



Center for **EXPLORATION
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PODEROSA

CET Member's Day, Friday,
October 29th 2021



Looking beyond the horizon: Inherited tectonic frameworks and ore deposit localization

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Acknowledgements:

S.G. Hagemann,
N. Thébaud, A.I.S. Kemp, J. Hronsky, T. Ireland, C. Villanes

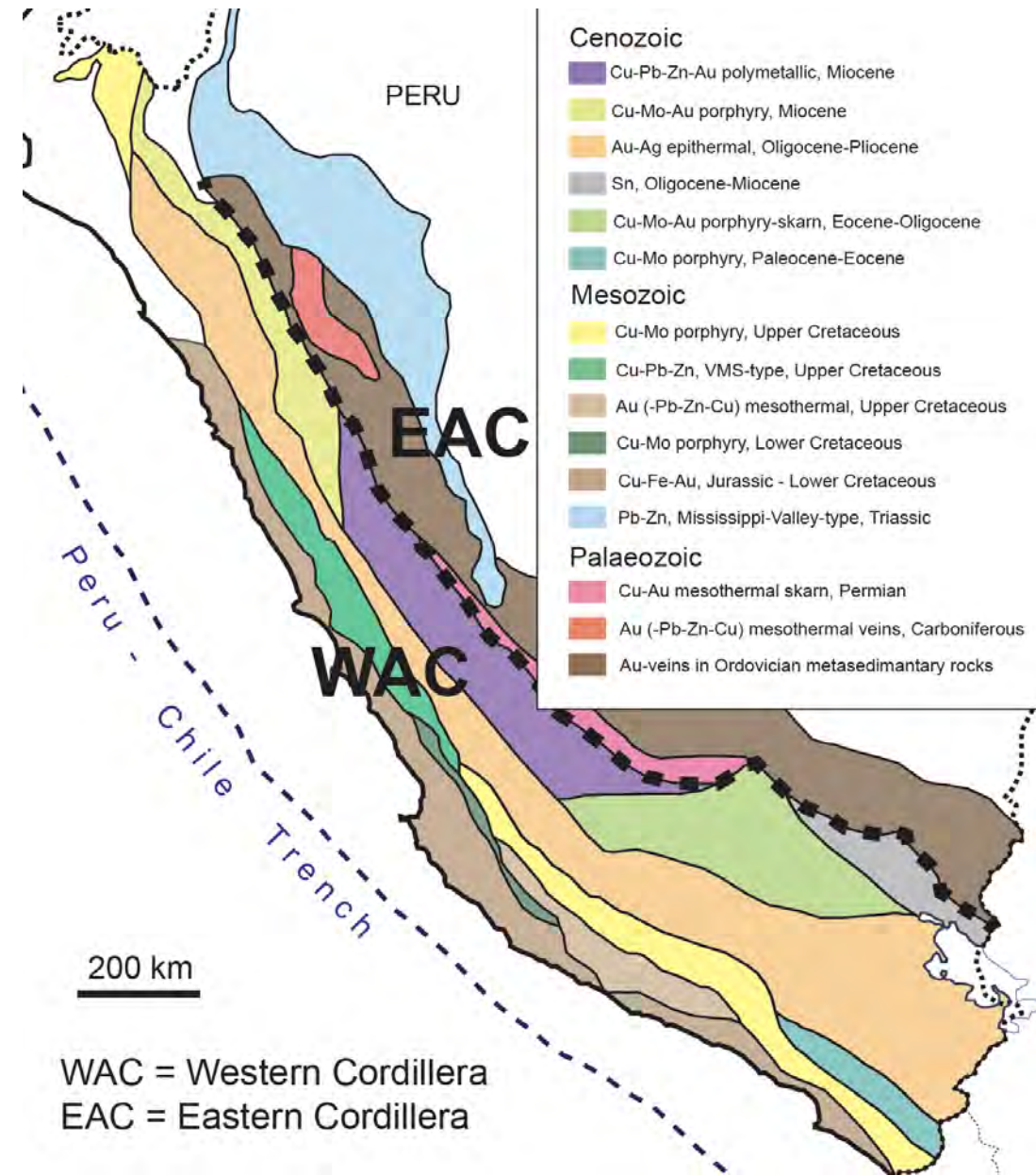


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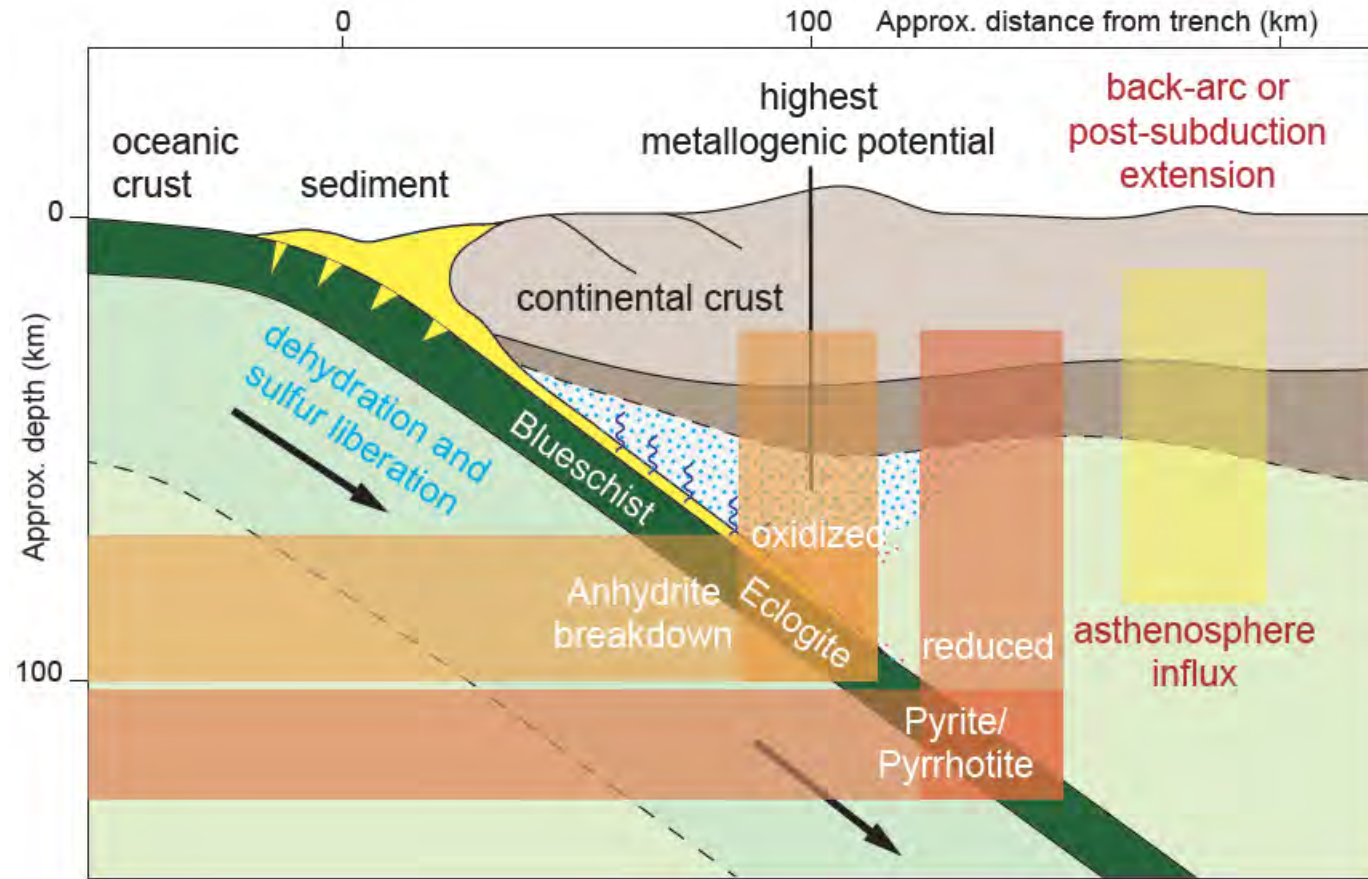


Andean Mineral Belts and Spatial Distribution of Deposits



WAC = Western Cordillera
EAC = Eastern Cordillera

Formation of Mineral Belts

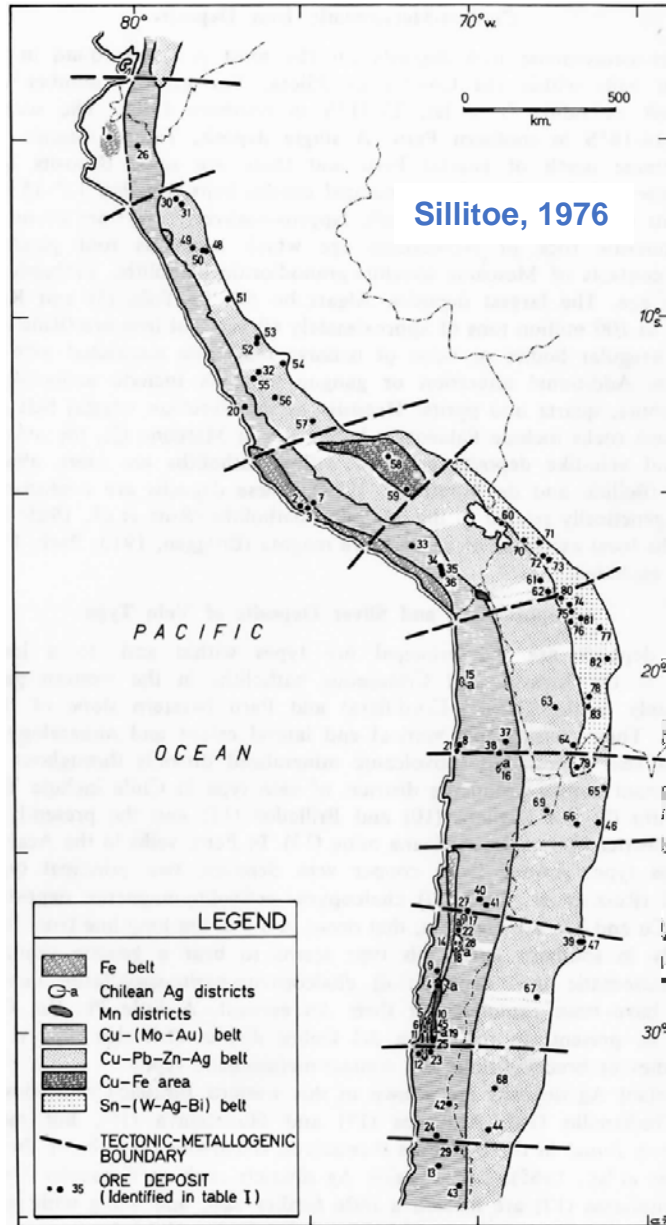


D. Wiemer, based on e.g., Sillitoe, 1976; Tomkins & Evans, 2015; Li et al., 2020

Andean Mineral Belts and Spatial Distribution of Deposits

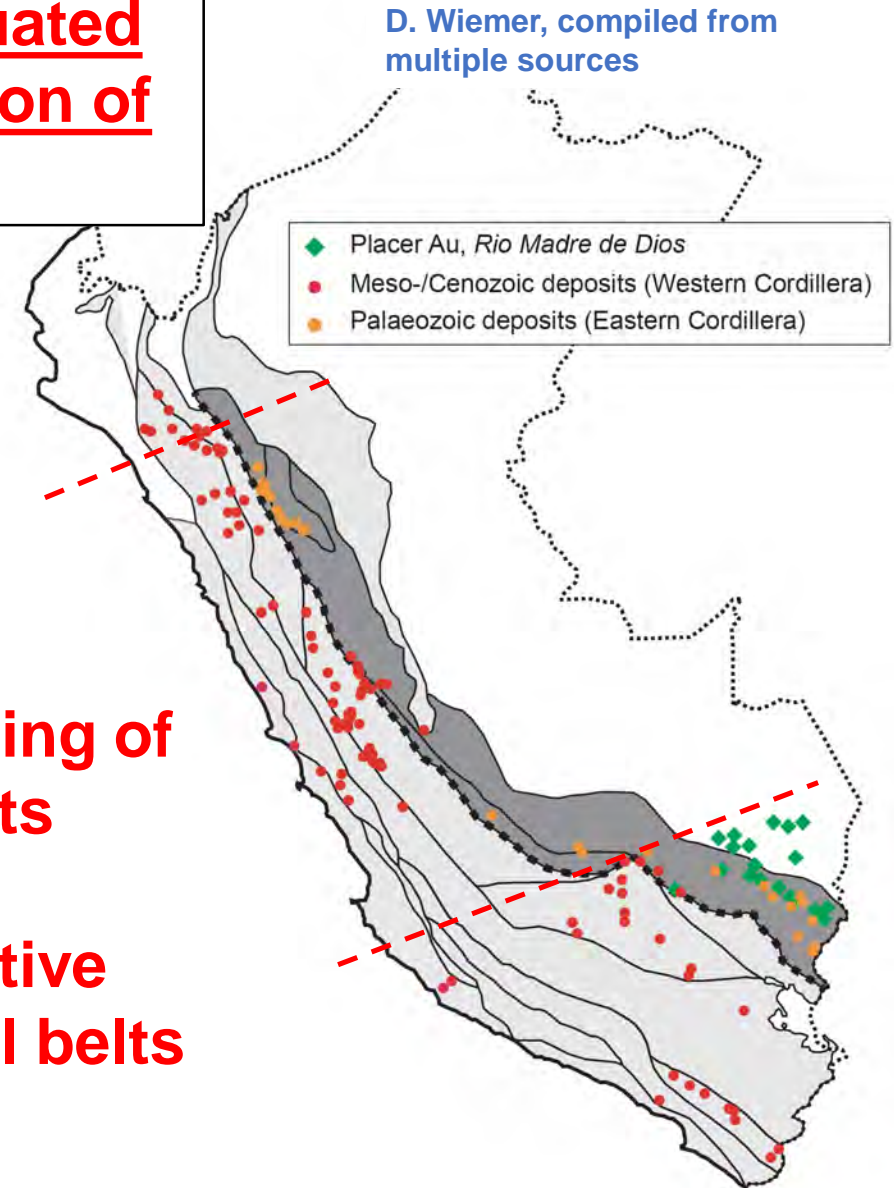
1. Along-strike orogenic segmentation

changes in
geology and
mineral
endowments



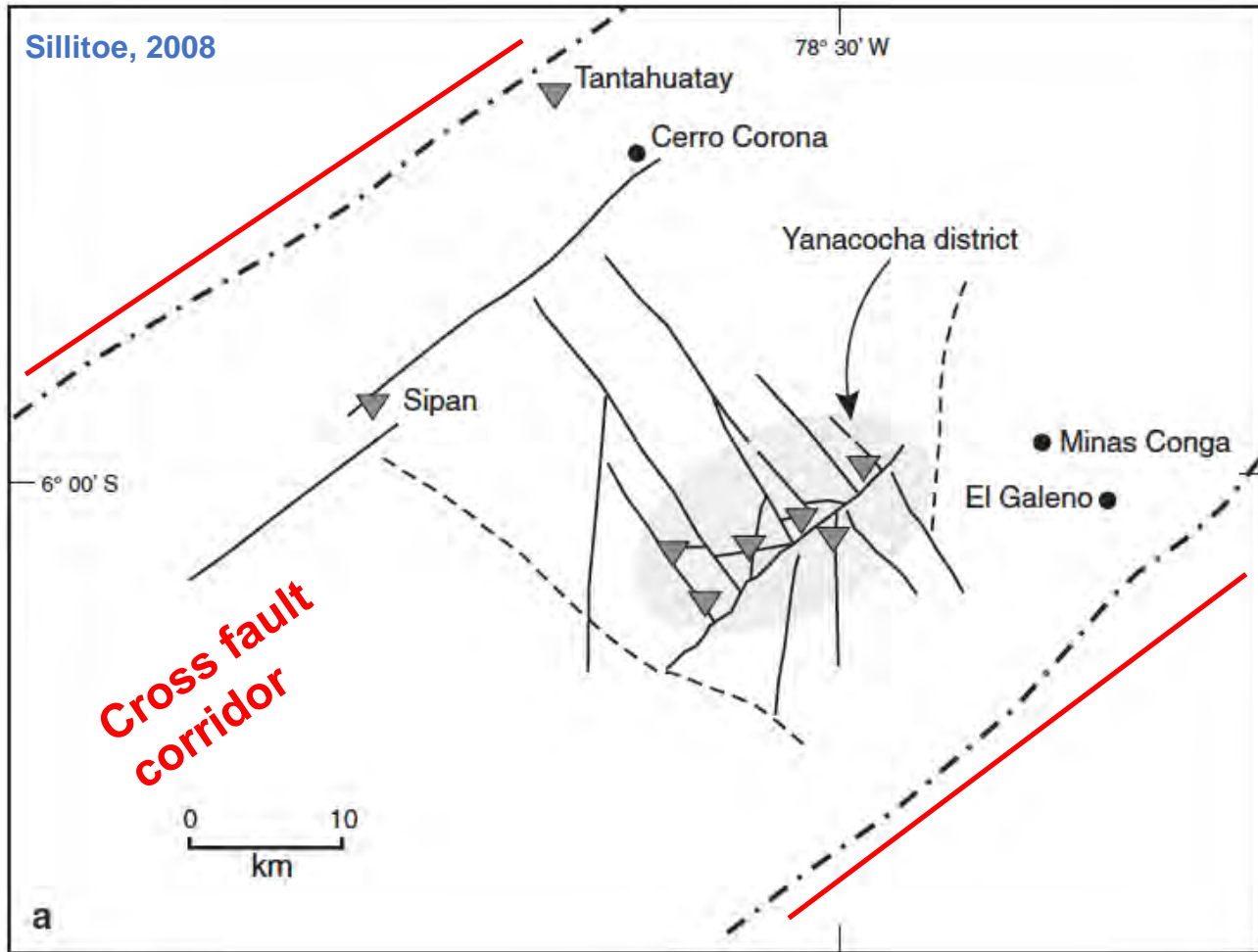
2. Punctuated distribution of deposits

clustering of
deposits
within
respective
mineral belts



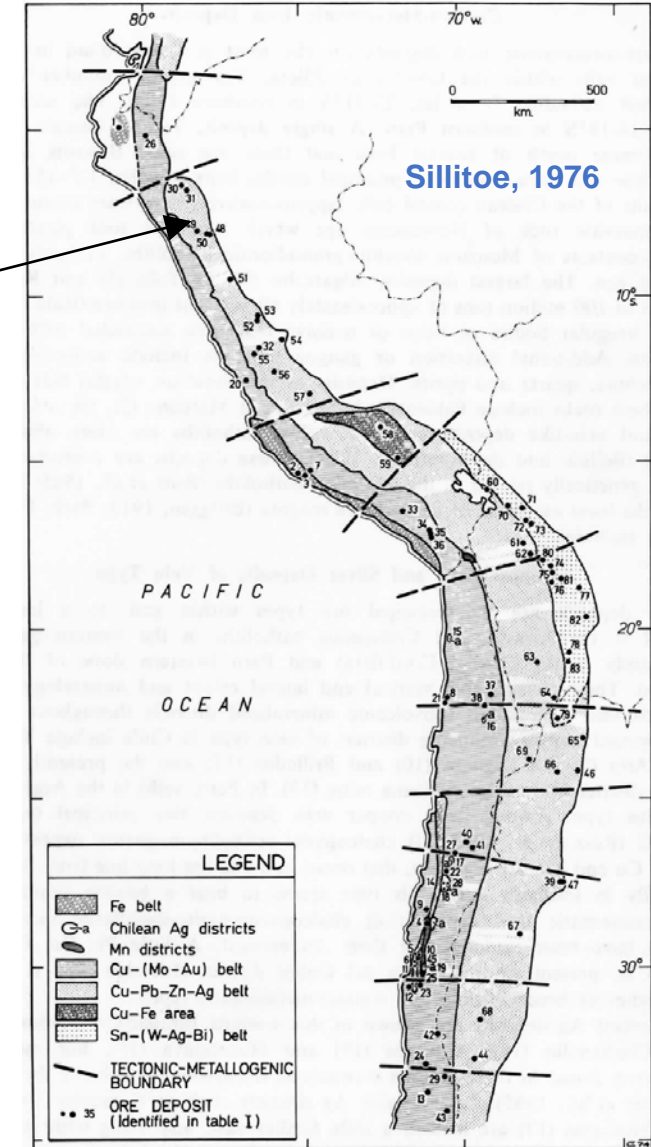
Current Model – Syn-Arc Cross Faults

- **Strike-normal cross structures associated with first-order faults**
- **Sub-parallel to along-strike orogenic segmentation**
- **Control sites of mineralization**



Yanacocha District

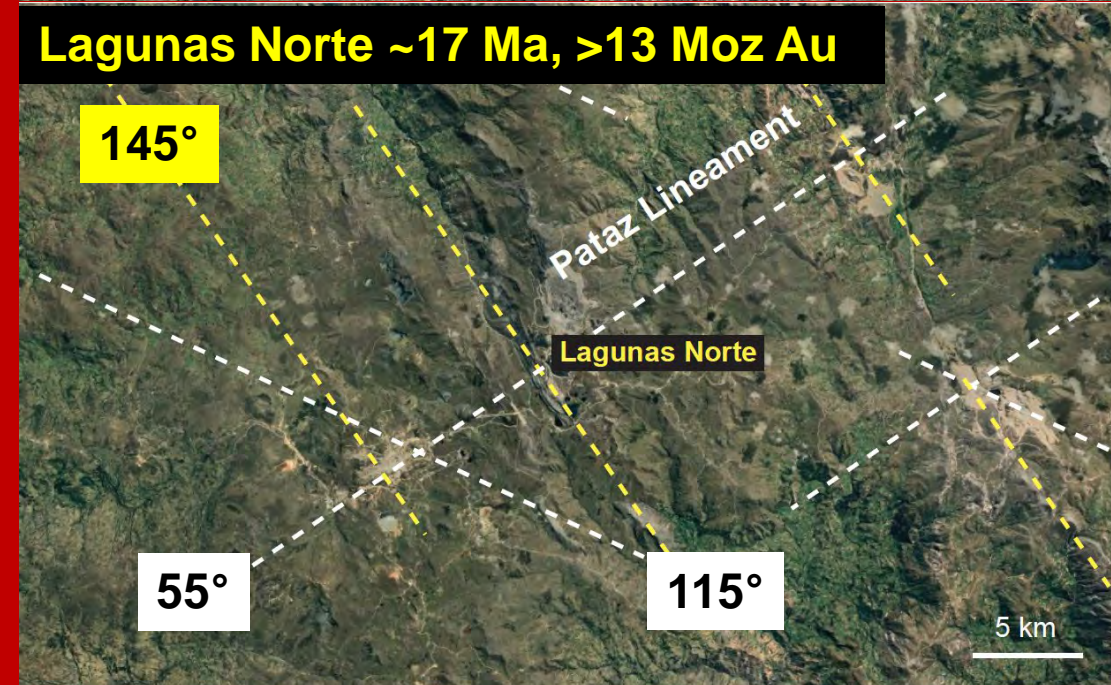
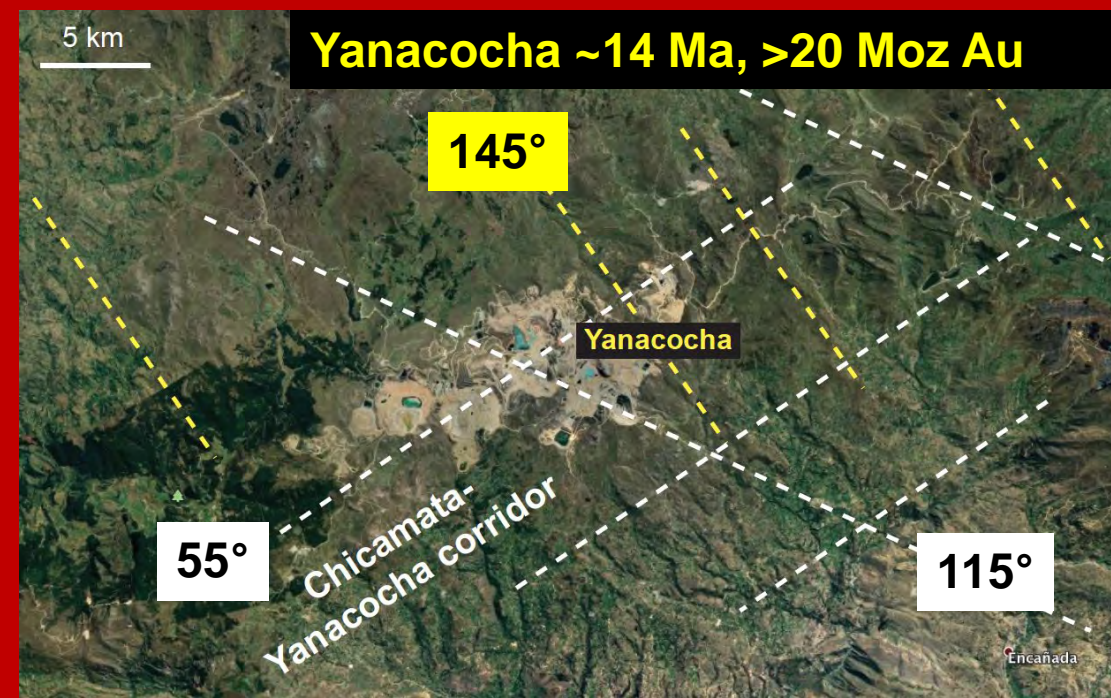
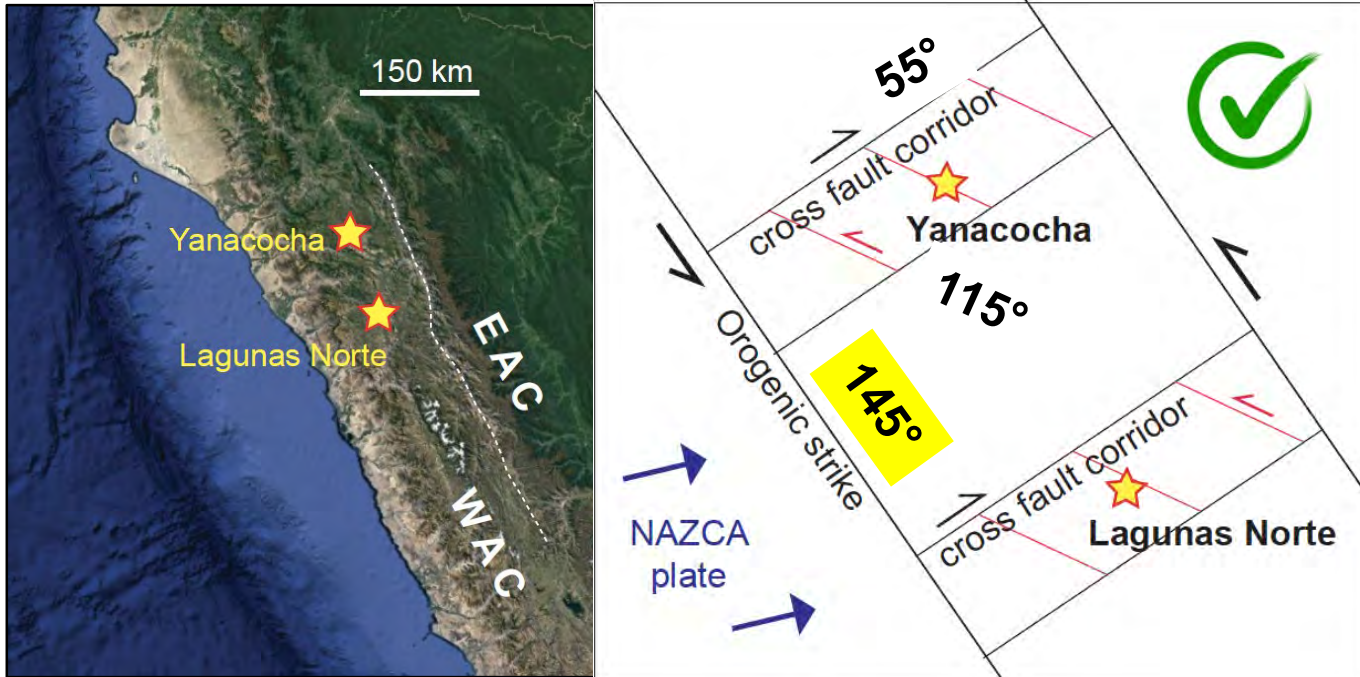
- Deposit type**
- ▼ High-sulfidation epithermal Au±Ag
 - ▲ Intermediate-sulfidation epithermal Au
 - Porphyry Cu-Au
- Fault**
- ▲▲ Reverse fault
 - - - Transverse fault / lineament
 - · - · - Structural corridor limits



Current Model – Syn-Arc Cross Faults

Testing - Case: Yanacocha and Lagunas Norte:

- 145°-striking 1st-order “Andean strike”
 - 55°-striking 2nd-order “Cross fault corridors”
 - 115° -striking 2nd/3rd-order transverse structures
- Reasonable kinematic framework!
- Deposits focus on structural intersections!
- Commonly observed spacing (~100 km)



Current Model – Syn-Arc Cross Faults

...HOWEVER:

PATAZ-PARCOY:

- Same structural trends: 55°, 145° and 115°
- Formed >300 Myrs earlier (distinct accretionary event!)

→ We must consider structural inheritance from the older continent to the east!

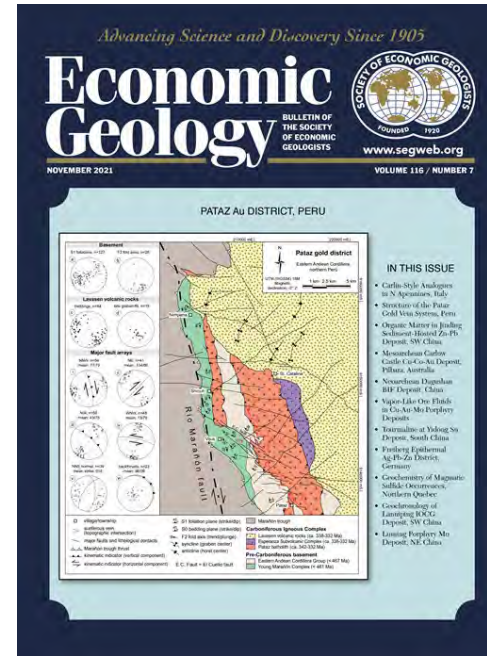


Inheritance – Pataz (>12 Moz Au) – District to deposit scale

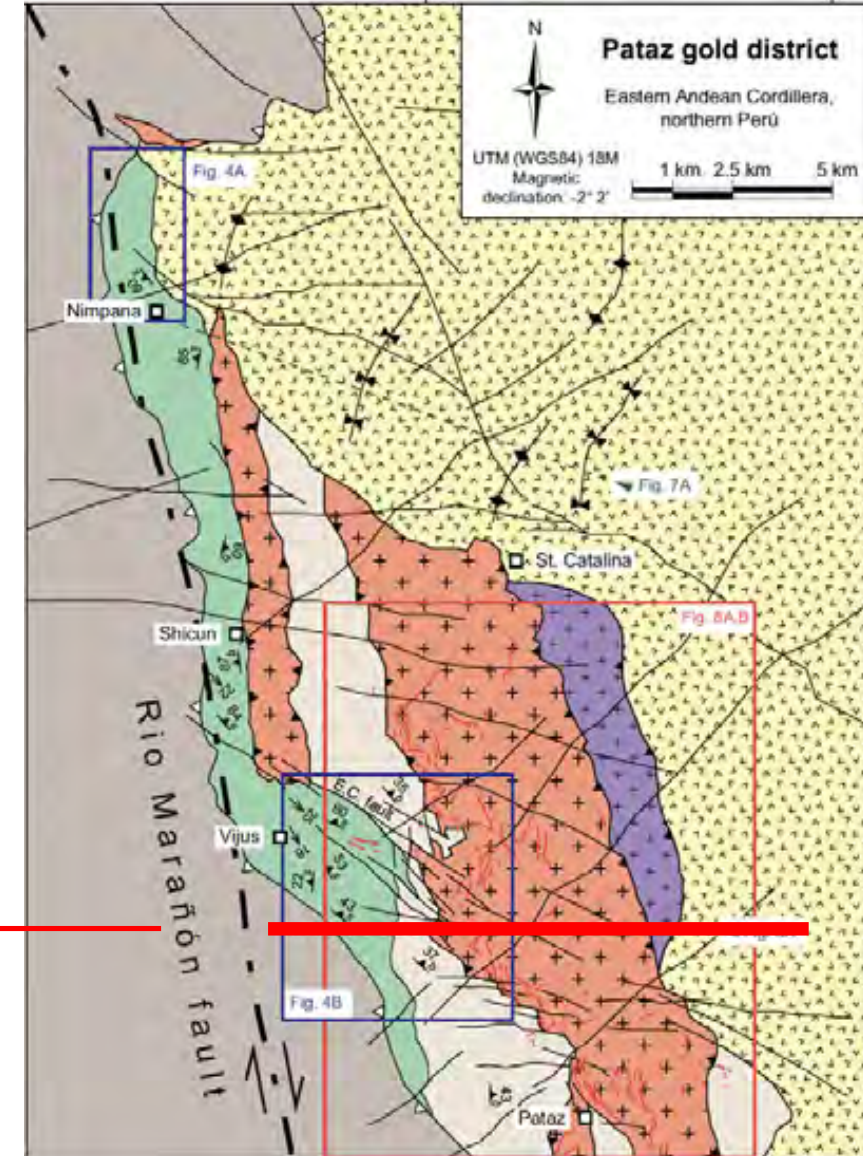
→ Two main paragenetic stages
I: Qz-Py, II: Qz-Py-Sp-Gn

→ Same structural-hydrothermal vein system architecture-geometry

→ Veins follow pre-existing weak-zones within the Pataz Batholith

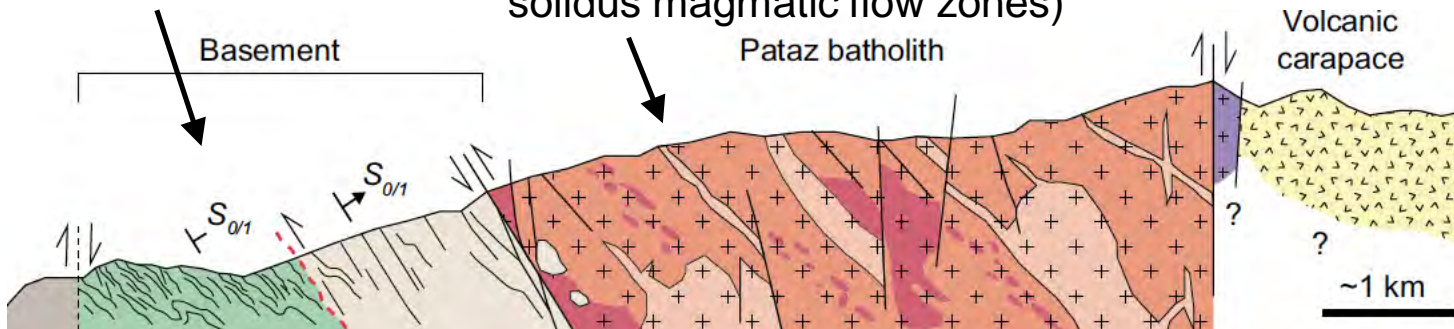


Wiemer et al., 2021



D₂ -basement structures

Inherited weak-zones
(intrusive contacts, supra-solidus magmatic flow zones)

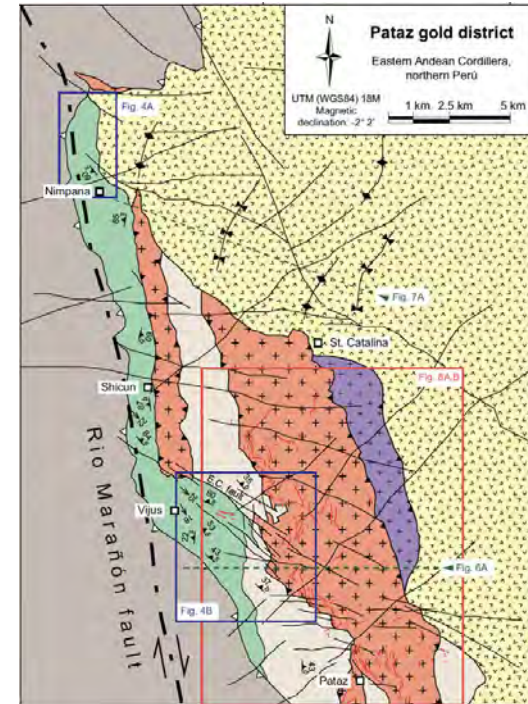
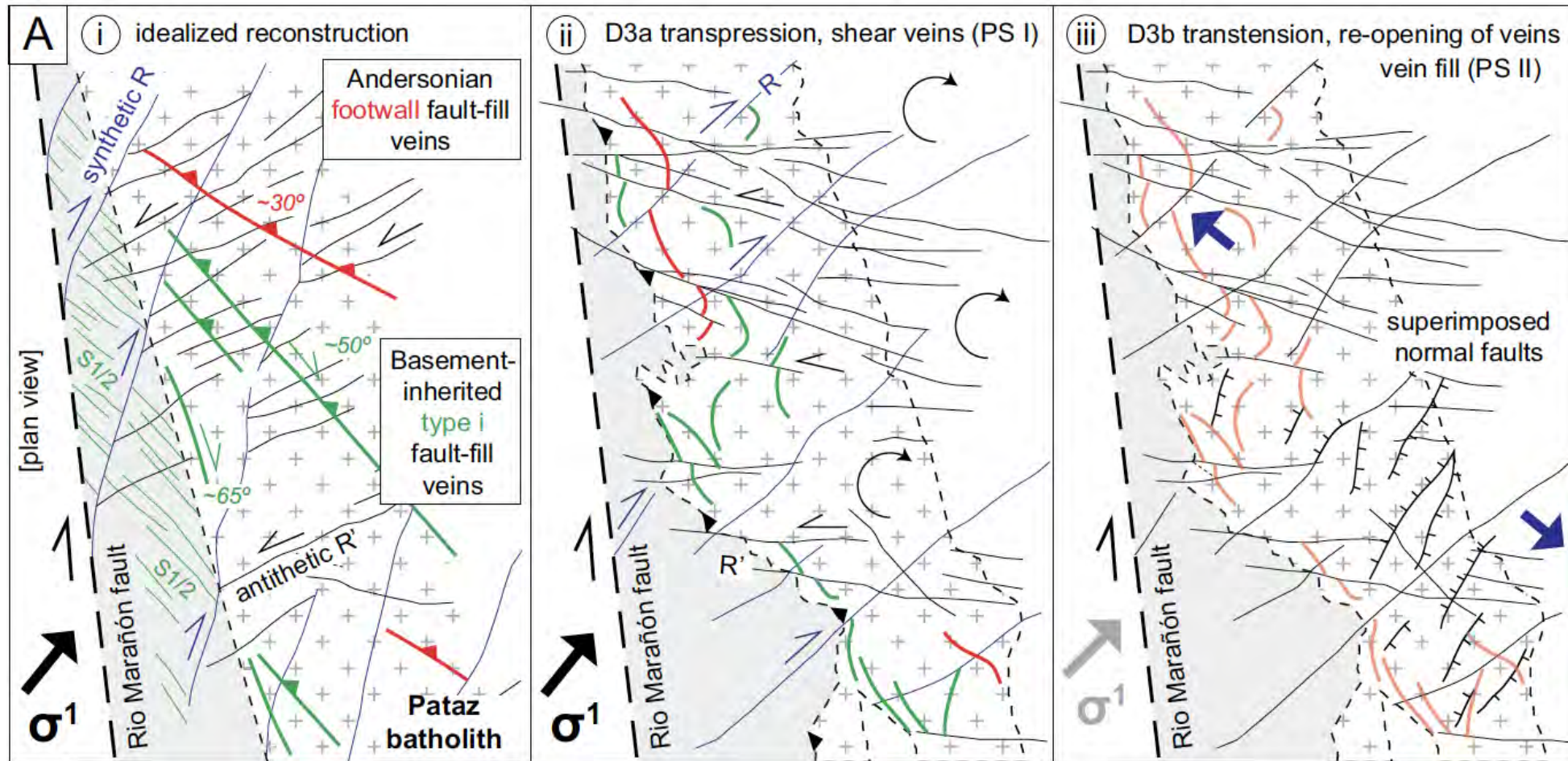


Inheritance – Pataz (>12 Moz Au) – District to deposit scale

District-deposit-vein scale kinematic framework and evolution

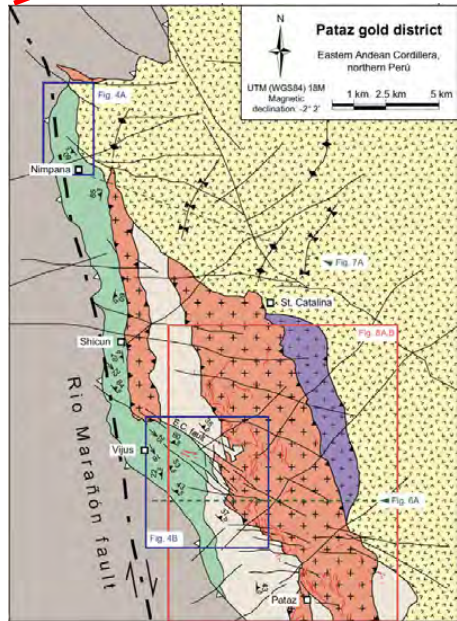
– **Critical at respective scale!**

i.e., where to put the next drill core, considering vein geometry and displacements

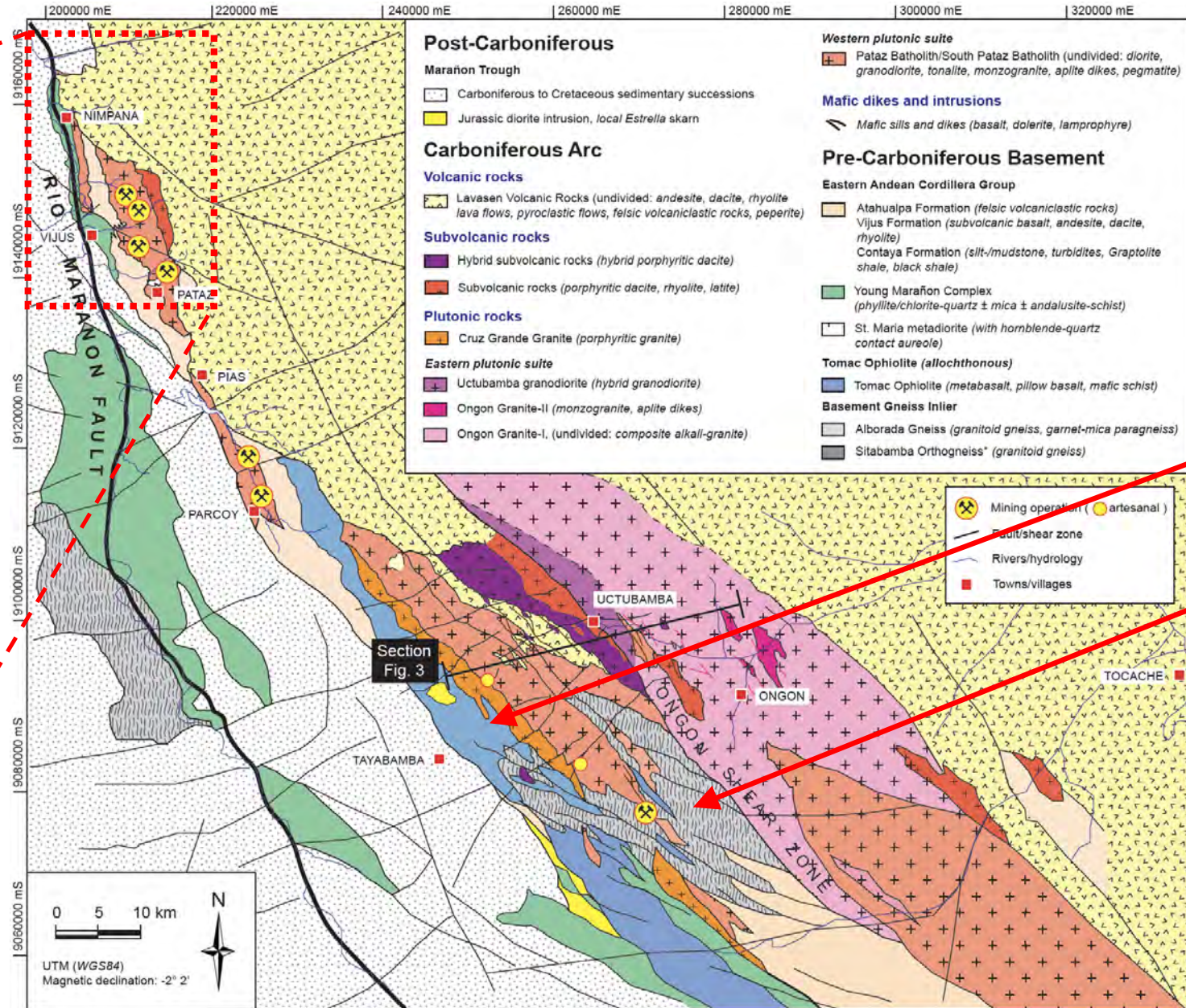


Wiemer et al., 2021

Inheritance – Pataz – Regional Scale



Wiemer et al., 2021



Pre-Carboniferous basement components

Tomac Ophiolite

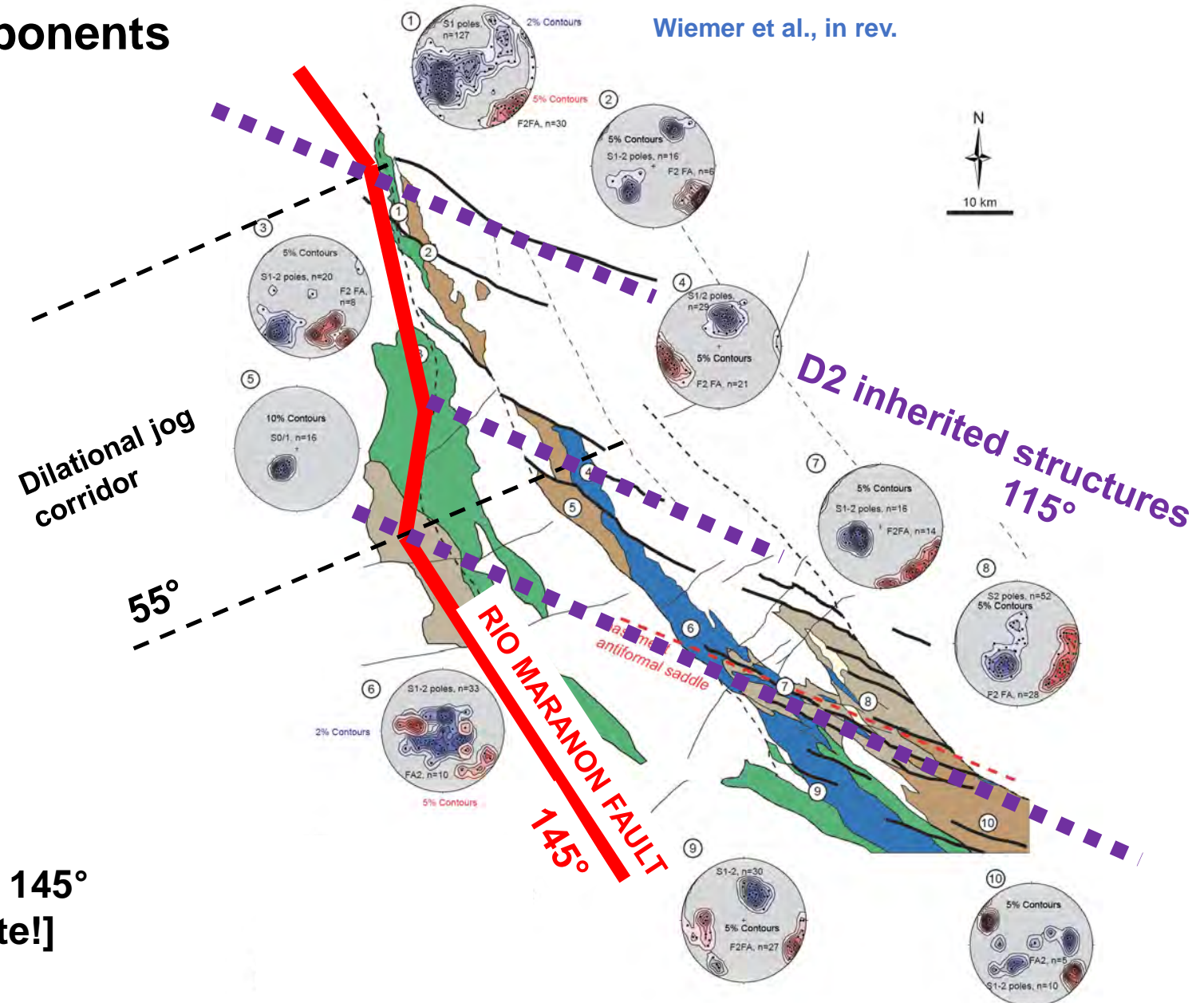
High-grade gneiss

Wiemer et al., in rev.

Inheritance – Pataz – Regional Scale

Pre-Carboniferous basement components

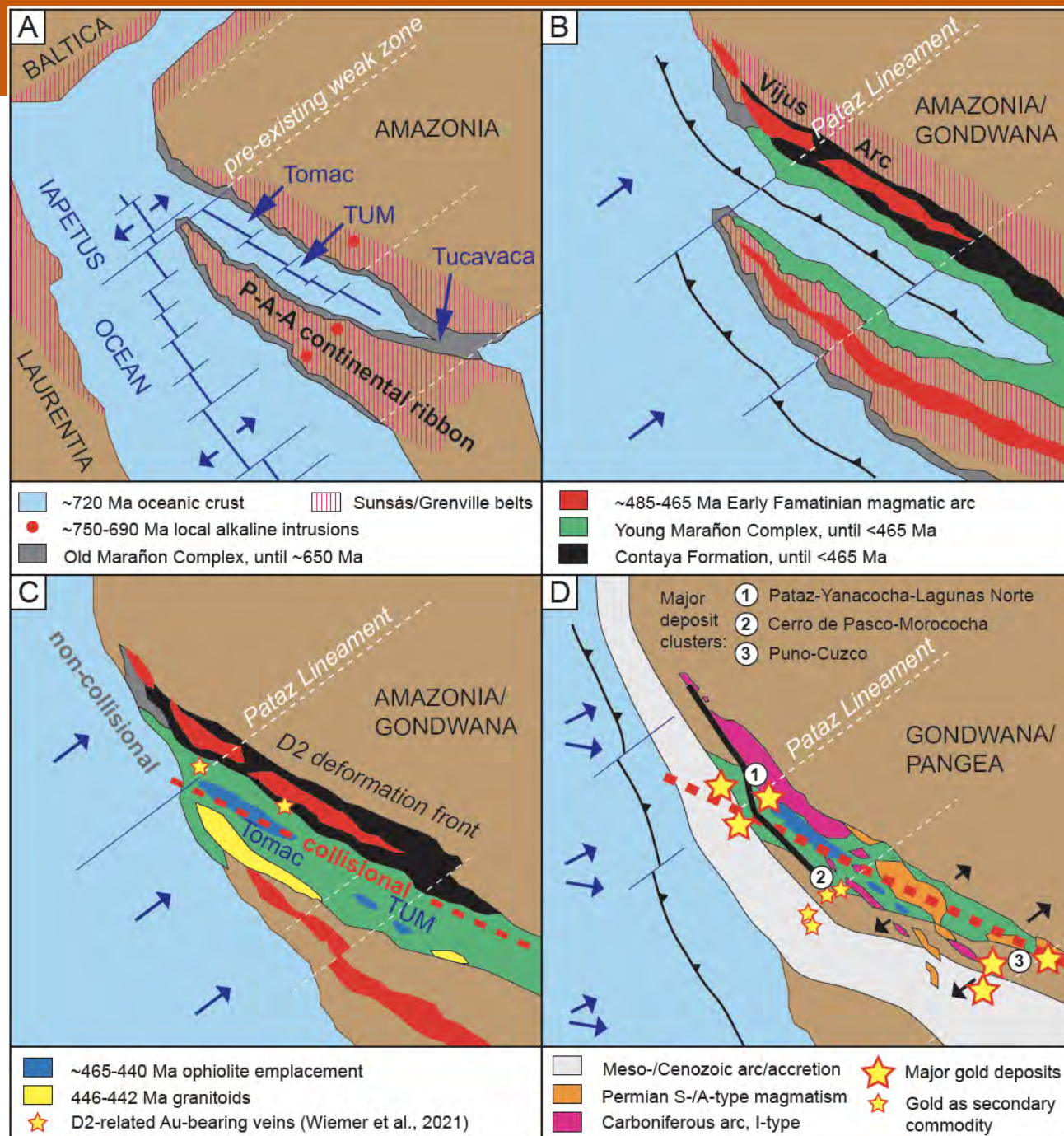
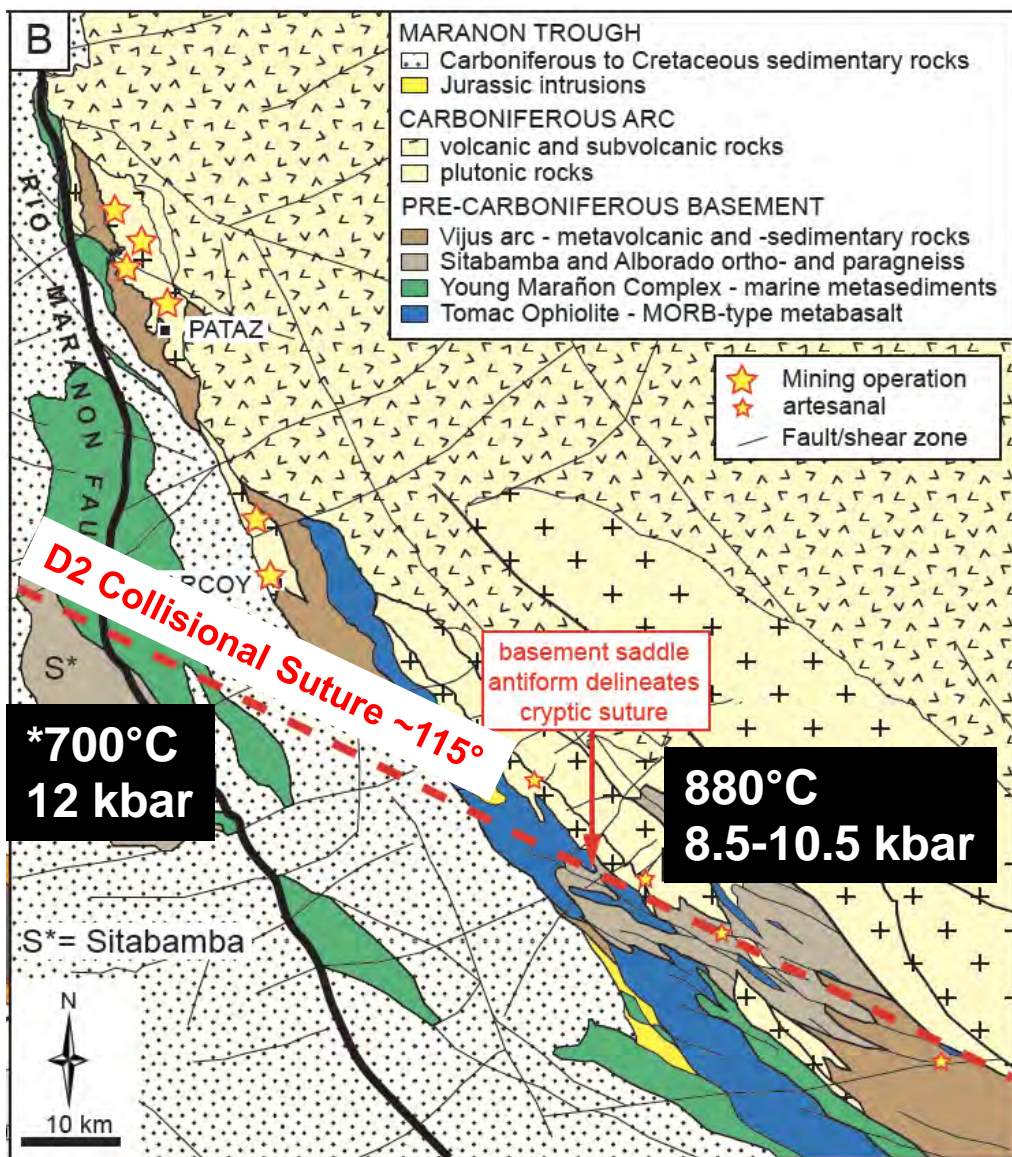
- Uplifted and exposed along Andean orogen strike-parallel structures (145°)
- But: distinct internal D2 structural grain
- Controlling regional-scale Carboniferous jog-geometry



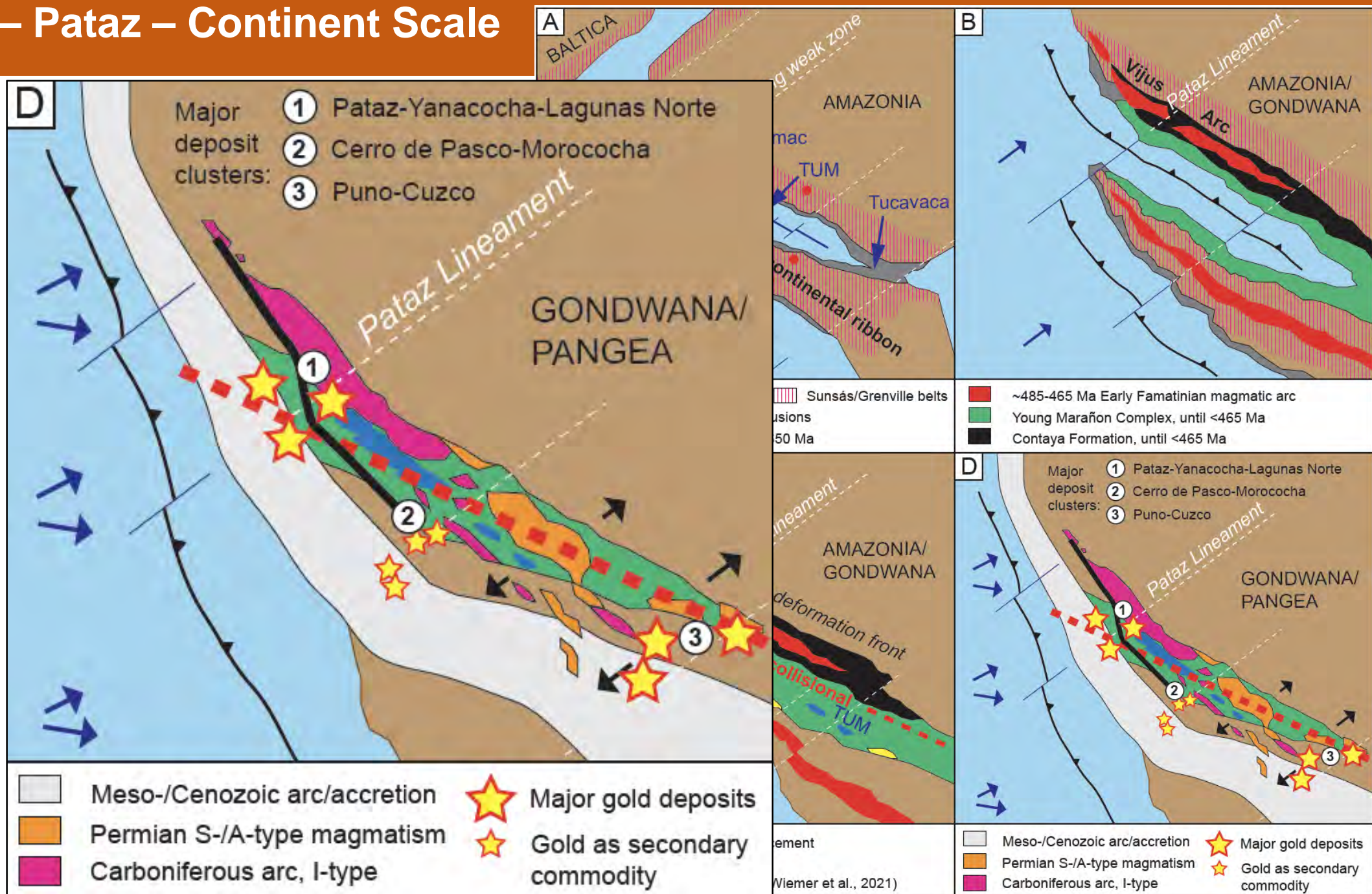
[Note: main structural trends: 55°, 115°, 145°
→ Remember: Yanacocha/Lagunas Norte!]

Inheritance – Pataz – Continent Scale

Wiemer et al., in rev.

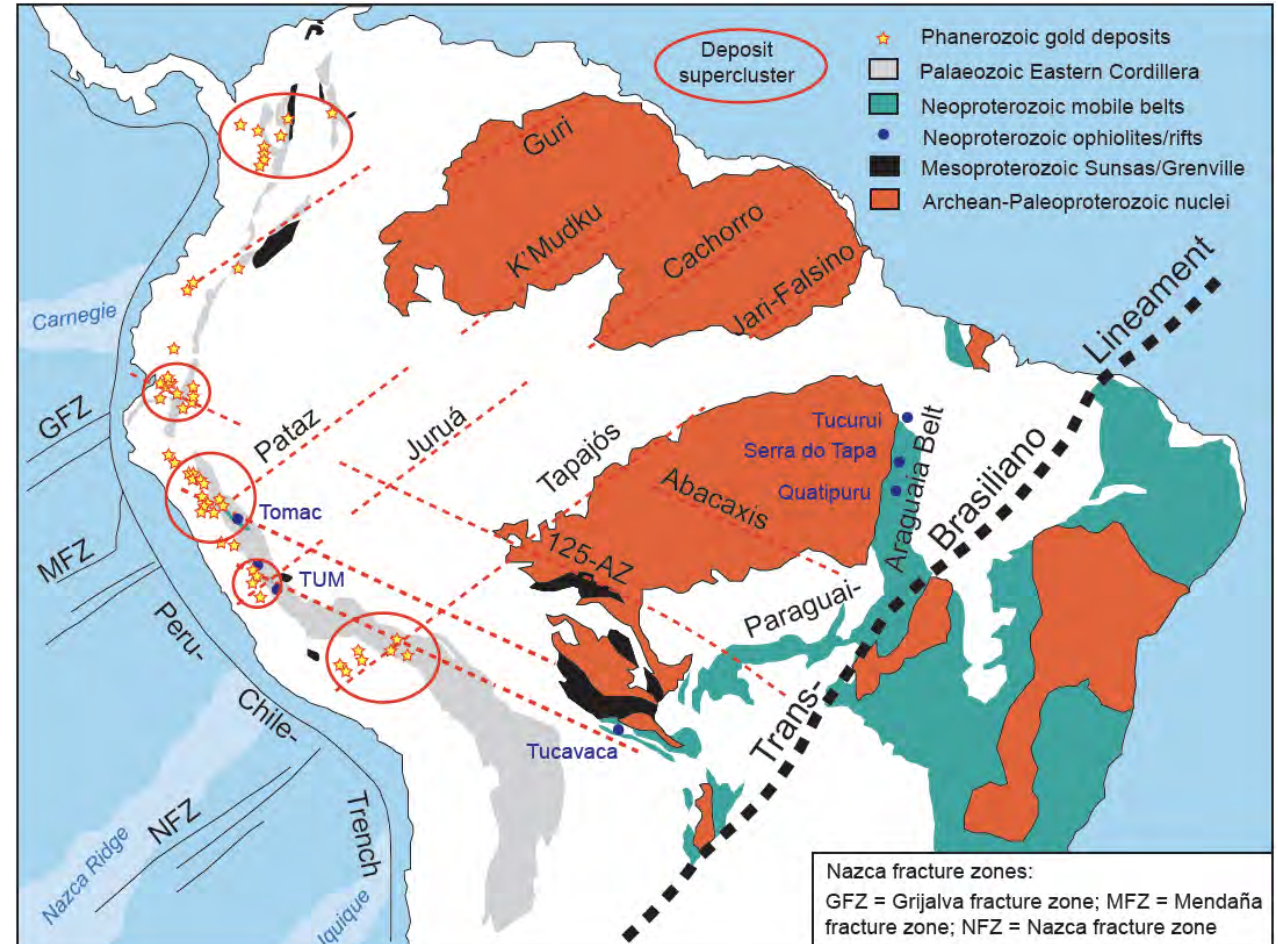
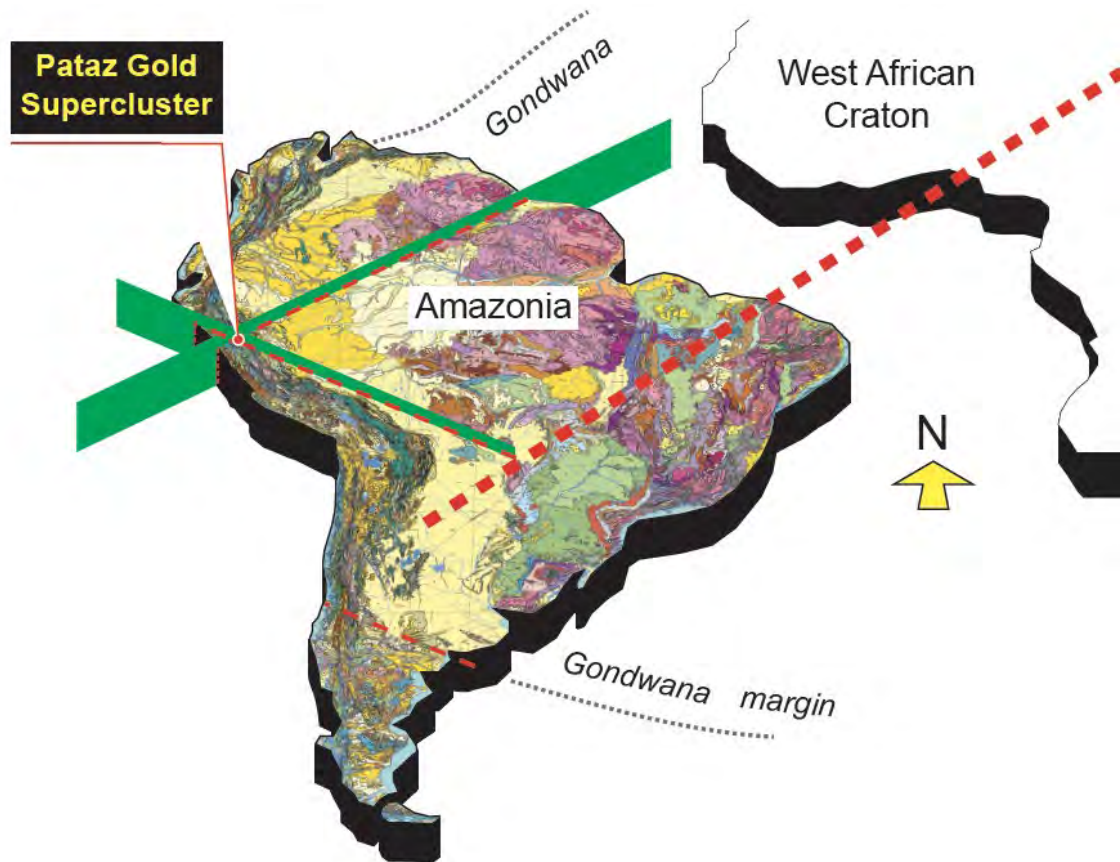


Inheritance – Pataz – Continent Scale



Inheritance – Continent Scale – Identification of Deposit SUPERCLUSTER

Intersections of inherited trans-lithospheric structures

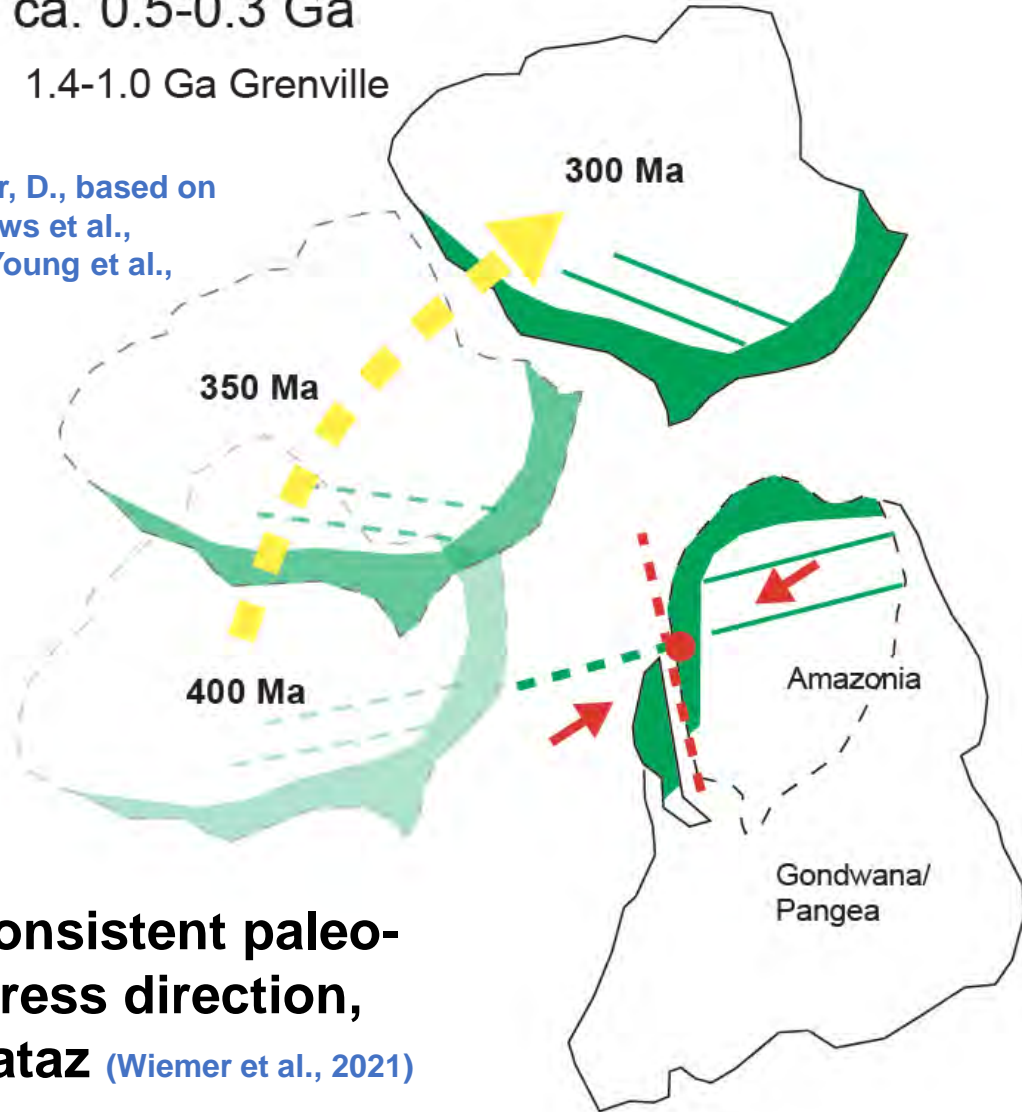


TEST – 1: IF ancient inheritance true, structures must also cut Laurentia

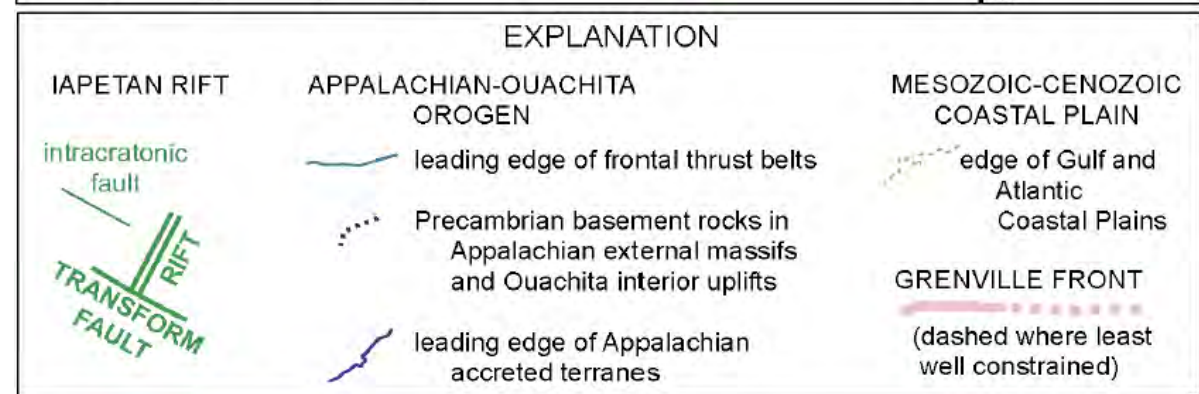
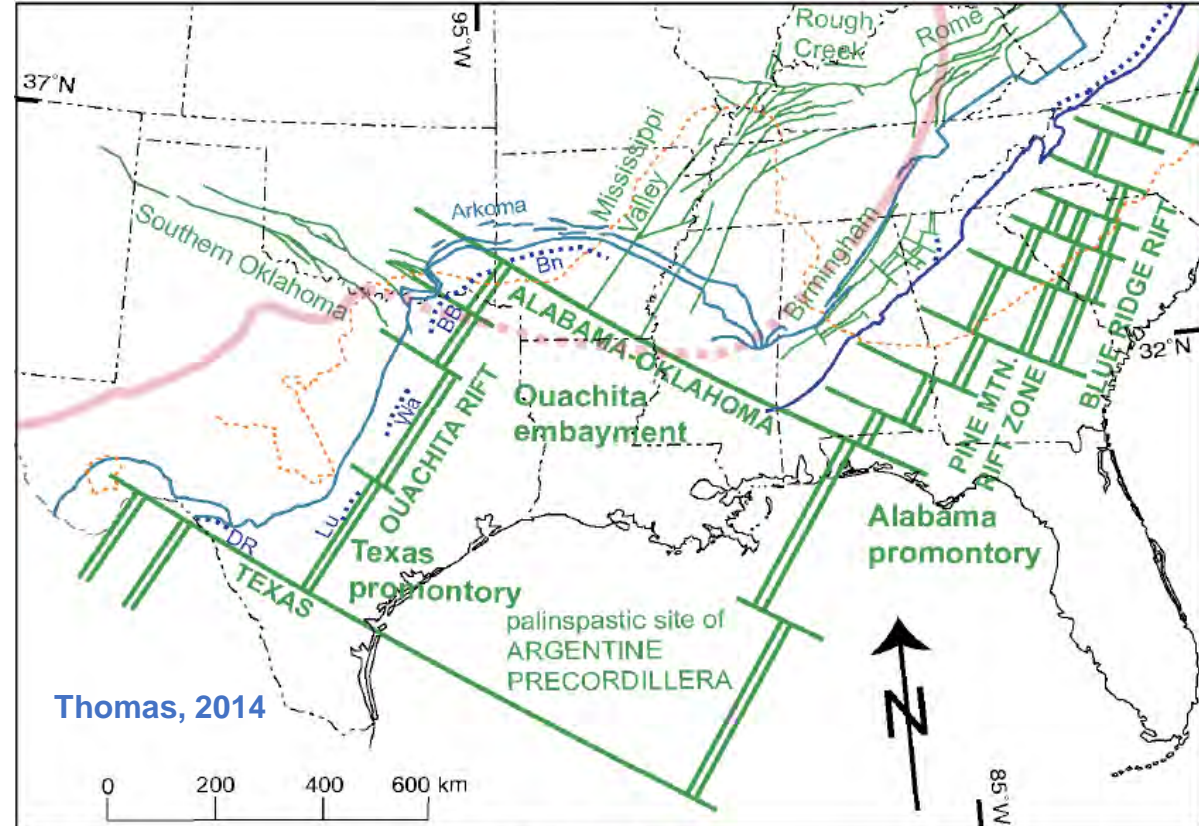
Gondwana to Pangea,
ca. 0.5-0.3 Ga

■ 1.4-1.0 Ga Grenville

Wiemer, D., based on
Matthews et al.,
2016; Young et al.,
2019



**Consistent paleo-
stress direction,
Pataz (Wiemer et al., 2021)**

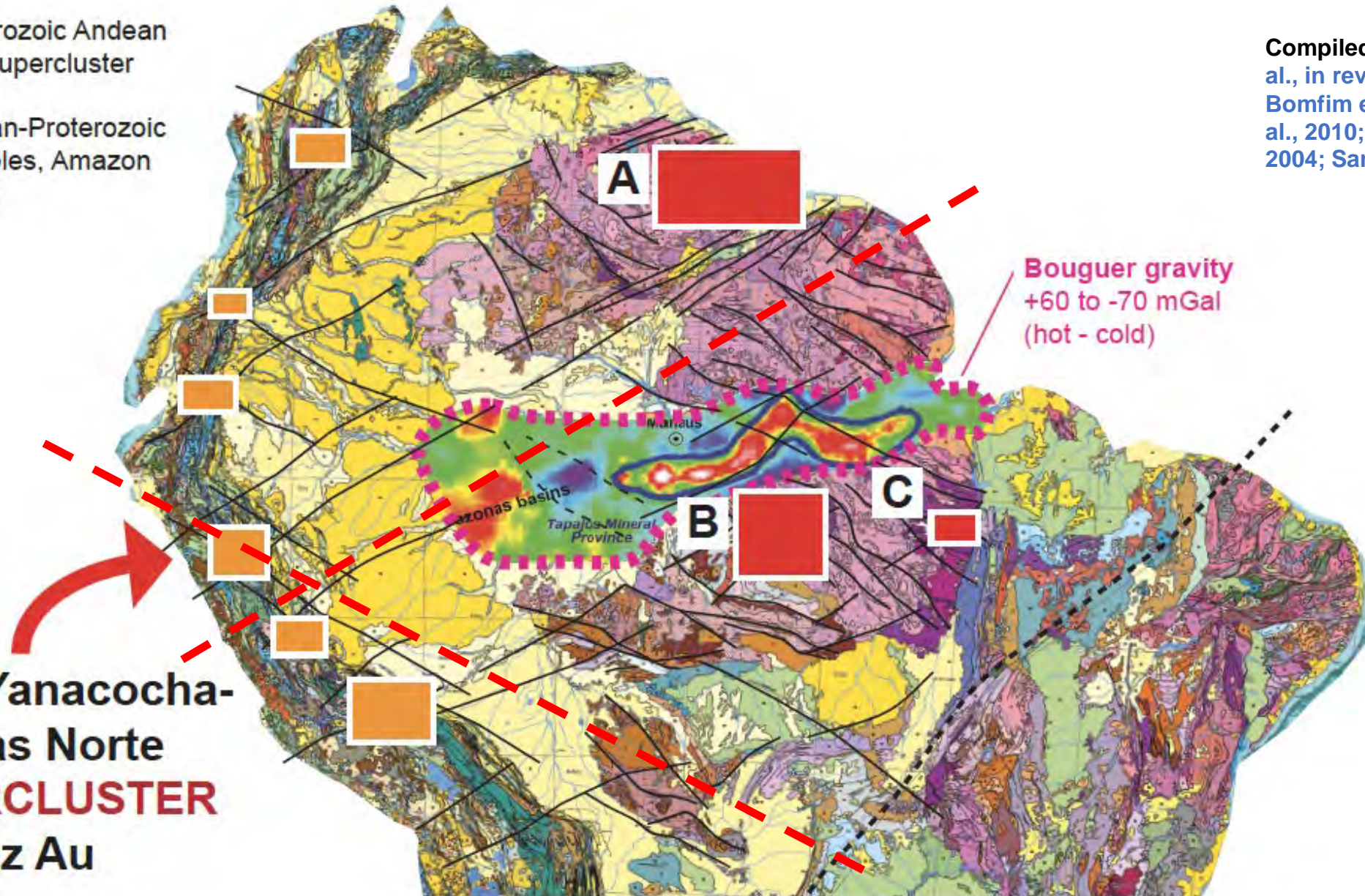


TEST – 2: Same structures / trends and **gold clusters** in the Amazon Craton?

Phanerozoic Andean Gold Supercluster

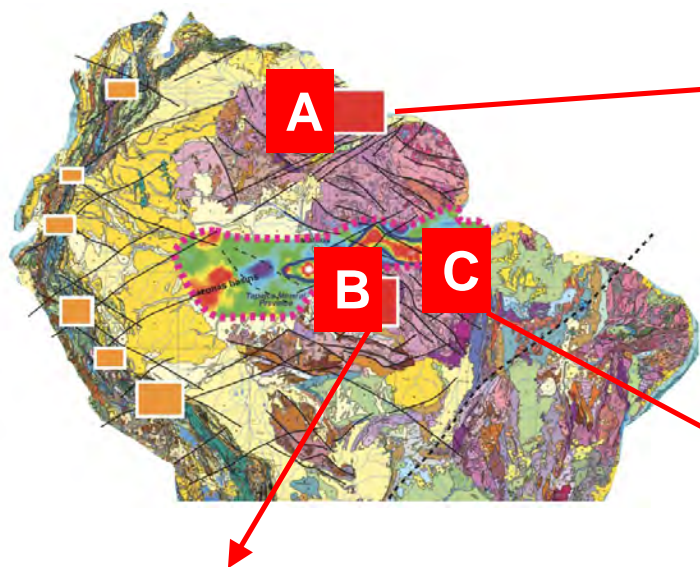
Archean-Proterozoic Examples, Amazon Craton

Compiled based on: [Wiemer et al., in rev.](#); [Juliani et al., 2021](#); [Bomfim et al., 2013](#); [Cordani et al., 2010](#); [Tessinari & Macambira, 2004](#); [Santos et al., 2000](#);



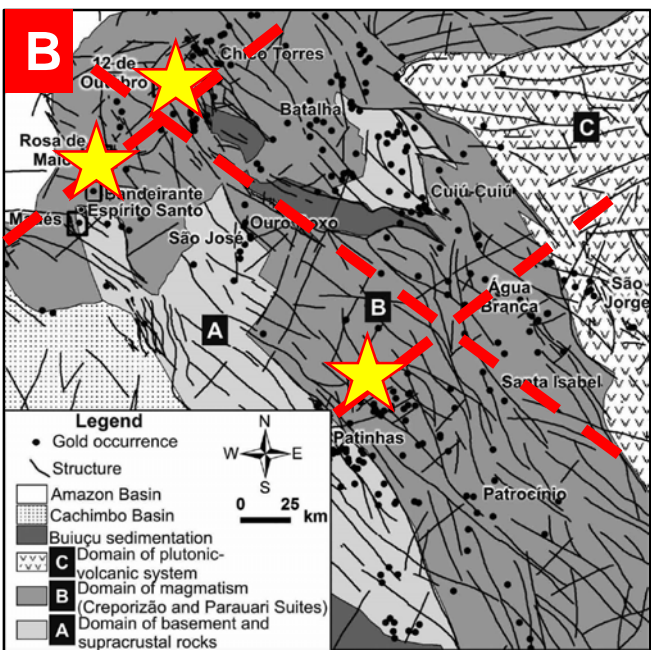
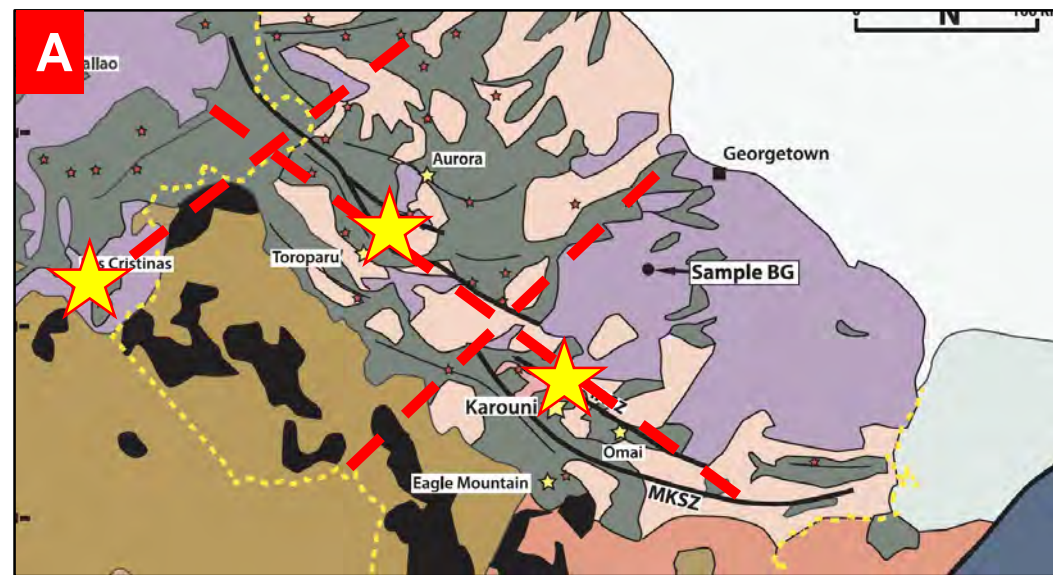
Pataz-Yanacocha-Lagunas Norte SUPERCLUSTER
>50 Moz Au

TEST – 2: Same structures / trends and gold clusters in the Amazon Craton?



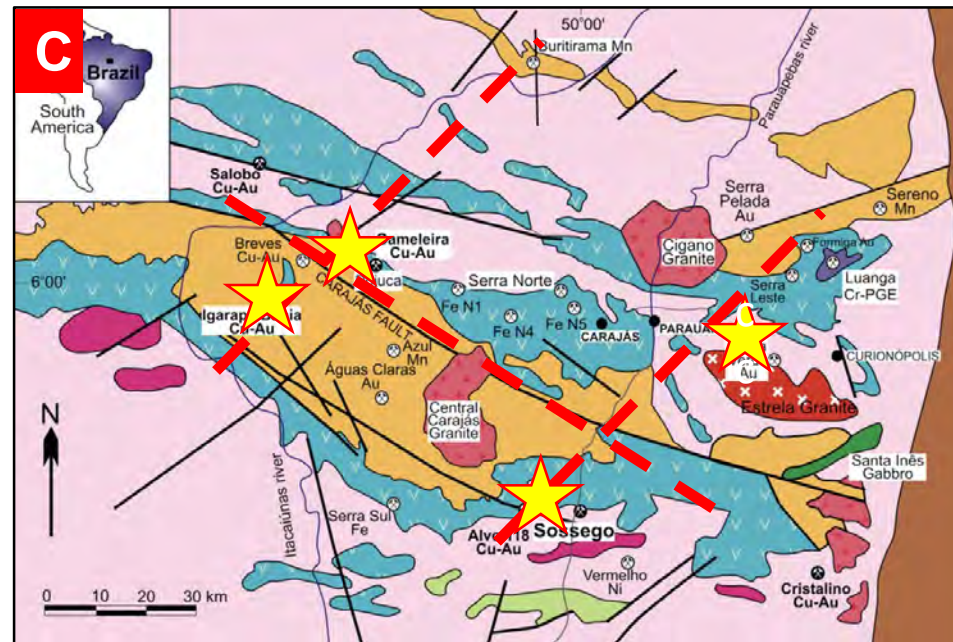
Karouni Gold district, Guyana
Gold: 2.1-2.0 Ga

Tedeschi et al., 2020



Carajas, Brazil
Gold: 2.7-1.9 Ga

Monteiro et al., 2008;
 Trunfull et al., 2020



Tapajos Gold province, Brazil
Gold: 1.9-1.0 Ga?

Carrino et al., 2015

Conclusions

1. Multi-scale integration is key

→ Deposit-scale **VERSUS** continent/lithosphere-scale:

Are you chasing a vein/drill-core **OR** the next 'supercluster'?

→ Start 'asap': Figure out where you are and why you are there!

2. Major structural intersections (trans-lithospheric) mark zones of enhanced mantle-to-crust permeability (magma and fluid conduits)

→ Sites of structural intersections and complexity!

3. Structural/tectonic inheritance

→ Focus investigation on the basement!

Further discussion and implications: see Poster...

In Search of Inherited Pre-Fertilized Mantle Source Domains for Cu and Au Ore at Polycyclic Supercontinent Margins
Daniel Wiemer^{1*}, Steffen G. Hagemann¹, Tony Kemp¹, Nicolas Thébaut¹, Jon Hronsky^{1,2}, Trevor Ireland³, Laure Martin¹, Carlos Villanés⁴

1. INTRODUCTION
Major ore deposits are commonly associated with trans-lithospheric structures, representing first-order pathways for ore-bearing magma and fluids from mantle to crust.
Subcontinent margins are loci of post-collisional extension and extension episodes, favourable for repeated ore-rich magma extractions.
Phanerozoic Cu, Au and associated base metal deposits of the Peruvian Andes (former Gondwana/Pangea margin) cluster along distinct structural corridors that trace the prominent NW-trending polymetamorphic Andean orogen at oblique strike orientation (Fig. 1).

2. EVIDENCE FOR TECTONIC-STRUCTURAL INHERITANCE
2.1 District- to regional-scale structural inheritance, Pataz region
Pataz gold vein system geometry follows basement inherited weak zones within the Carboniferous Pataz batholith (Wiemer et al., 2021).
Deposits are situated within a regional dioxalonal jog, marked by the bend in the first-order Rio Marañon Fault (Fig. 2).
The dioxalonal jog is controlled by the Pre-Carboniferous basement tectonic framework and its inherited SE structural grain.
Ophiolite and interfolded high-grade gneiss basement components delineate a tectonic collisional suture, marking the Famatinian (ca. 475-450 Ma) collision between Gondwana and the Paracas micro-terrace (Fig. 2, Fig. 3).
2.2 Continent/lithosphere-scale inheritance and structural intersections as sites of deposit superclusters

3. IN SEARCH OF PRE-FERTILIZED MANTLE SOURCES
3.1 370-330 Ma Subduction-Accretion and Sub-Arc Mantle Evolution
Carboniferous magmatic arc parental, most primitive magma, hydrous, volatile- and melt-enriched "high-K", high Hf/Ba ratios.
Incremental deep- to mid-crustal reservoir accumulation through repeated sub-arc mantle recharge, following characteristic timescales of ca. 5-Myr episodicity (Fig. 5).
3.2 330-310 Ma Post-Subduction Extension and the Sub-Continental Lithospheric Mantle
Post-subduction magmatism characterized by re-working (anasthesia) of earlier granulites during thermal rejuvenation as a consequence of extensional crustal thinning and asthenosphere upflow.
Injection of mafic dikes led to substantial hybrid magma formation (granite + mafic melt).
Mafic injections include calc-alkaline lamprophyres that occur close to the inherited collisional suture, and E-MORB-type dolerite dikes that dominate at greater distance to the suture (Fig. 6).
Hybridized granulites and intrusions in the vicinity of inherited structures display sub-mantle 5180 zircon values.
We argue that the lamprophyres and the sub-mantle 5180 zircon values originate from a pre-fertilized (enriched) sub-continental lithospheric mantle dating back to the Famatinian collisional event.

4. CONCLUSIONS
1. We demonstrate that the localization of Phanerozoic Cu and Au deposit superclusters in the Andes is controlled by lithosphere-scale structural inheritance.
2. Preliminary geochemical and isotopic results suggest that the structural inheritance also involves inheritance of pre-fertilized mantle domains.
3. Although mineral deposits may form instantaneously, "settling up the stage" can take 400s of million to billion years.

REFERENCES CITED
Hagemann, S.G., and Wiemer, D., 2013. Fluid vaporization during early stages of gold deposits. Nature Geoscience, v. 6, p. 204-205.
Wiemer, D., Hagemann, S.G., Thébaut, N., and Ireland, T.R.V., 2021. Role of basement structure inheritance and 370-330 Ma subduction in the formation of the Pataz gold vein system, Eastern Andean Cordillera, Southern Peru. Economic Geology, v. 116, p. 1163-1176.

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