlate with low MVI amplitude.

Capping andesites are variably magnetic and not well resolved by the modelling.

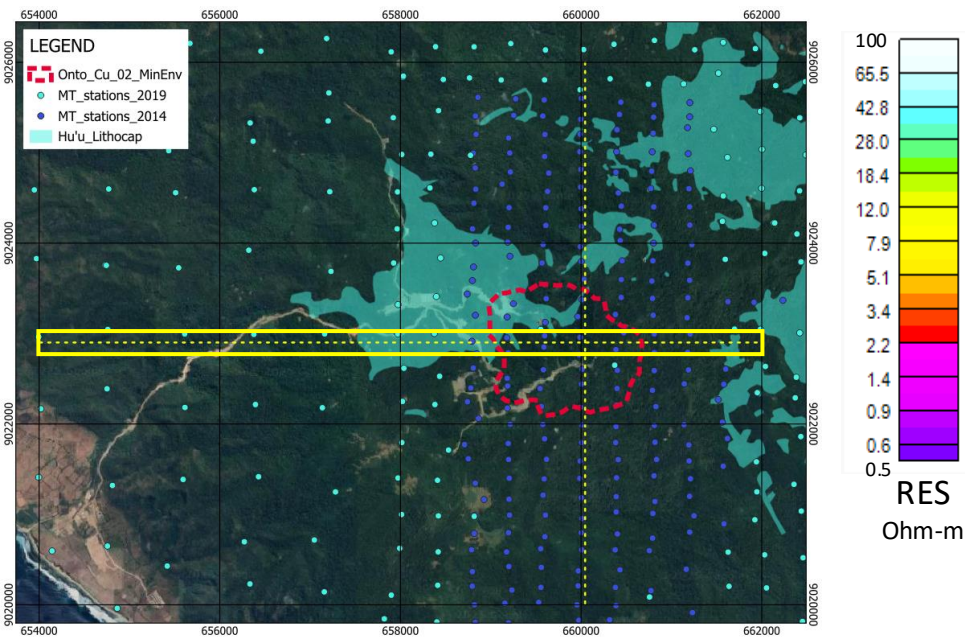
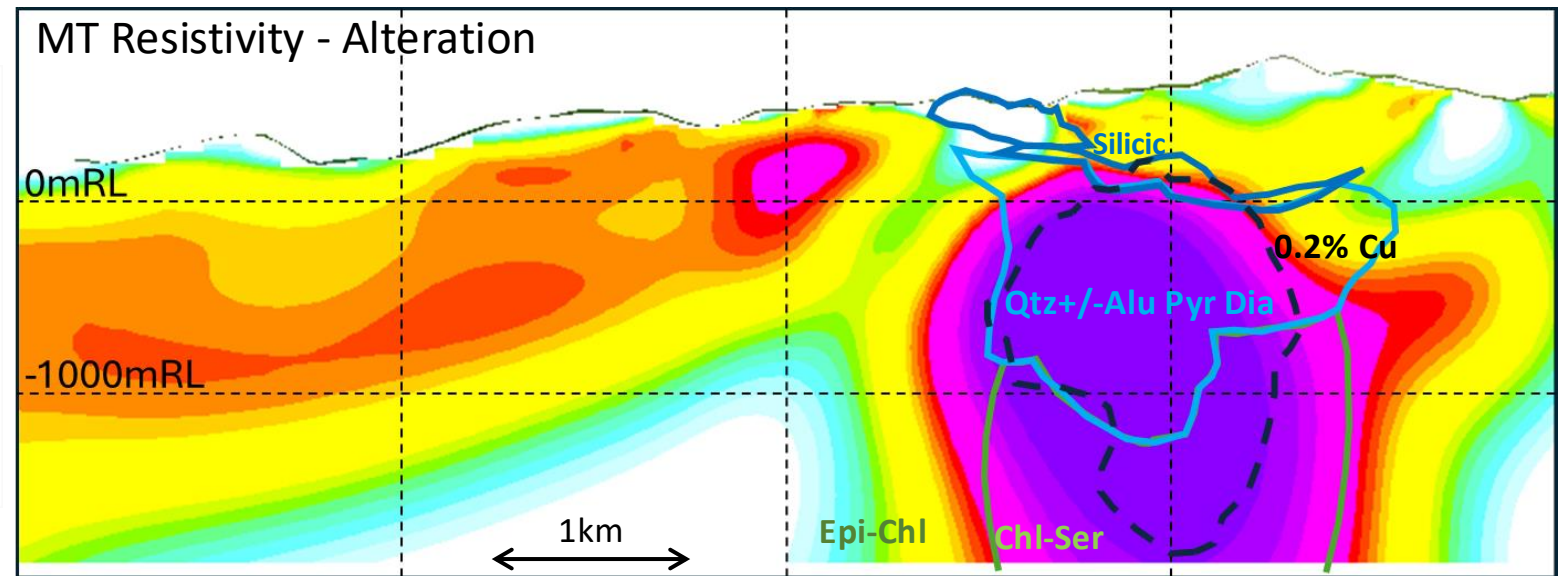
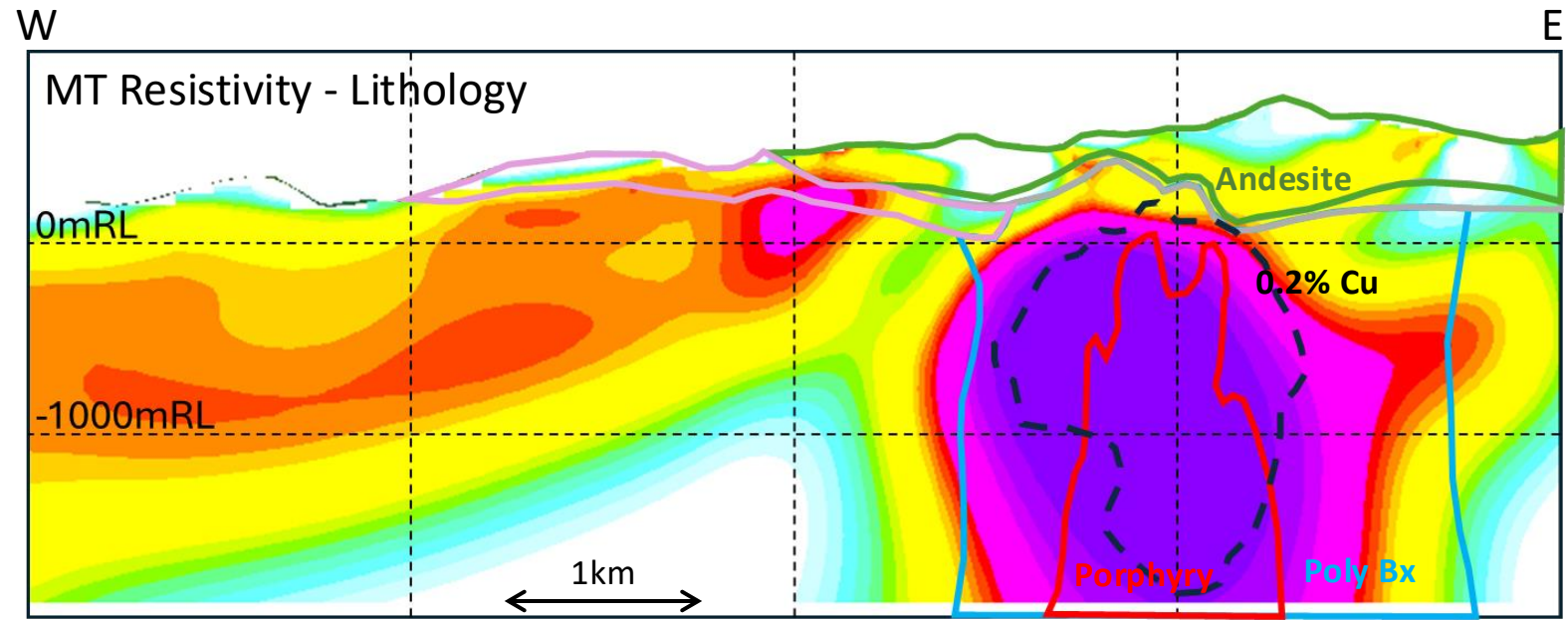


Onto MT – EW Section

3D modelled Resistivity

Strong correlation between very low modelled resistivity (<2 Ohm-m) and both logged porphyry intrusives and mineralization. Very low resistivity confined with the diatreme (polymictic breccia).

Also, a good correlation with the High Sulphidation alteration.



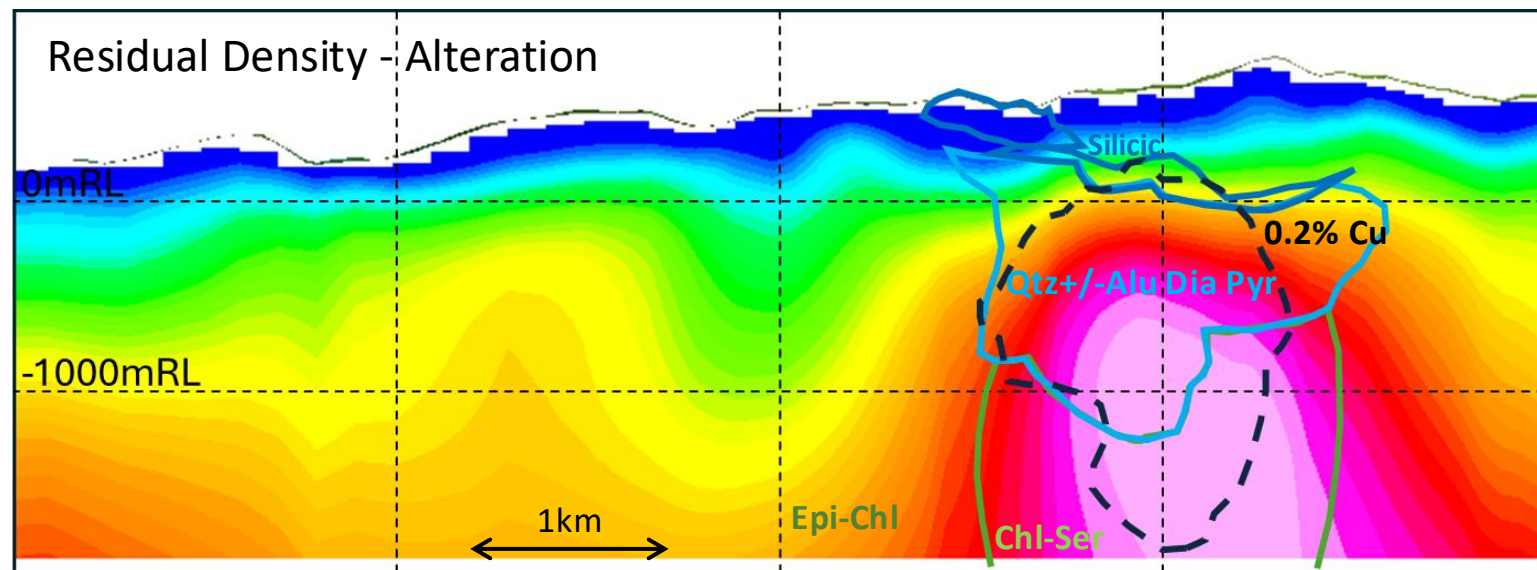
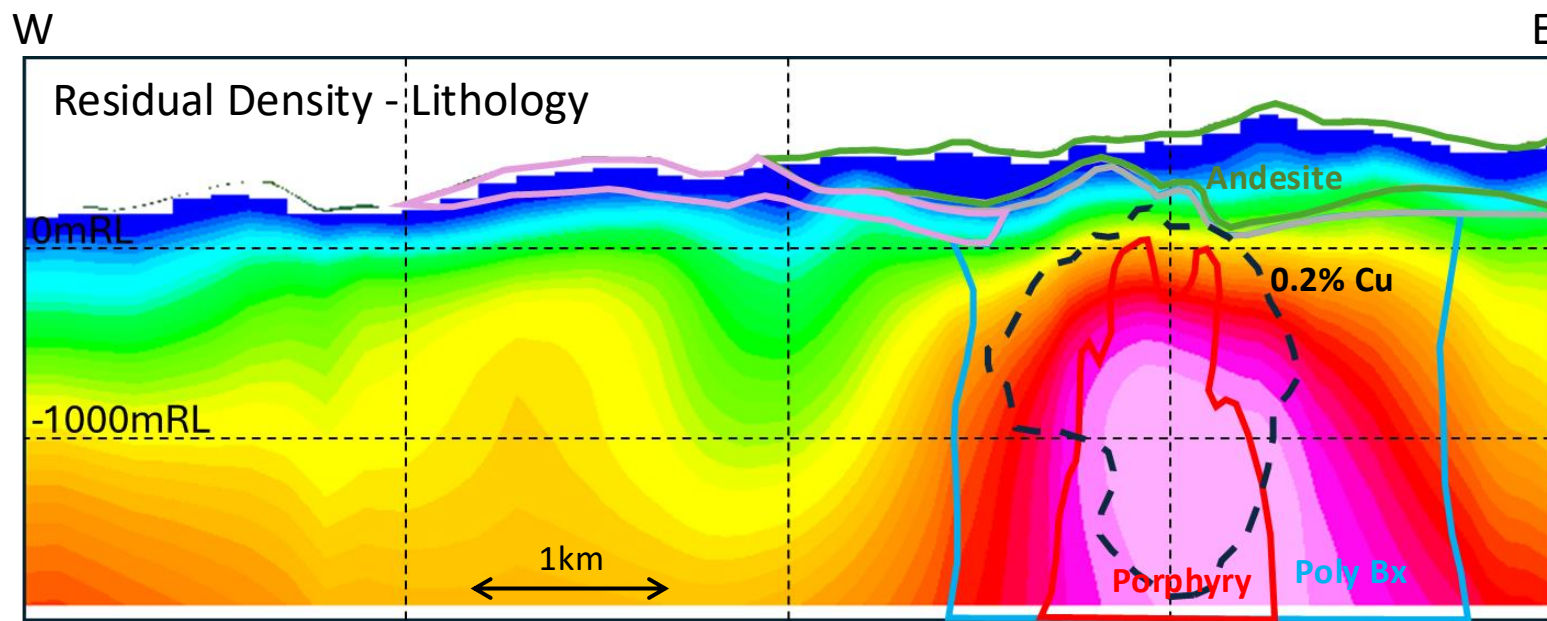
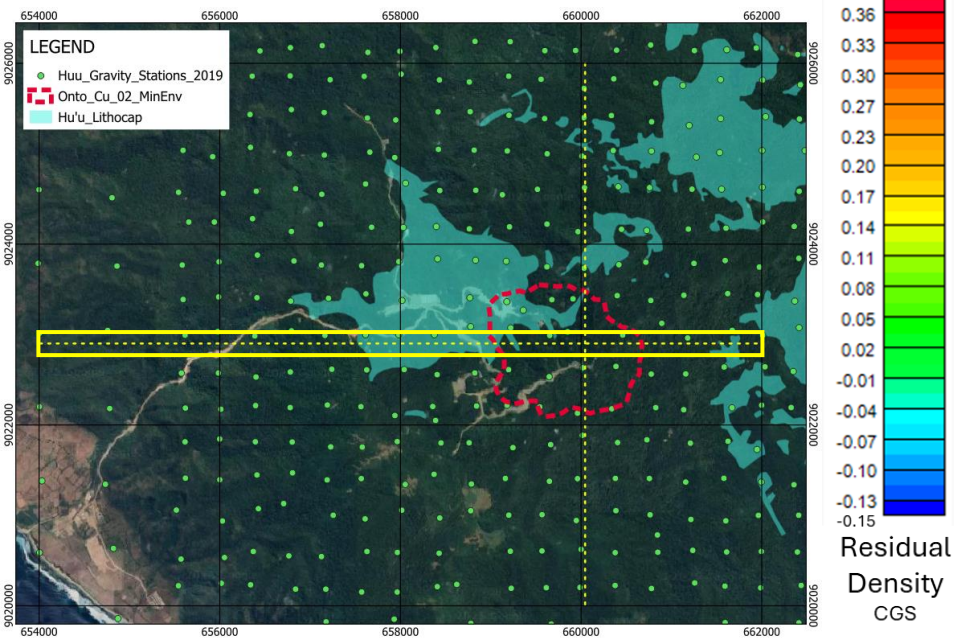
Onto Gravity – EW Section

3D modelled Density

Good correlation between increased density ($>2.9 \text{ g/cm}^3$) and both logged porphyry intrusives and mineralization.

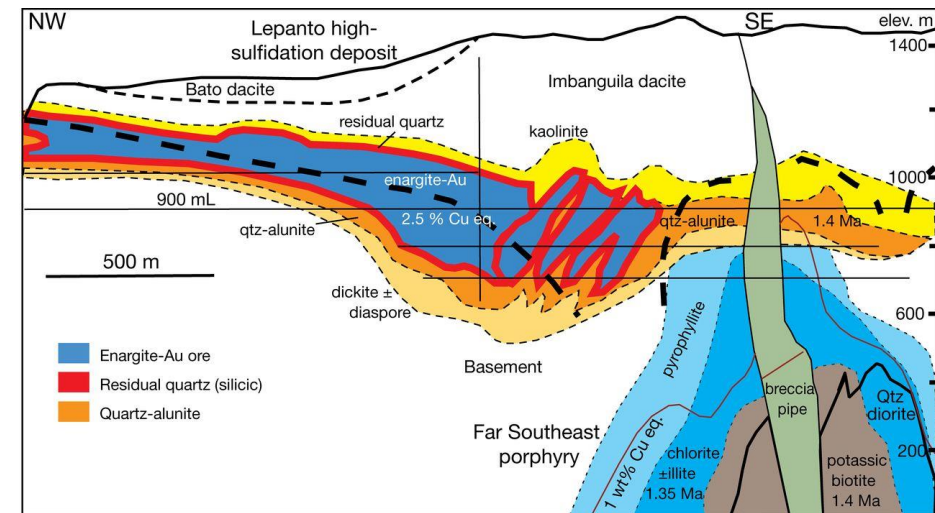
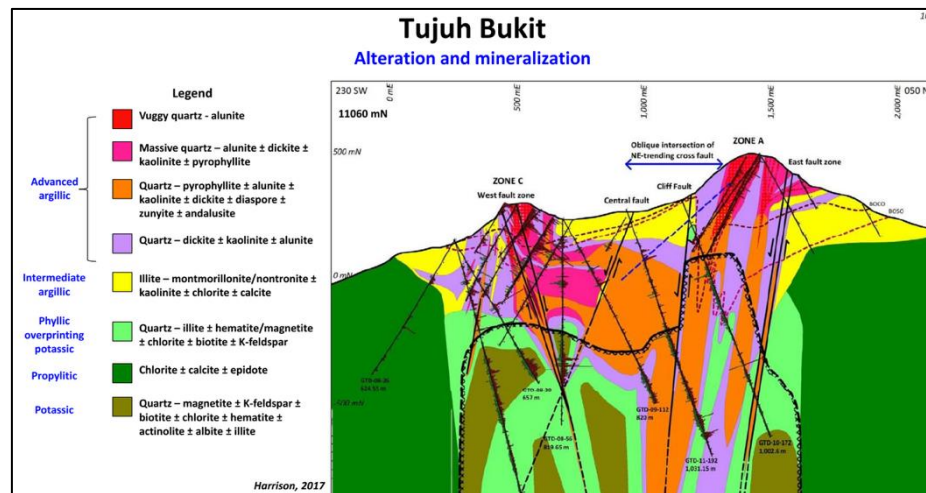
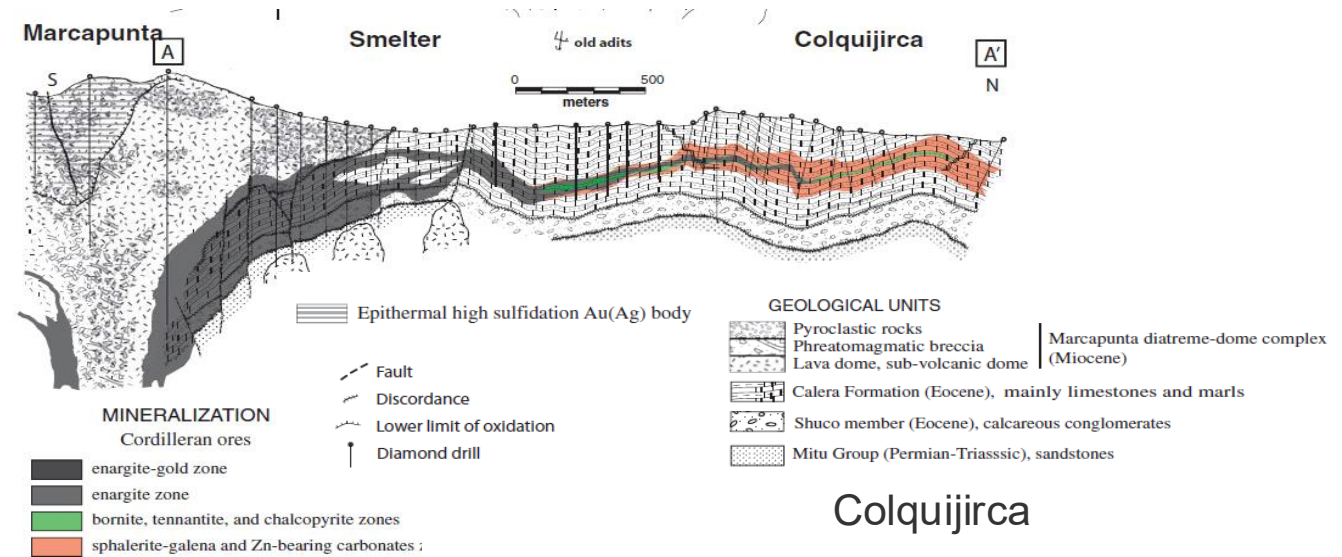
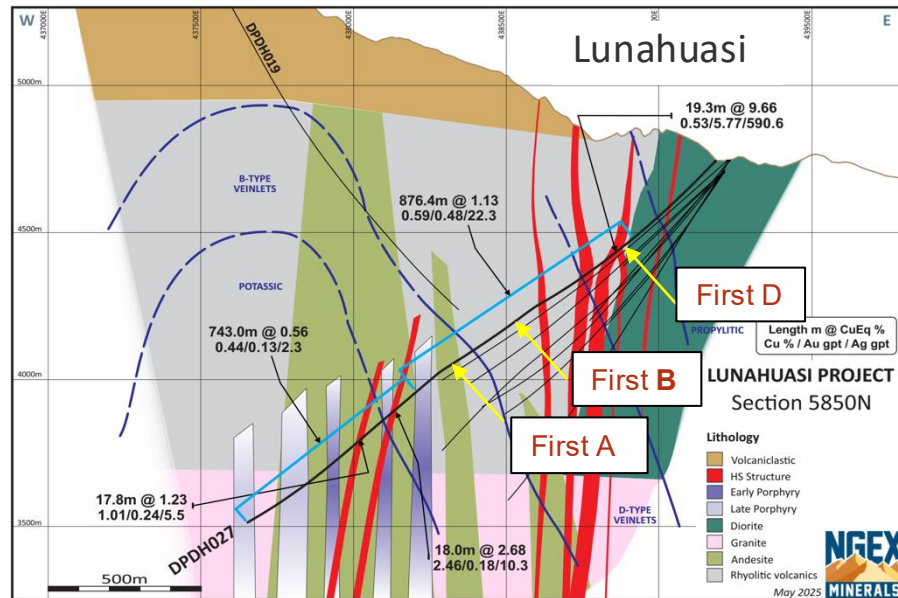
Measurements for resource calculation indicate the mineralization averages 2.77 g/cm^3 .

The deposit averages $>15\%$ sulphides.



Lithocap Exploration and Evaluation

Variable Geometry and different styles of mineralization

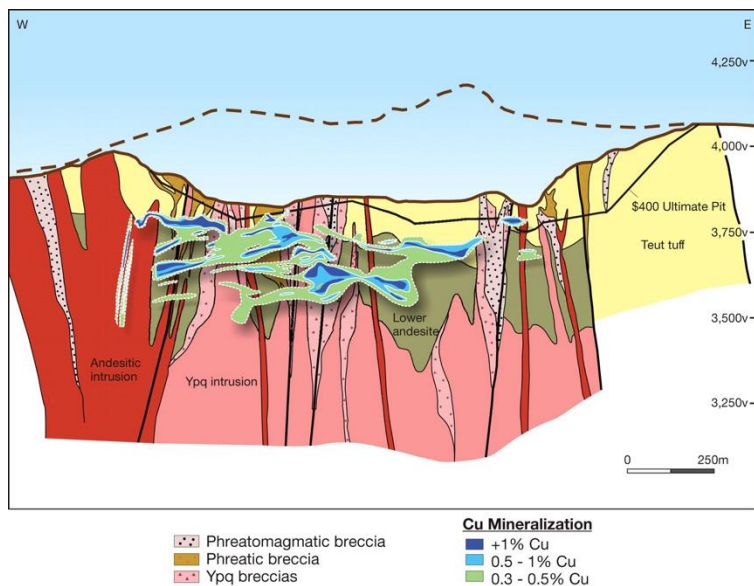


Tujuh Bukit HS and Tampangpitu porphyry

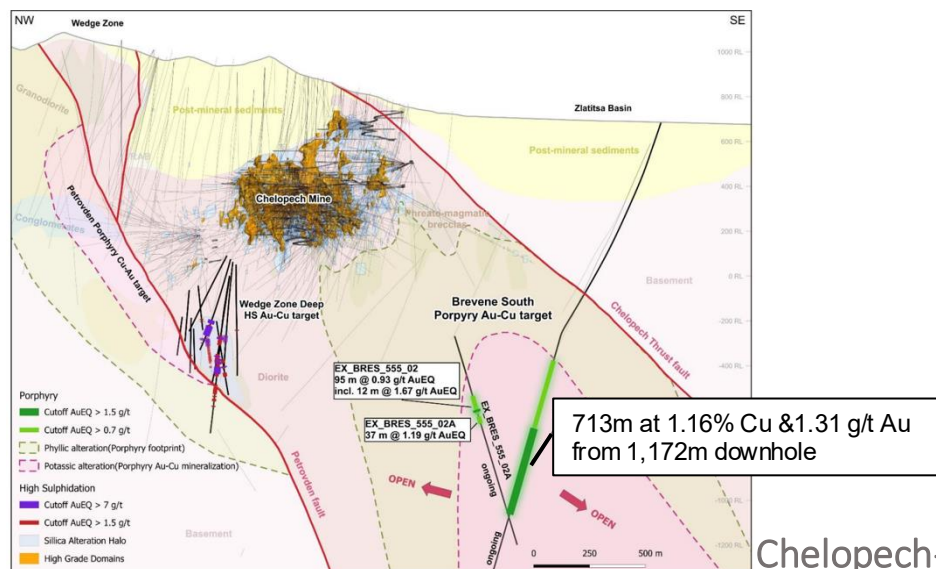
Lepanto HS-FSE porphyry

Lithocap Exploration and Evaluation

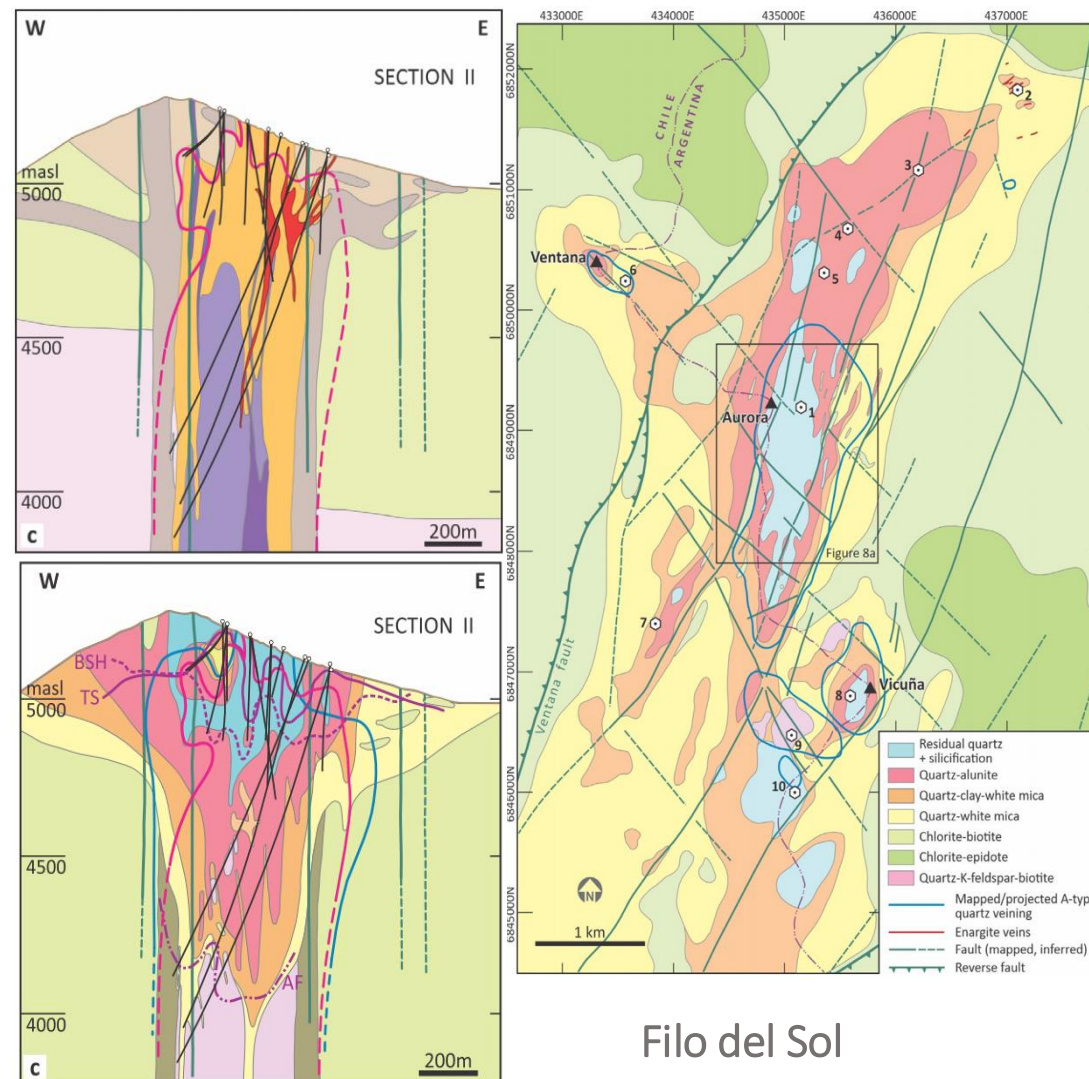
Variable Geometry and different styles of mineralization



Yanacochoa



Chelopech- Brevne South Porphyry

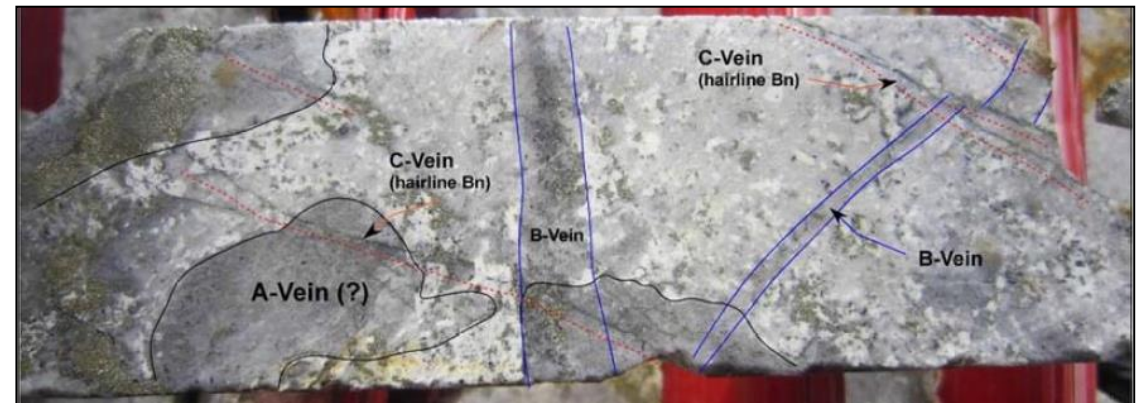
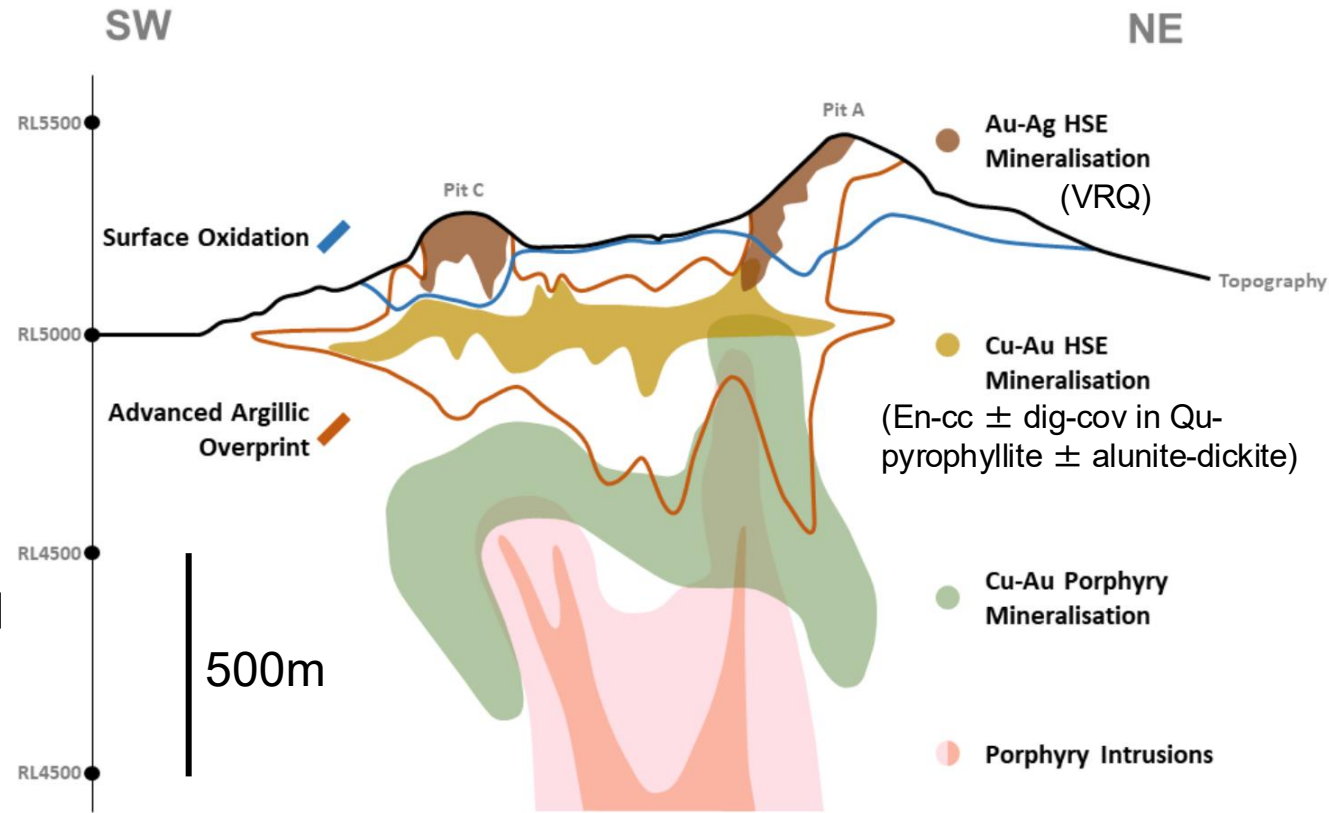


Filo del Sol

Tujuh Bukit

Alteration and Mineralization

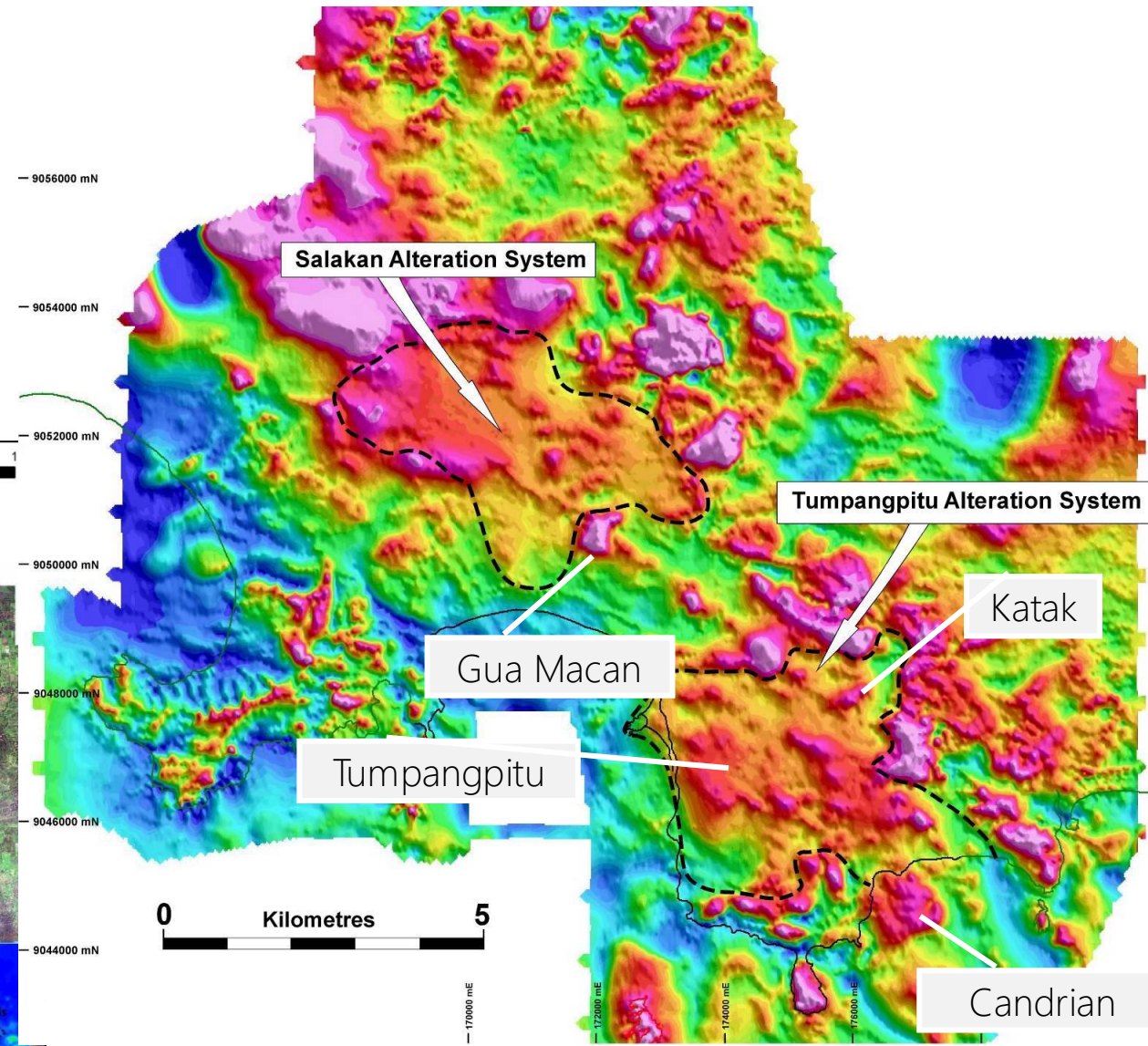
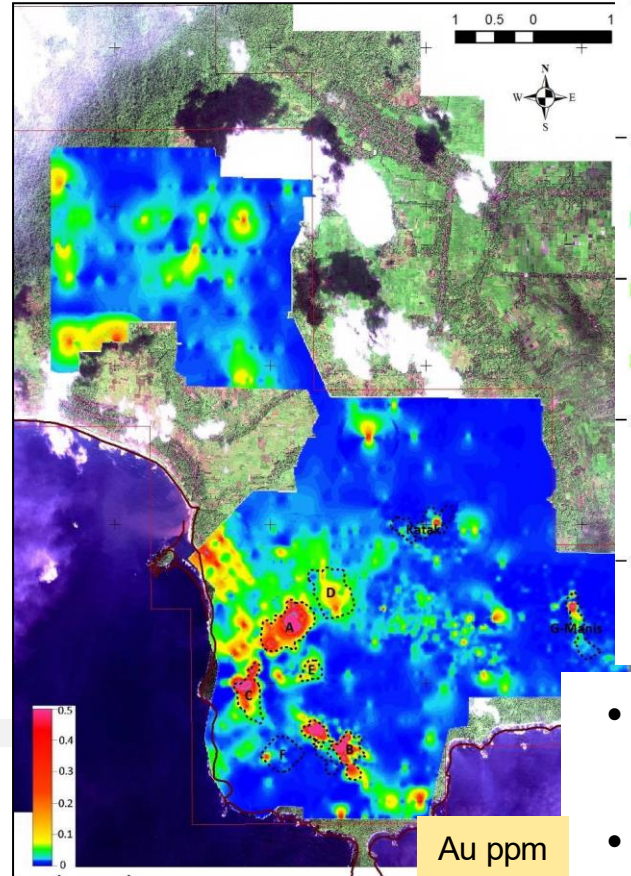
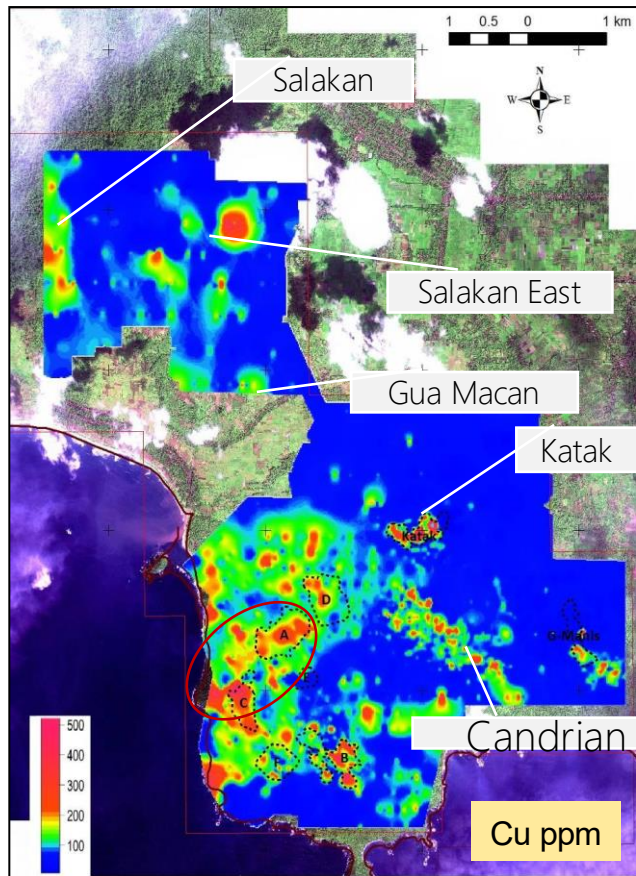
- Upper oxidized Au-Ag zones (A & C) in vuggy residual quartz being mined in open pits
- Tumpangpitu Porphyry portion (~4.5 Ma) in FS for underground mining (1.7 Bt at 0.47% Cu 0.50 g/t Au; Ind+Inf)
- HS and porphyry portions essentially connected
- So far at least 7 centers recognized.
Tumpangpitu, Candrian, Gua Macan (276 Mt at 0.23 g/t Au and 0.16% Cu), Candrian, Kanak, Salakan (to North)
- Despite intense advanced argillic alteration and brecciation see relicts of porphyry-style mineralization. Often, quartz veins are only feature preserved
- Wide variety of pre- and post mineral diatremes.



Advanced Argillic alteration overprinting porphyry system-related A and B quartz veins. CTD-09-112 at 731.2m

Lithocap Geochemistry and Geophysics

Tujuh Bukit, East Java Cu and Au soil geochemistry (both ppm)

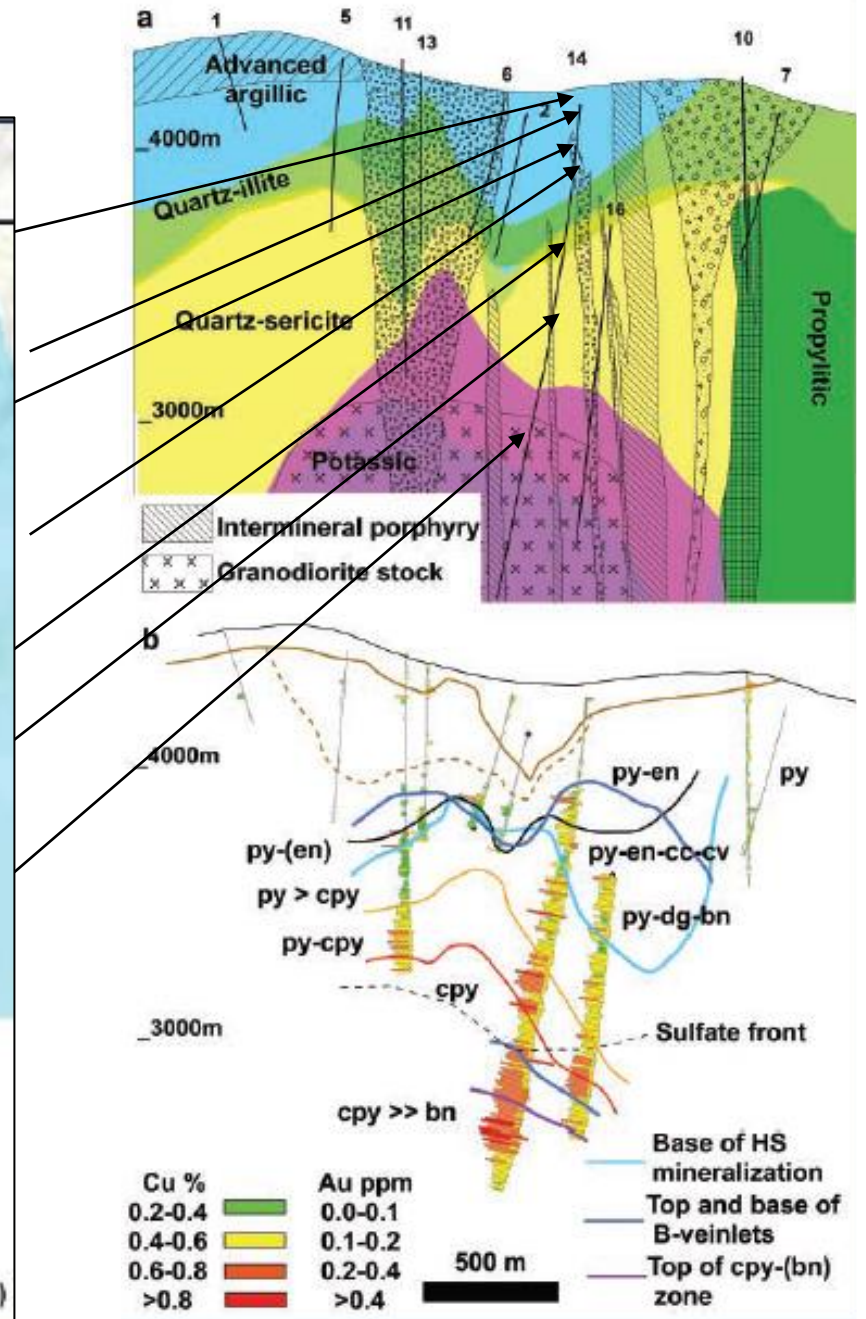
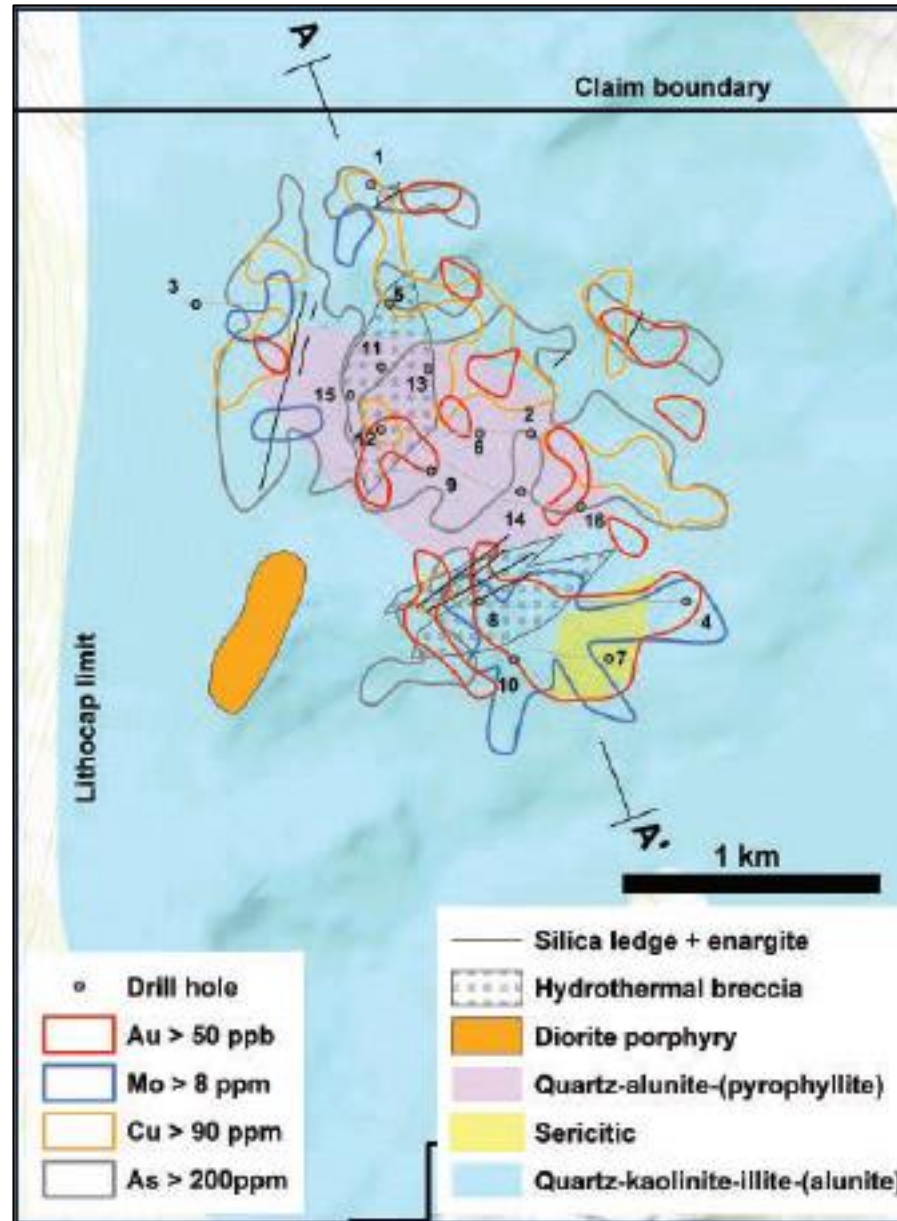


- Advanced argillic alteration in lithocap typically “blurred” signature as magnetite destroyed
- Magnetics highs correspond to mineralized diorite intrusions where lithocap is thin

Lithocap Geochemistry

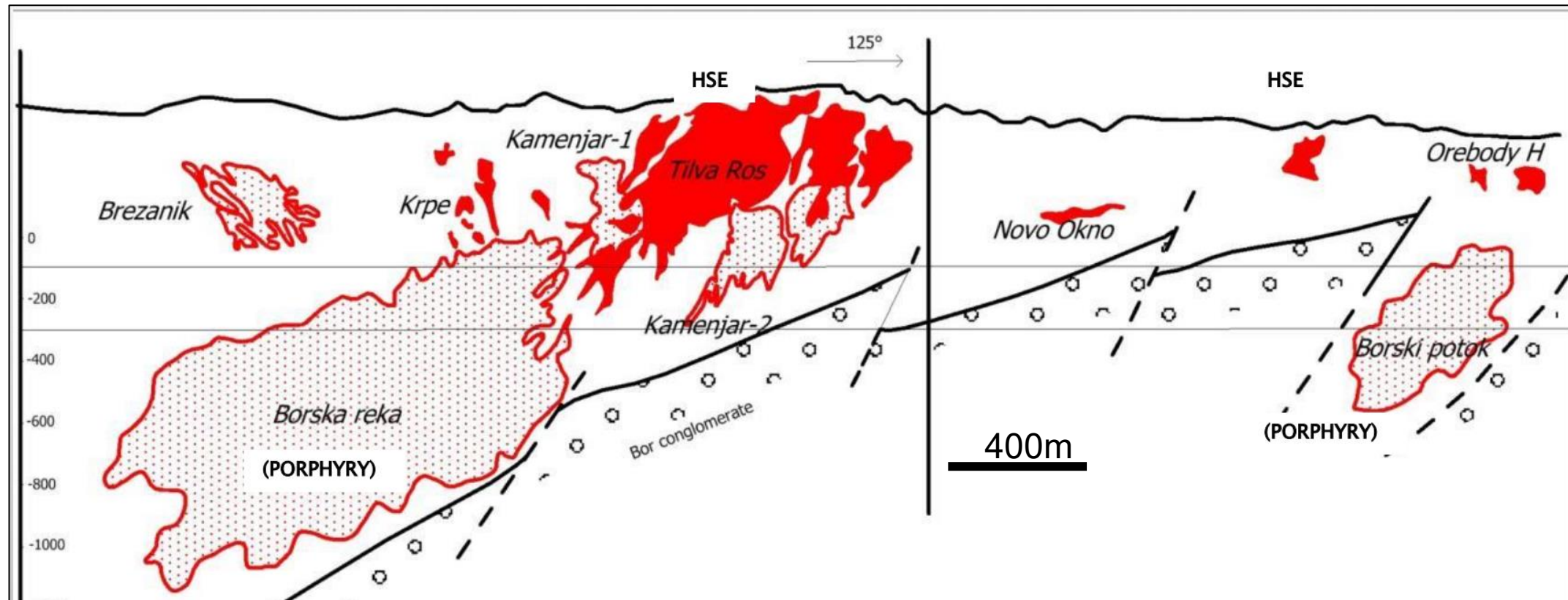
Valeriano, Chile

- Strong response in soil geochemistry for As and lesser extent Au. Cu largely leached in AA alteration
- At 250m downhole a sharp increase in Cu > 300ppm, 0.1 to 0.5 ppm Au and Mo > 50 to 200ppm.
- At depths of ~1,000 to >1,800m chalcopyrite ± bornite-bearing, potassic altered porphyry, with grades of 0.7 to 1.2% Cu_{Equiv}
- Classic sulphide zonation from cpy >> bn to cpy to cpy-py to py > cpy and then py-dg-bn to py-enargite in lithocap



Bor / Čukaru Peki District, Serbia

Porphyry systems with overlying HS lenses

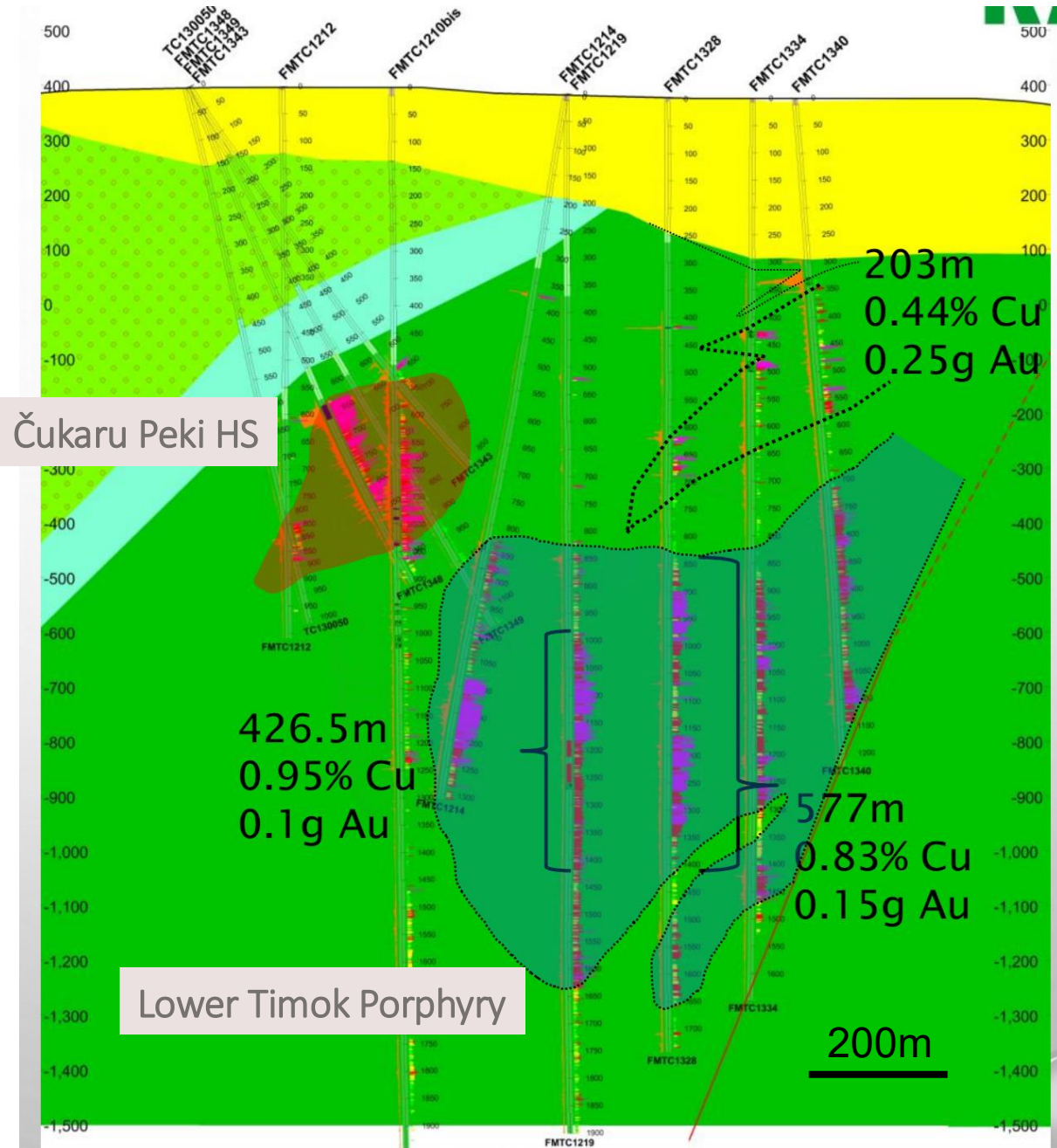


Tethyan Belt. Upper Cretaceous belt (92-67Ma). Mineralization 87-82Ma. Bor ~ 6.7 Mt Cu at 0.84% Cu
Bor HS deposits like Tilva Rosh mined since Roman times; porphyries discovered in late 1970s
0.5-10 Mt exceptionally rich (up to 7% Cu) HS massive sulfide orebodies in Qu-kaol-anhyd-diaspore alteration
Pyrite + covellite + chalcocite/digenite and minor enargite hosted in andesites.

Bor / Čukaru Peki Lithocaps

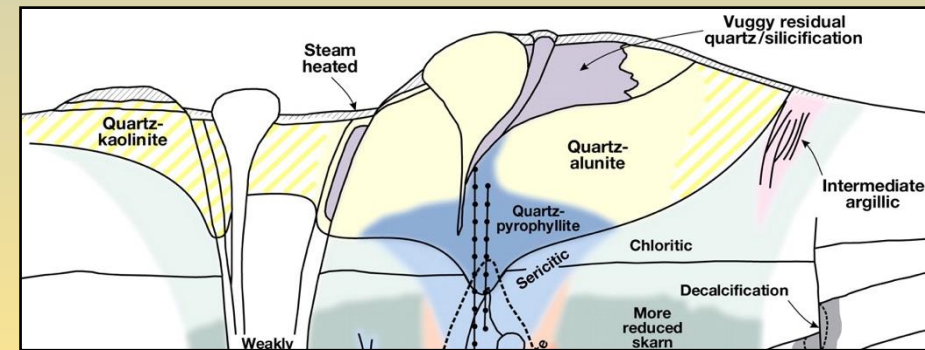
Porphyry systems with overlying HS lenses

- Eastern portion of belt largely covered by post-mineral Cretaceous and later Miocene sediments up to 400m thick, shown in yellow
- Reservoir Minerals traced mineralization under this Miocene cover and targeted CSAMT in underlying andesites
- Discovered an upper high-grade covellite-pyrite Cukaru Peki deposit
 - Mineralization in narrow VRQ and Qu-alunite alteration
 - 27Mt at 3.3 % Cu, 2.1 g/t Au 2018 Reserve
- Later the Lower Timok porphyry
 - 1.7Bt at 0.86% Cu, 0.18 g/t Au & <50ppm As (14.3Mt Cu, 9.6 Moz Au). 2026 inferred Resource
- As is typical in Bor, limited separation of ~ 150m
- Malka Golaja discovery 7km to SE : 150Mt at 1.9% Cu & 0.61 g/t Au.
- Purchased by Nevsun and eventually Zijin Mining



Lessons for Lithocap Exploration: Alteration Zonation

- Assessment of alteration is primarily aimed at vectoring in lithocap towards keel / up flow zone above the causative porphyry
- Intact **vertically zoned alteration** with indications of lateral fluid flow in an “alteration plume” rather than discrete structural controlled feeders / ledges with unaltered rock in between.
- Higher temperature roots (keel) may also contain high temperature aluminosilicates such as andalusite and corundum ($> 370^{\circ}\text{C}$).
- **Topaz** and **zunyite** may indicate proximal up flow zones
- Ideally target Quartz-pyrophyllite zone $\pm$ diaspore zone as it transitions downward to sericitic or sericite-chlorite; patchy textures common at this level.
- Important to look carefully for indications of porphyry style veining (D, B, A veinlets) and relict potassic alteration.



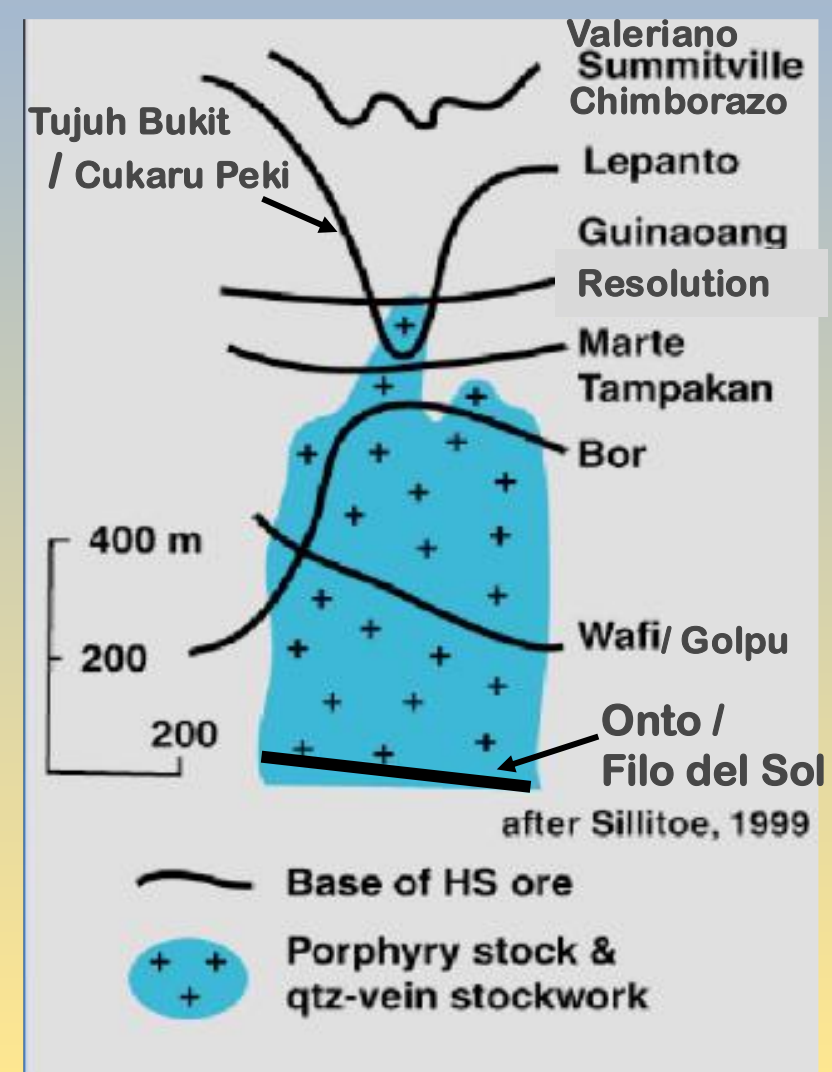
Lessons for Lithocap Exploration: Alteration Zonation

- Short Wavelength Infrared (**SWIR**) data critical (Terraspec, Halo etc); removes guesswork
 - SWIR easy to measure on pulps and RC chips or average over drill core or various more sophisticated core scanning systems
 - First pass structural /alteration analysis with ASTER and increasing variety of new airborne (AVERIS, HyVista/ **HyMap**) and satellite-borne (**Worldview3**, PRISMA, EO-1) hyperspectral systems available
- **Use caution when trying to vector** using alunite 1480nm peak position, and element ratios such as La/Pb and Sr/Pb in alunite and alunite-bearing whole rock samples- doesn't work in Onto where there is a large dataset
- Permeability critical in focussing alteration and HS mineralization (e.g. diatreme in Onto and Alturas, pyroclastic packages as in Yanacocha and Lepanto)
- Phreatomagmatic (diatreme) and /or phreatic **breccias** important
 - ✓ Erupt through, and disrupt, earlier lithocap alteration / porphyries → fragments of underlying alteration and / or mineralization. **Free Drill Holes!**



Lithocap Exploration: Geometry and Zonation

- High sulphidation style mineralization is superimposed on the lithocap alteration or forms at same time as alteration
- Variable separation of HS epithermal mineralization from the porphyry-related mineralization
 - Superimposed (Onto), to impinged (Tujit Bukit, Golpu) to close (Čukaru Peki) to separated by 500m or more vertically (e.g. Chimborazo)
- Lithocap alteration and HS mineralization often lateral rather than above PCD (e.g. Lepanto, Chelopech)
- Tabular HS veins can overprint PCD (e.g. Chuquicamata, Collahuasi) or margin portions of PCD (Lunahuasi)
- Disseminated Au-Ag orebodies (e.g. Yanacocha, Pascua-Lama) can occur in upper vuggy residual quartz / silicic alterations; causative porphyry not evident



Lessons for Lithocap Exploration

- Very large copper deposits (> 20 Mt Cu, 37Moz Au) can form very quickly in < 400,000 years in very **young** rocks (0.8 to 0.4 Ma in Onto)
 - ✓ target very young arc sequences where subdued volcanic landforms are still visible
 - ✓ In older arcs, burial by post-mineral cover beneficial
- The Onto deposit formed within and under part of a **largely barren AAA lithocap**
 - ✓ Upper vuggy residual quartz and silicic alteration barren at Onto. Several HS systems have stacked vuggy residual zones with upper ones are barren (e.g. Quimsacocha, Ecuador)
 - ✓ **Reassess lithocaps that were considered to be barren**; gold companies looking for oxidized high sulphidation systems (holes < 250m)
- The vast majority of Cu-Au mineralization at Onto is hosted in **quartz alunite and quartz-alunite-pyrophyllite alteration** often well below (>200m) the sub-horizontal vuggy residual quartz horizons
- Looking for **thick continuous AA lithocap with Ponding and** trapping of fluids and metals below relatively impermeable (capping andesites at Onto; mafic dikes /sills at Filo del Sol) or silicified VRQ (Onto)



Lessons for Lithocap Exploration: Geochemistry & HS Zonation

- Determining the position, i.e. **level of erosion**, in an advanced argillic lithocap is critical
 - **Upper parts of lithocap often barren.** Extremely subtle response if high level (e.g. Onto), to moderate (Valeriano, Capiche) to strong response (e.g. Tujuh Bukit with > 300ppm Cu and > 200 ppb Au)
- Cu (and other metals) strongly leached and depleted by supergene weathering facilitated by low buffering capacity of advanced argillic alteration and high pyrite content
- Initially, **selective sampling** may be more effective than grid-based sampling in early-stage high level lithocap environments
 - ✓ Sample phreatic breccias, diatremes and fault zones; “leakage” from concealed mineralization
- High level of Sb-As- Bi-Hg-S⁰ vs deeper Cu-Au and Mo
- Proximal Py-Cv core with more distal Py-En-Lz (lateral); Cp to Bo-Dg to Cov with ↑ fS₂ (vertical)
- Intact systems, like Onto, show an “upper” Ag-As-Sb-Bi horizon, 30 to 150 above main copper-gold zones of mineralization



Lessons for Lithocap Exploration: Geophysics

- **Magnetic** surveys useful first pass for geology.
 - Lithocaps generally demagnetized with total loss of magnetite: magnetic lows / subdued signature
 - In many case studies (e.g. Mankayan, Yanacocha) lithocaps not particularly evident in magnetic surveys
 - May **detect magnetic dioritic intrusions** with potassic alteration if lithocap is thin or eroded (HLE, Tujuh Bukit)
- **Magnetotellurics** (MT) surveys can be useful for outlining conductive sulphides and / or alteration
 - The Onto HS deposit is defined by very low resistivity (<2 Ohm-m) within low resistivity host rock
 - Modeling indicate airborne MT (MobileMT, ZTEM) would not detect Onto deposit at > 500 m
 - Silicic and vuggy residual quartz alteration delineated as resistivity highs- often host gold with pyrite
- **Induced Polarization** can outline pyrite in lithocap mineralization but limited potential to detect porphyry system within / beneath HS mineralization. Quantec's Titan / Orion systems- deep IP + MT



Lithocap Exploration

Why target lithocaps?

1. Targeting lithocaps means that the **complete porphyry system** is potentially present at depth, including high grade ore shell over top of the porphyry intrusions
 2. Commonly the **prize can be the overlying higher grade (> 3% Cu) HS mineralization** rather than the lower grade porphyry portion (Bor, Onto)
 - Encouraging that in several districts' **covellite** $\pm$ digenite-chalcocite is dominant, rather than enargite
 - Overprinting AA alteration / HS mineralization enhances grade of porphyry mineralization (Resolution, Oyu Tolgoi) –improves economics!
 3. The presence of well-developed HS epithermal mineralization or even a barren lithocap makes an underlying porphyry system likely to be present
 - At most, < 1 km below, and / or 1-3 km lateral but **usually much less**
 - Can be complicated if different aged events are superimposed
 4. The advantage of exploring in a lithocap is that it presents a much **bigger target** than the actual mineralized portion of the porphyry system...but easy to be out on fringes
 5. Determining the position, i.e. **level of erosion**, in an advanced argillic lithocap is critical for understanding the expected geochemical and geophysical response
- No “silver bullets” in lithocap exploration; requires thorough understanding geology and the alteration and sulphide zonation
 - **Persistence and a generous budget for drilling deep holes!**

