Record of the oldest vein-type gold mineralization throughout the Neoproterozoic Nubian shield: the Galat Sufar South gold deposit, NE Sudan

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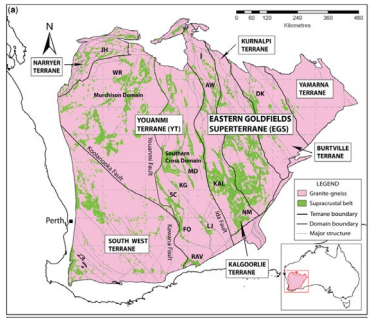
I. Introduction

Major gold provinces through time

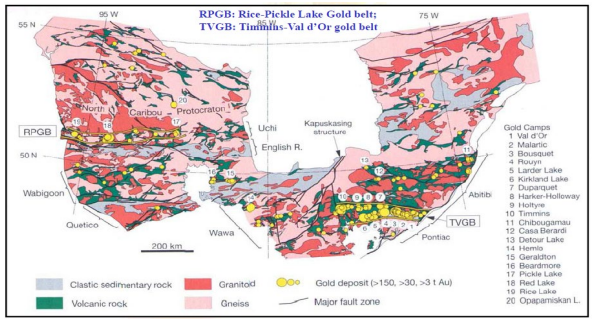
Yilgarn (*ca.* 2.9-2.6 Ga)



Mole et al. (2013)

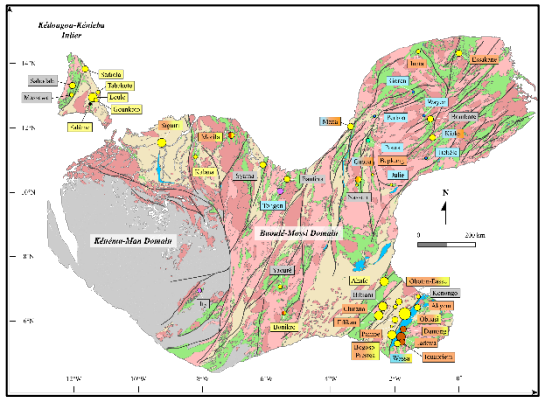
~800 km

Superior province (*ca.* 2.8-2.5 Ga)



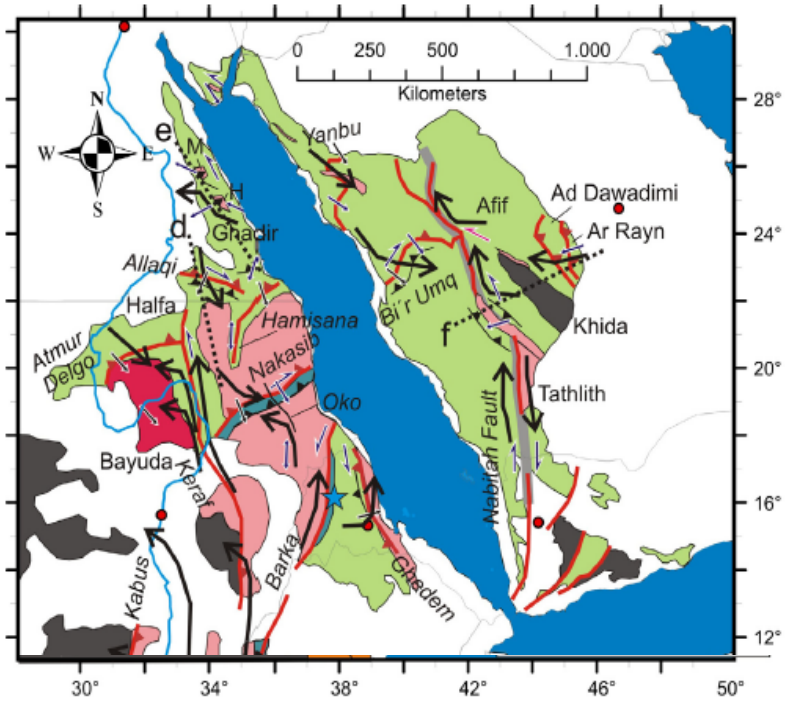
Card (1990)

southern WAC (*ca.* 2.5-1.6 Ga)



Masurel et al. (2021)

Arabian-Nubian shield (ANS) (*ca.* 1.0-0.5 Ga)



modified after Fritz et al. (2013)

- ✓ The largest track of Neoproterozoic juvenile crust on Earth *(Johnson, 2014)*.
- ✓ **The main Neoproterozoic gold resource worldwide** *(Johnson et al.,2017; Zoheir et al., 2019).*
- ✓ Largely under-explored area *(Trench and Groves, 2015)*.

I. Introduction

The Arabian-Nubian shield: a rich gold mining heritage

From Pharaonic times...

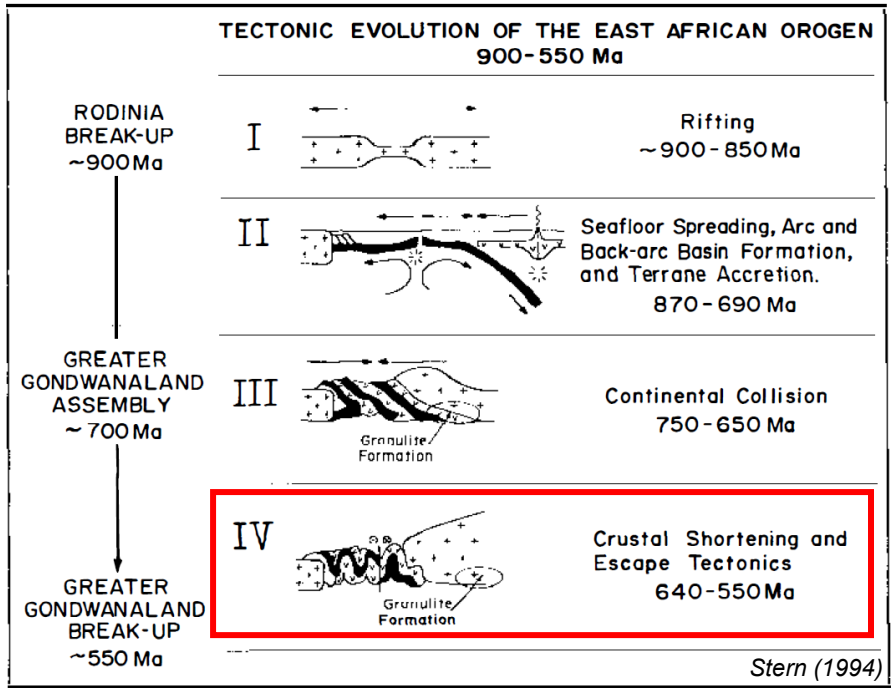
Klemm and Klemm (2013)

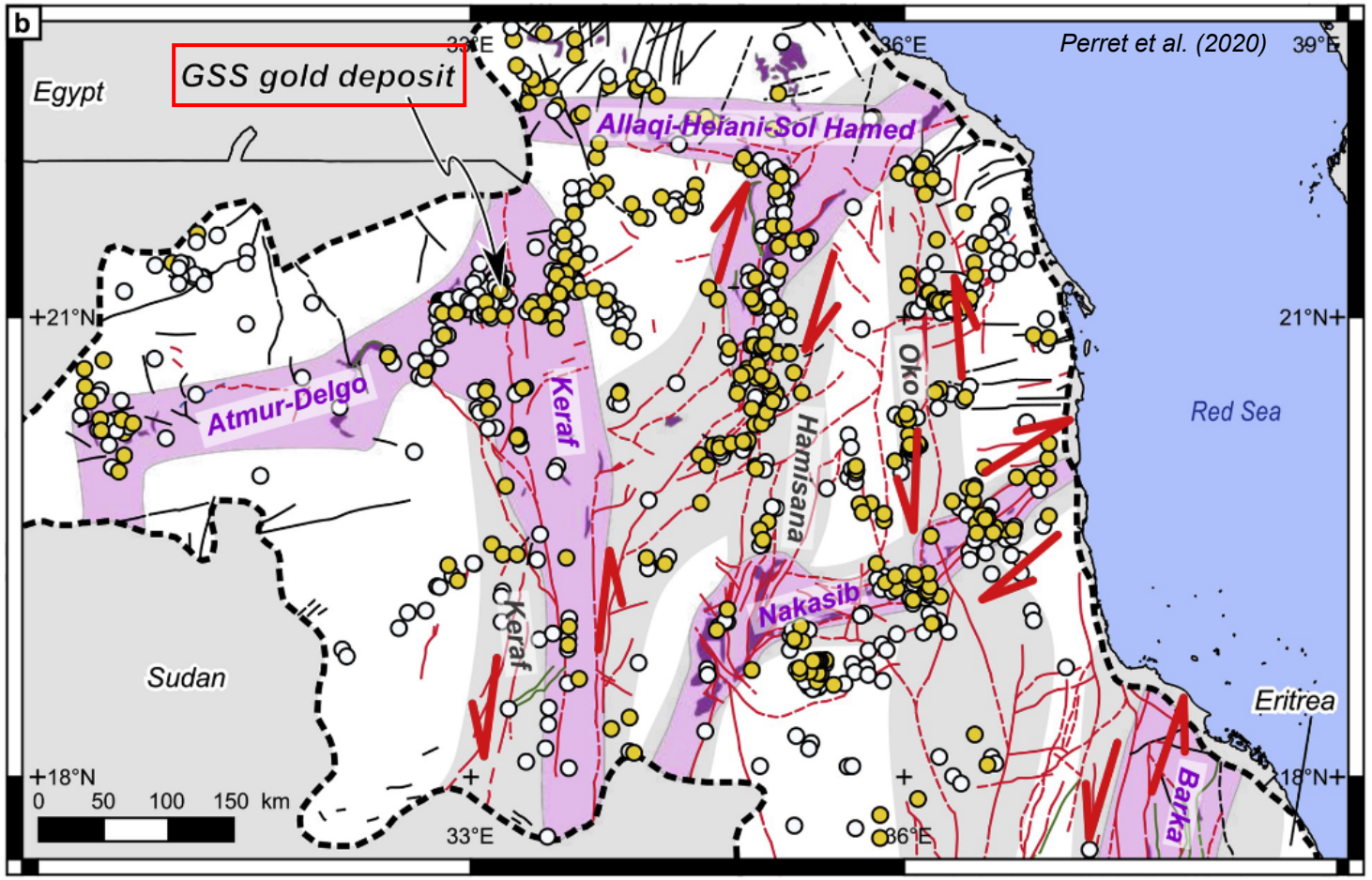
... to modern times

© J. Perret, Red Sea Hills, Sudan, 2019

I. Introduction

The Nubian shield gold



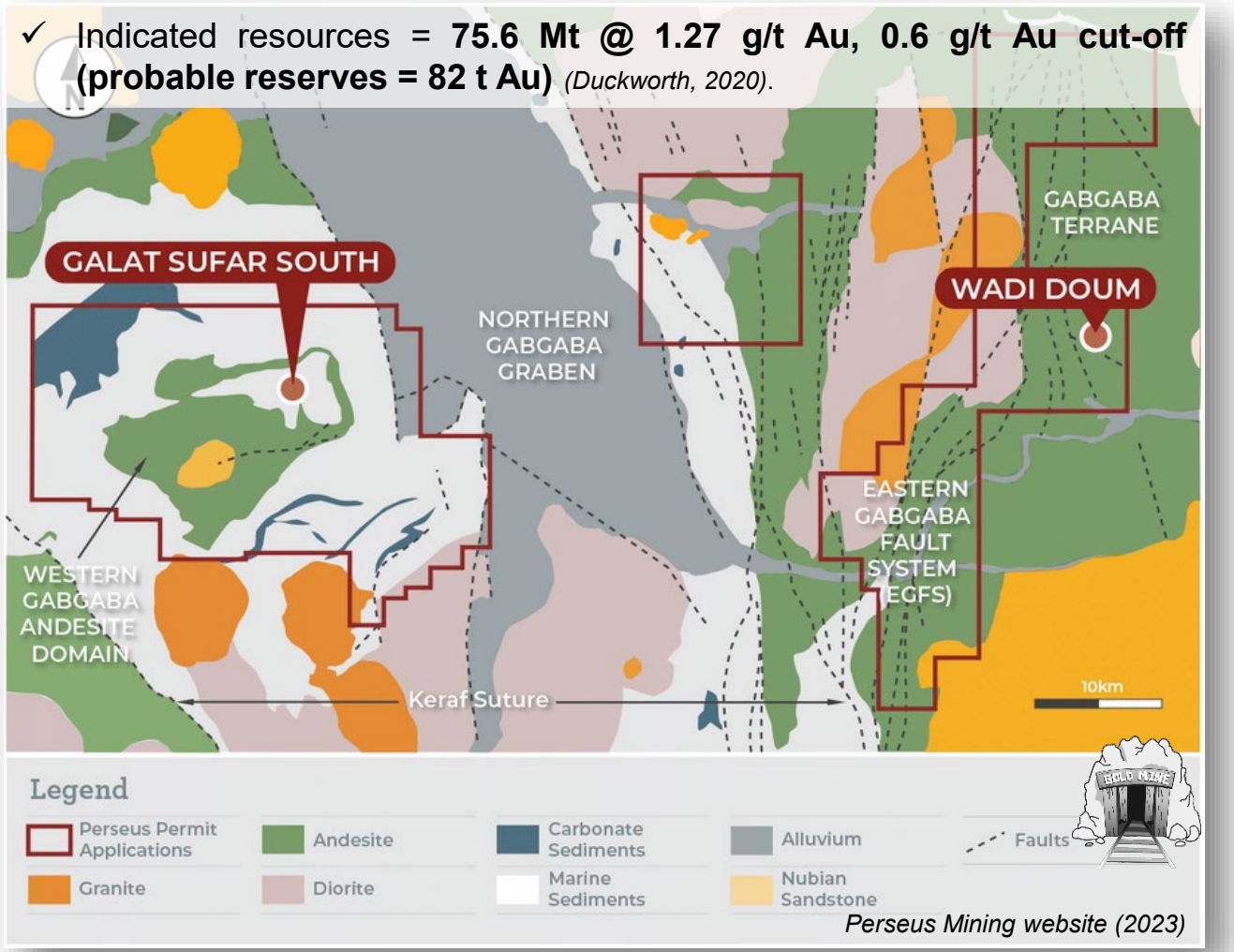


- ✓ **Distribution of lode gold occurrences strongly controlled by late tectonic, strike-slip structures**.
- ✓ *e.g., s*patial relationship between the Galat Sufar South (GSS) gold deposit and the Keraf and/or Atmur-Delgo sutures, **does it imply any genetic relationship? To which structure?**

I. Introduction

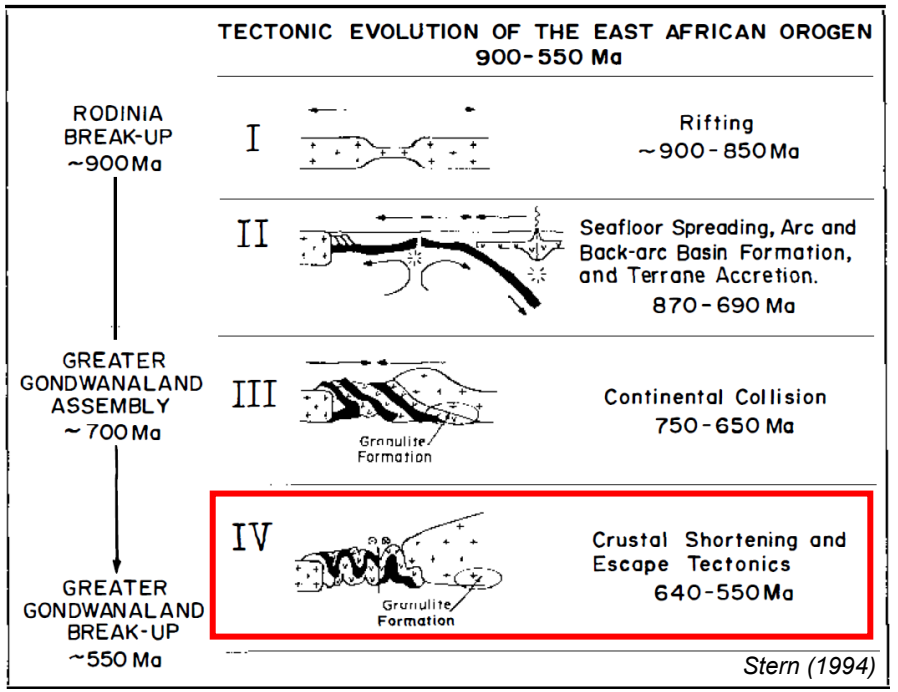
GSS gold deposit

✓ Indicated resources = **75.6 Mt @ 1.27 g/t Au, 0.6 g/t Au cut-off (probable reserves = 82 t Au)** *(Duckworth, 2020)*.



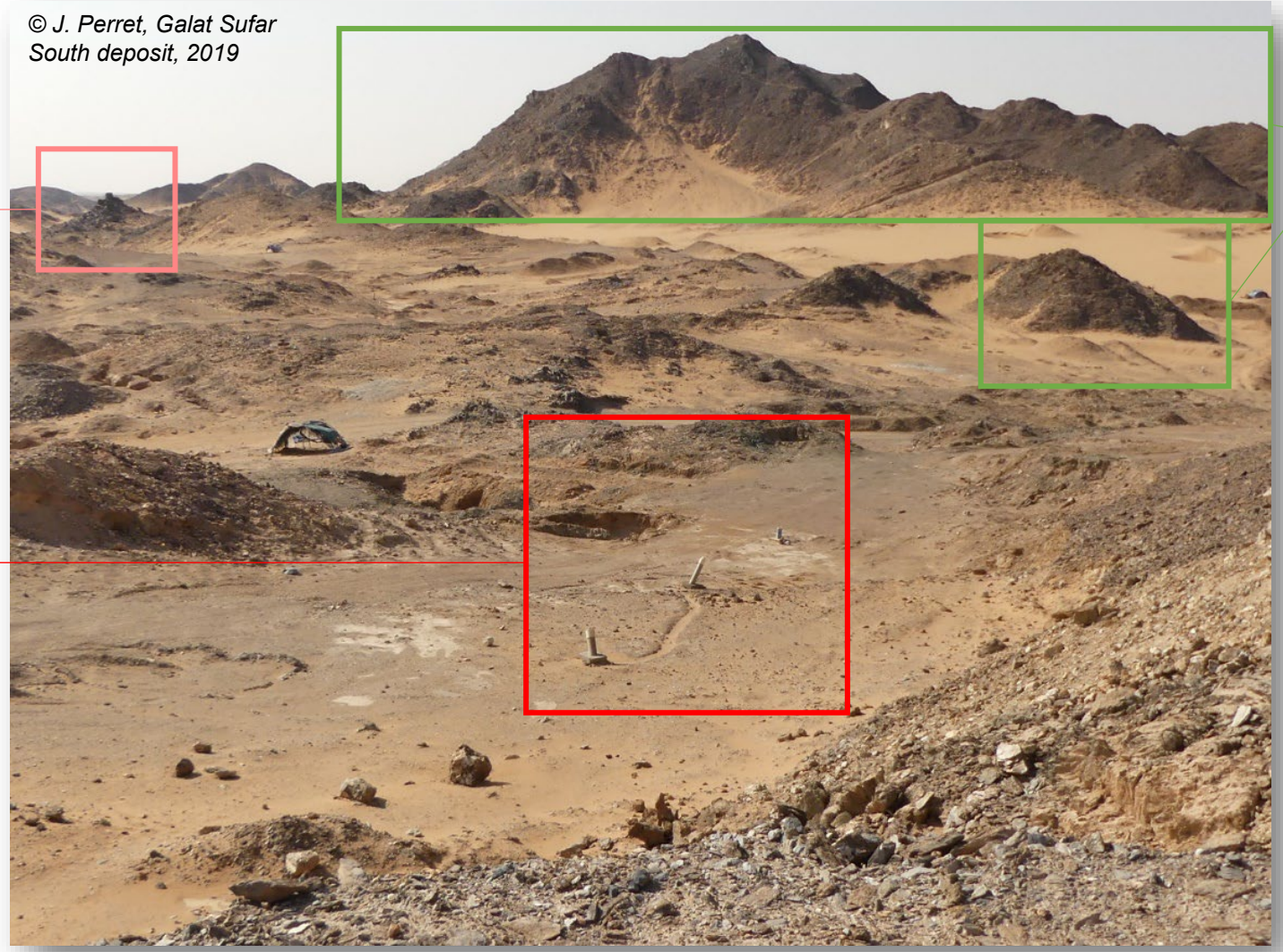
Perseus Mining website (2023)

*"At Galat Sufar, currently the best known example of orogenic gold along the **Keraf suture**, mapping and drilling reveal **mesozonal, shear-zone-hosted orogenic gold** [...]" – Johnson et al. (2017)*



II. Structural control on GSS mineralization

Access to structural information at GSS



post-tectonic intrusion

DDH collars

meta-volcanosed. series + rare ante- to syn-tectonic intrusive bodies

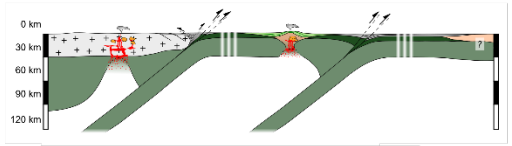
+ Satellite imagery and thin sections back to the lab…

II. Structural control on GSS mineralization

Continuity of the structural control expressed at every scale…

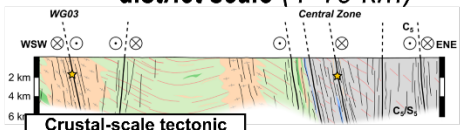
Scale of study

province scale *(10-100 km)*



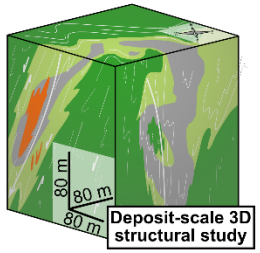
Lithospheric-scale geodynamical evolution
Crustal growth and gold fertilization

district scale *(1-10 km)*



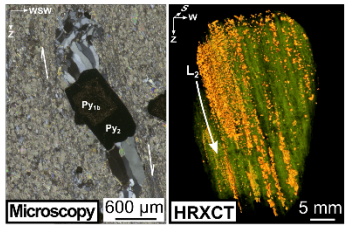
Crustal-scale tectonic integration of gold events

deposit scale *(m to km)*

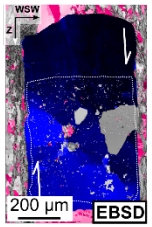


Deposit-scale 3D structural study

ore mineral to ore shoot scale *(µm to dm)*



crystal scale *(up to hundreds of µm)*



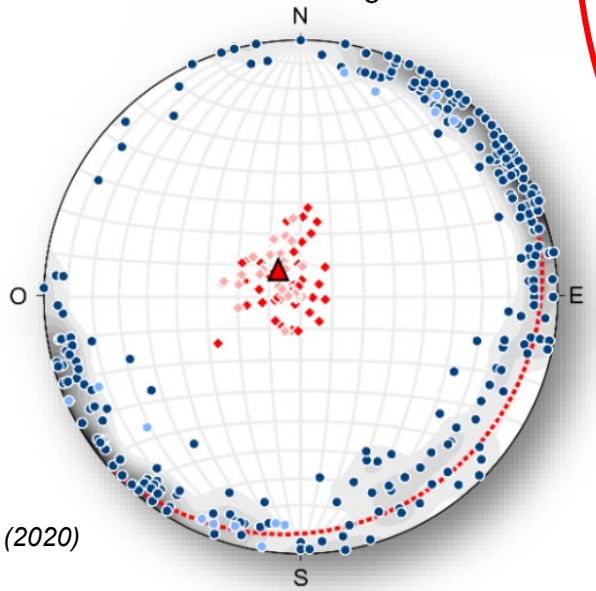
Tools

- province-, district- to deposit-scale mapping
- geological transect
- sampling
- remote sensing

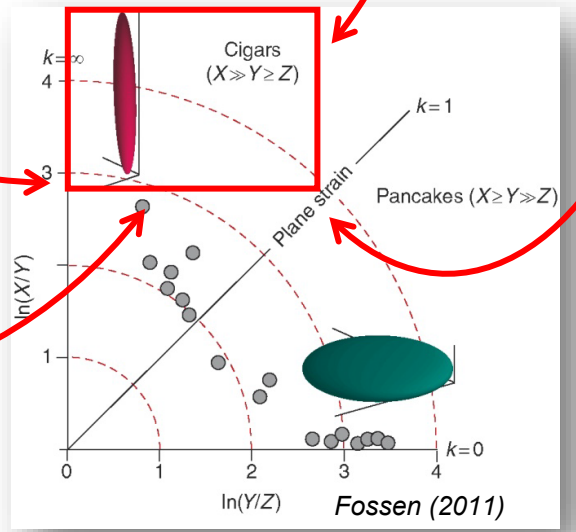
- deposit-scale mapping
- (oriented) core logging
- conventional structural geology
- sampling

- optical microscopy, SEM
- XRF
- HRXCT
- LA-ICP-MS

- EBSD
- LA-ICP-MS



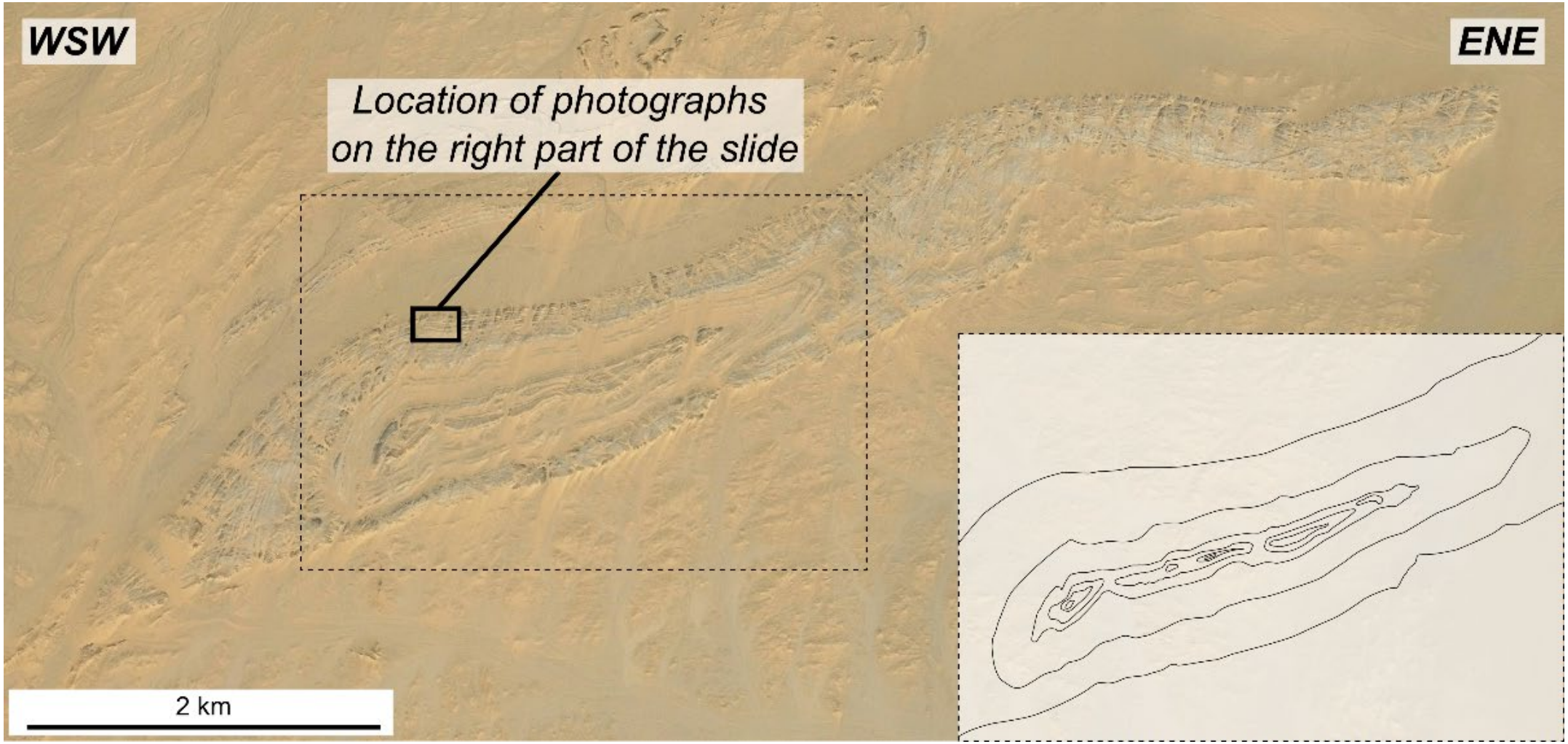
Perret et al. (2020)



Fossen (2011)

II. Structural control on GSS mineralization

Continuity of the structural control expressed at every scale…



Perret et al. (2020)

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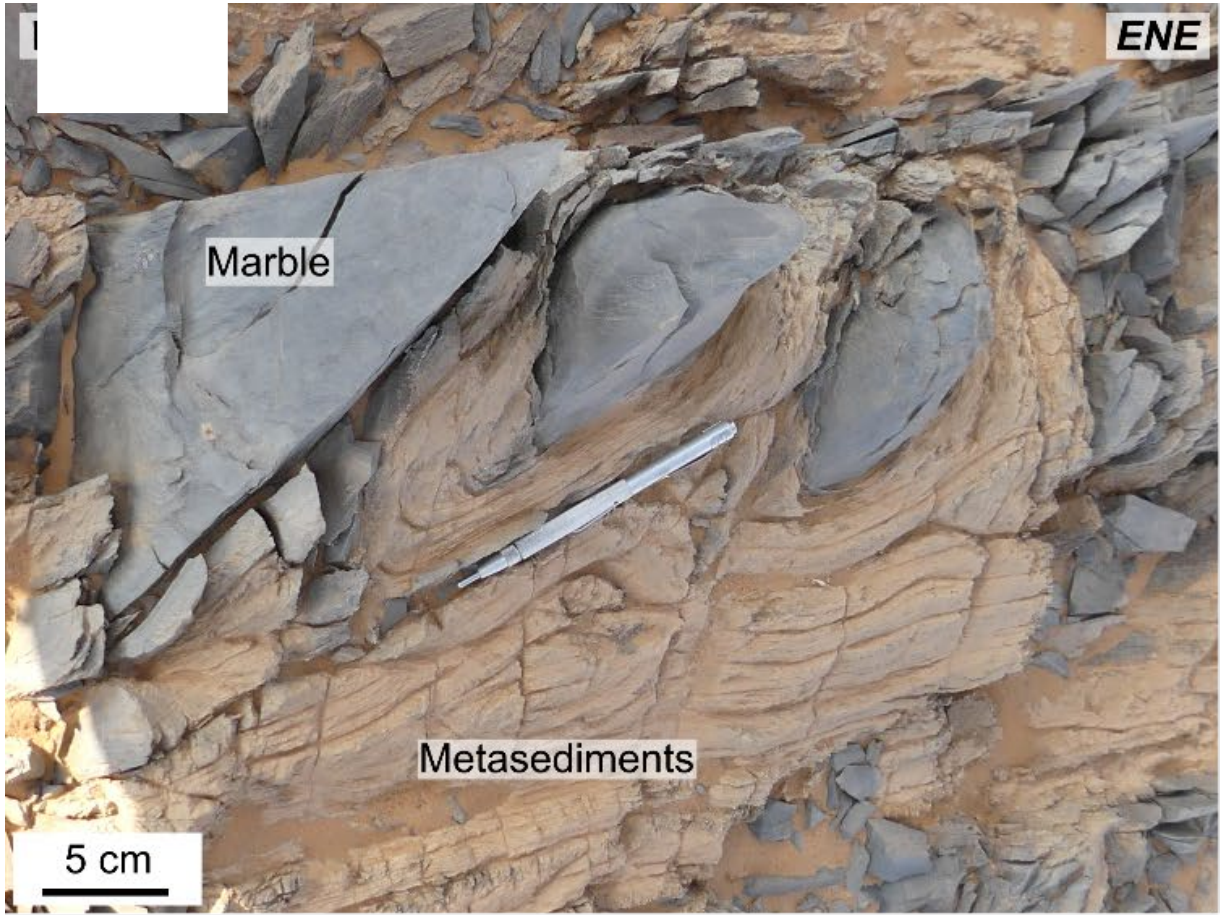

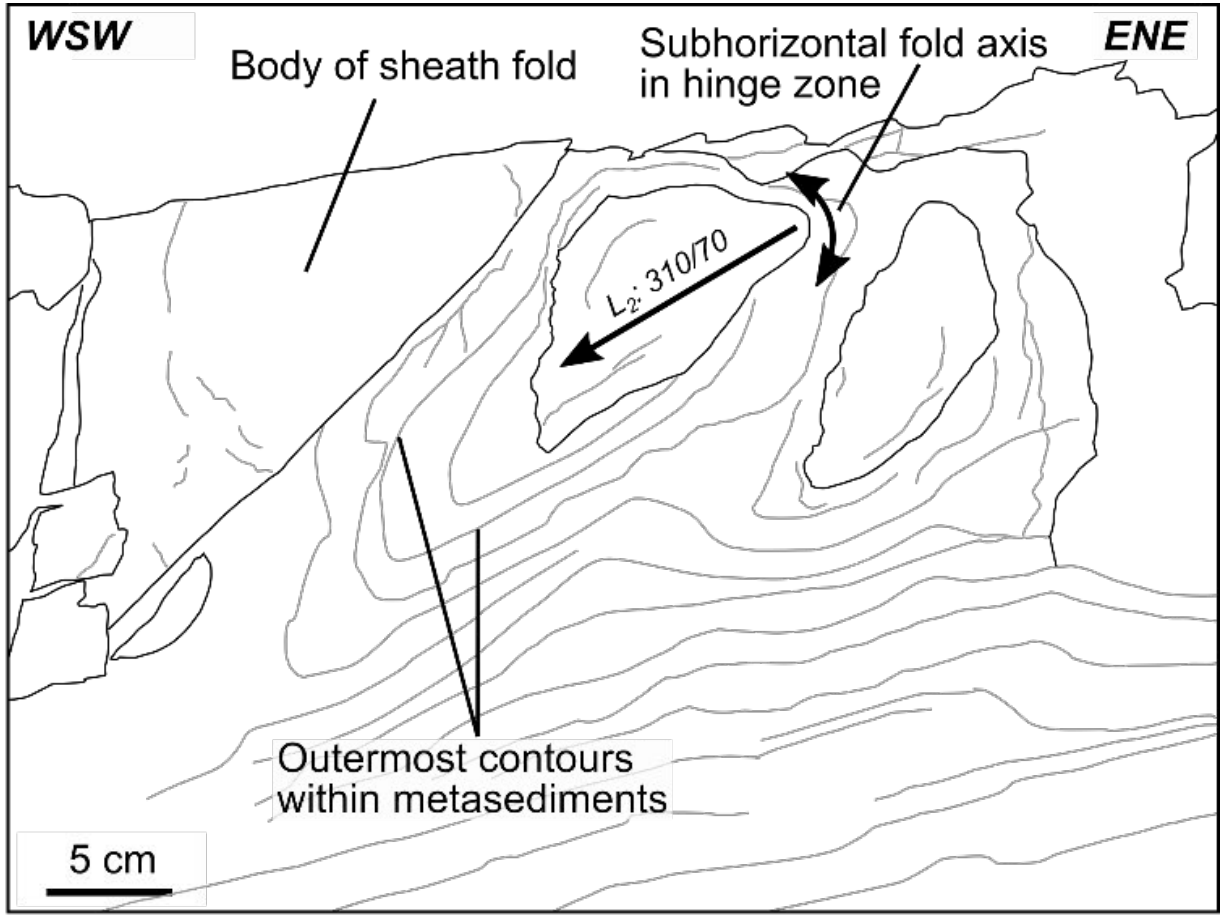

Perret et al. (2020)

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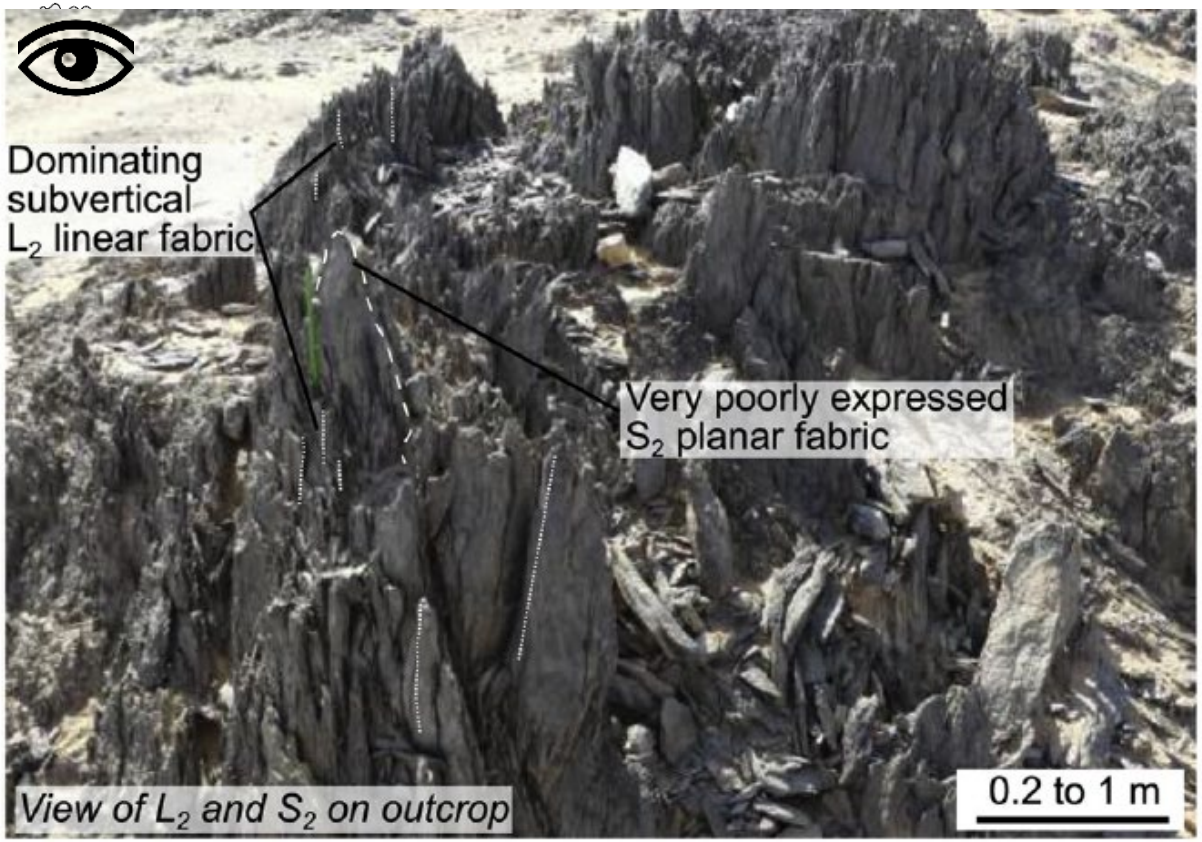
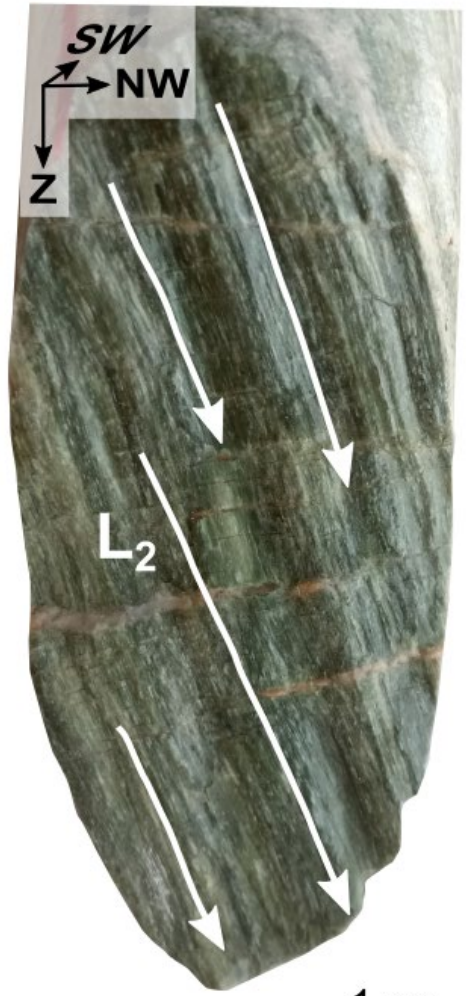


Perret et al. (2020)



Perret et al. (2020)

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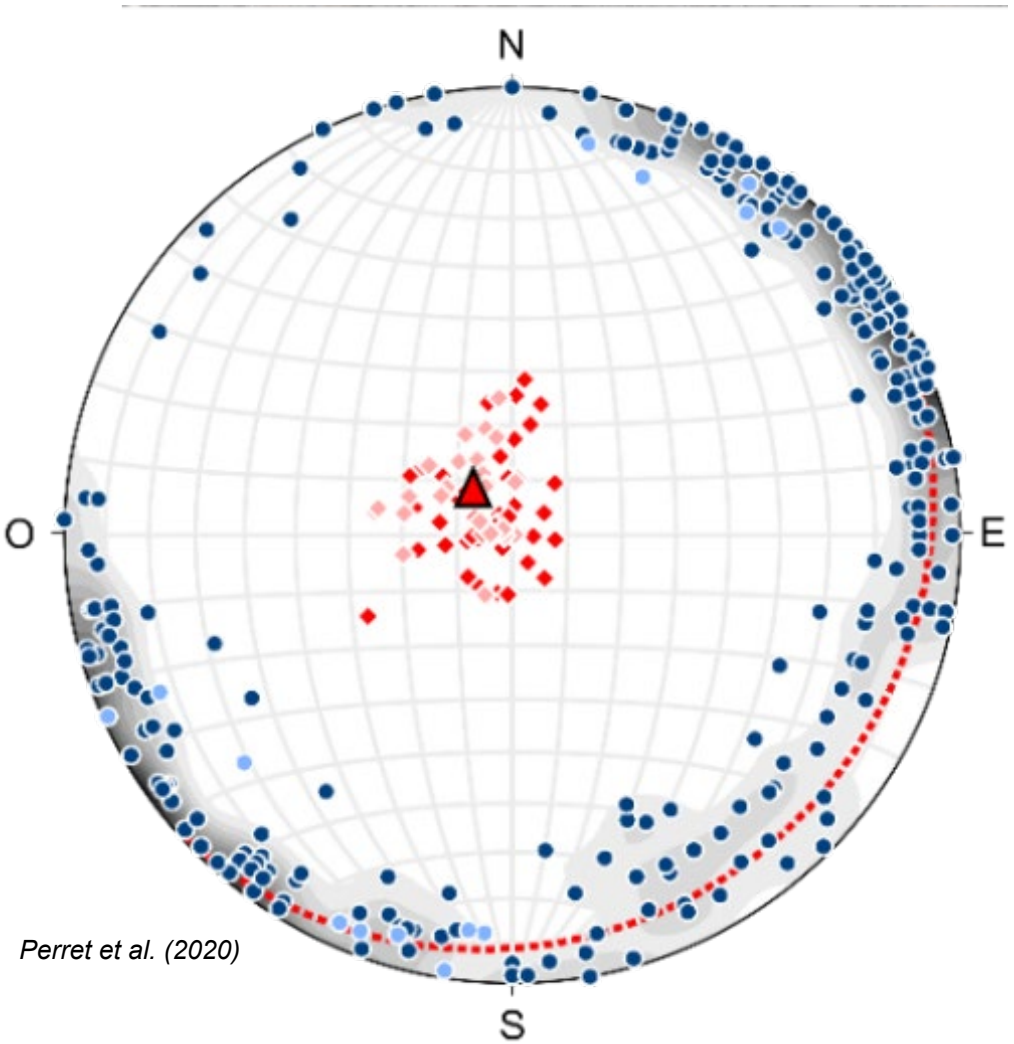
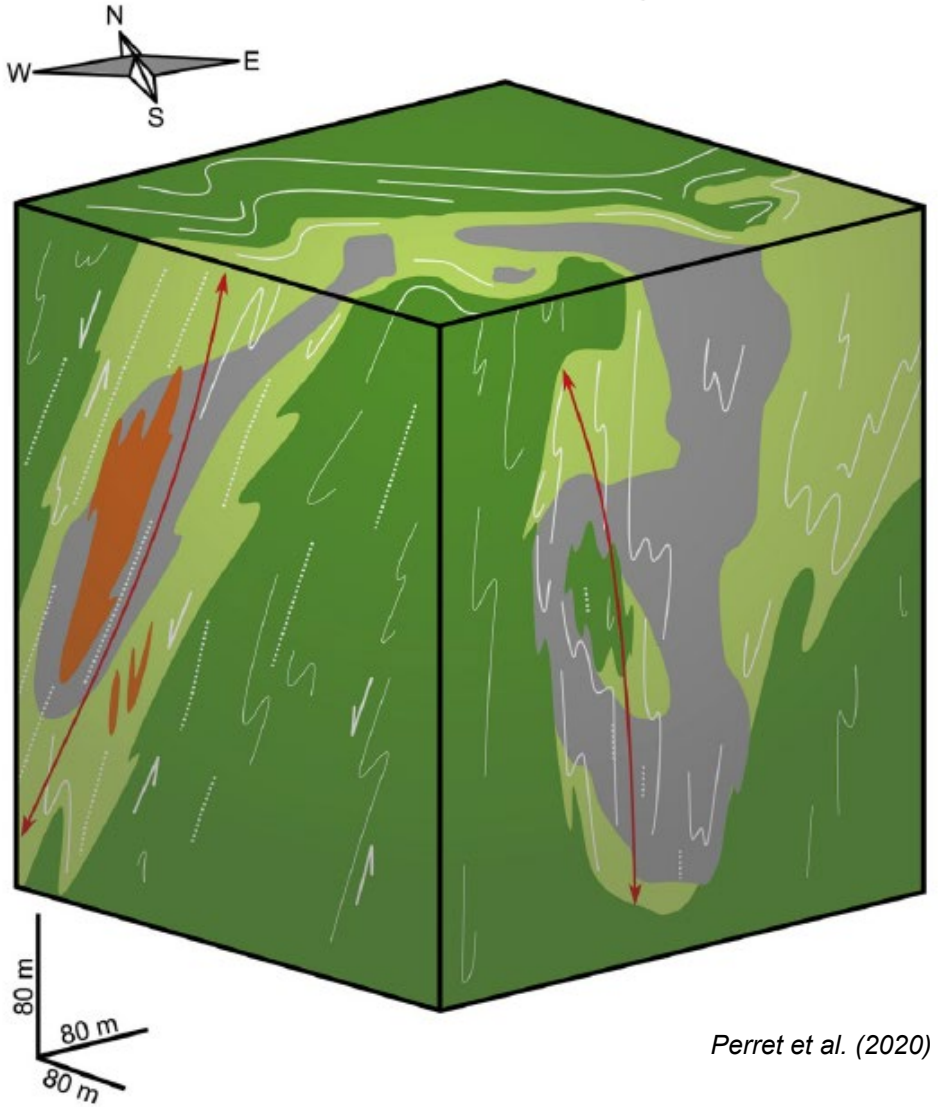


Perret et al. (2020)



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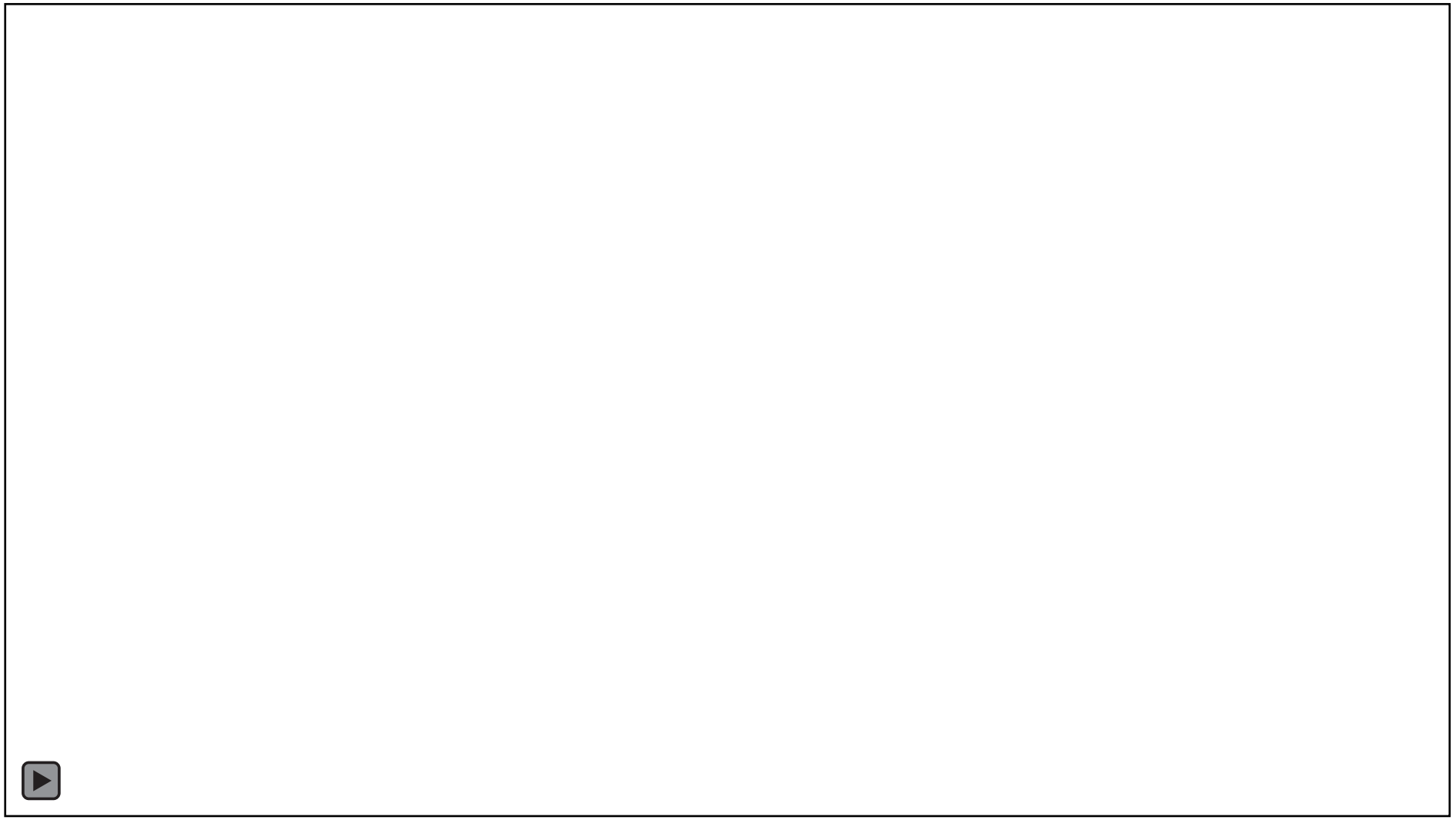

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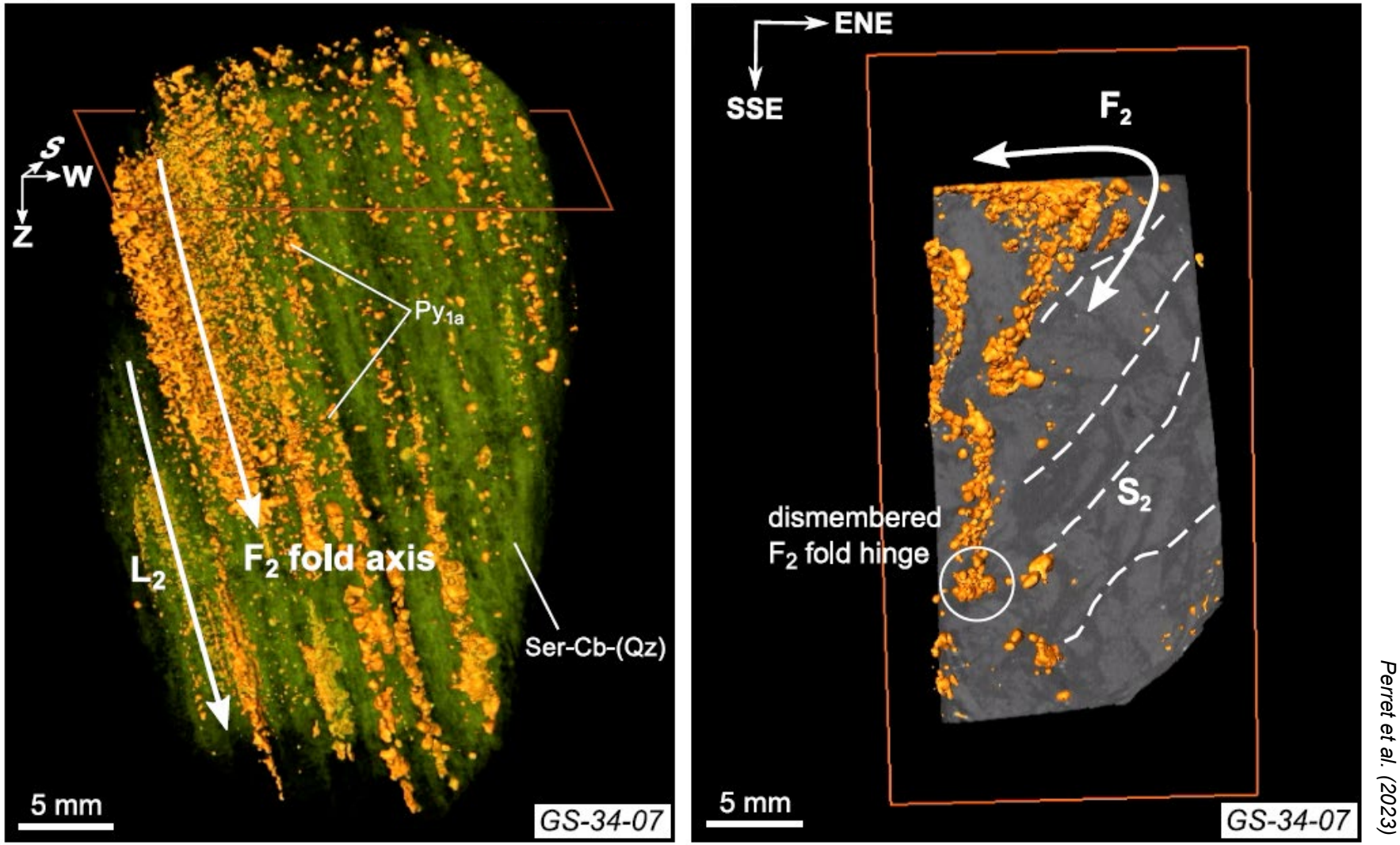
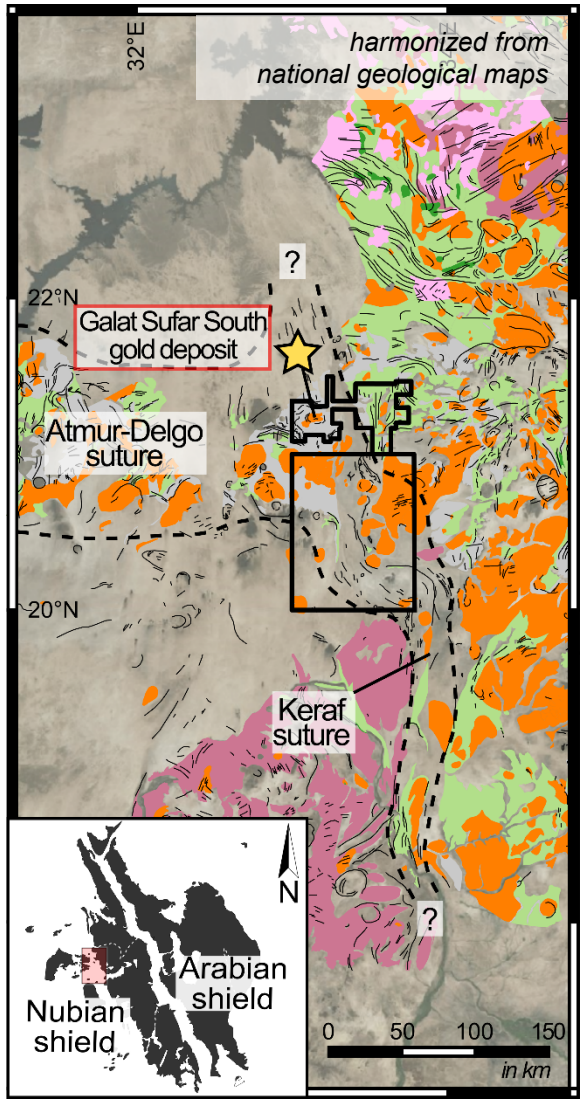
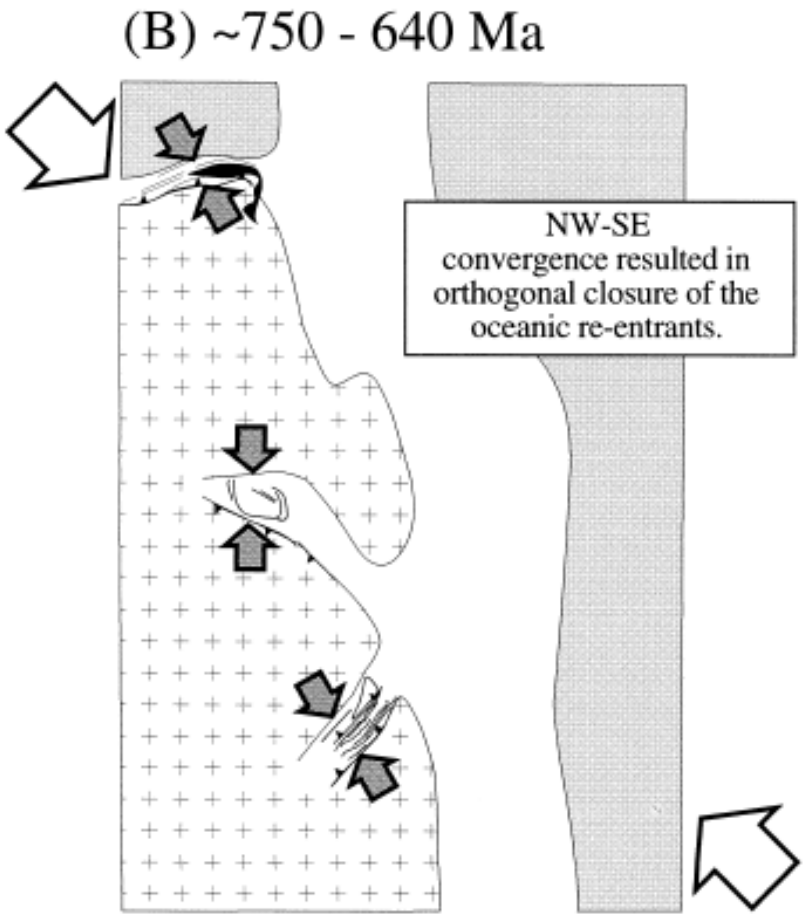


Perret et al. (2023)

II. Structural control on GSS mineralization

… likely related to Atmur-Delgo suturing!





Abdelsalam et al. (1998)

*"The GSS gold deposit is therefore likely a **structural marker of the ADS suturing** in the northwesternmost Nubian Shield.*

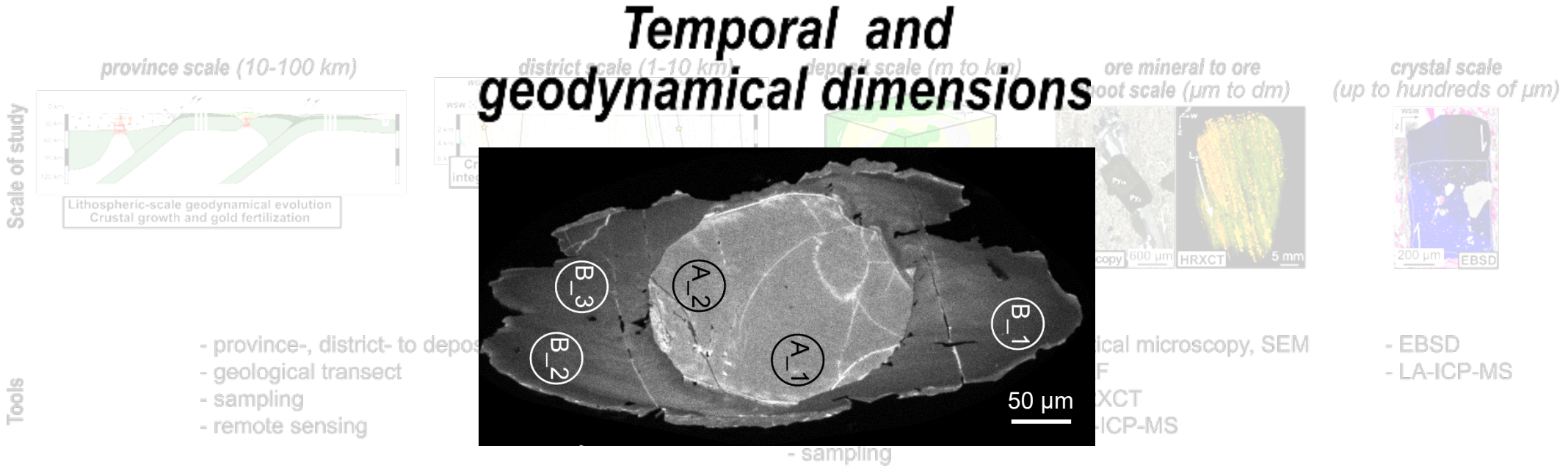
[…]

*Yet, no shear zone with subhorizontal stretching direction has been observed in the Block 14 area. **It rules out the possibility to consider that the GSS deposit formation is related to the KSZ transpressive tectonics** […]"*

– Perret et al. (2020)

III. *P-T-t-d* constraints on GSS gold mineralisation

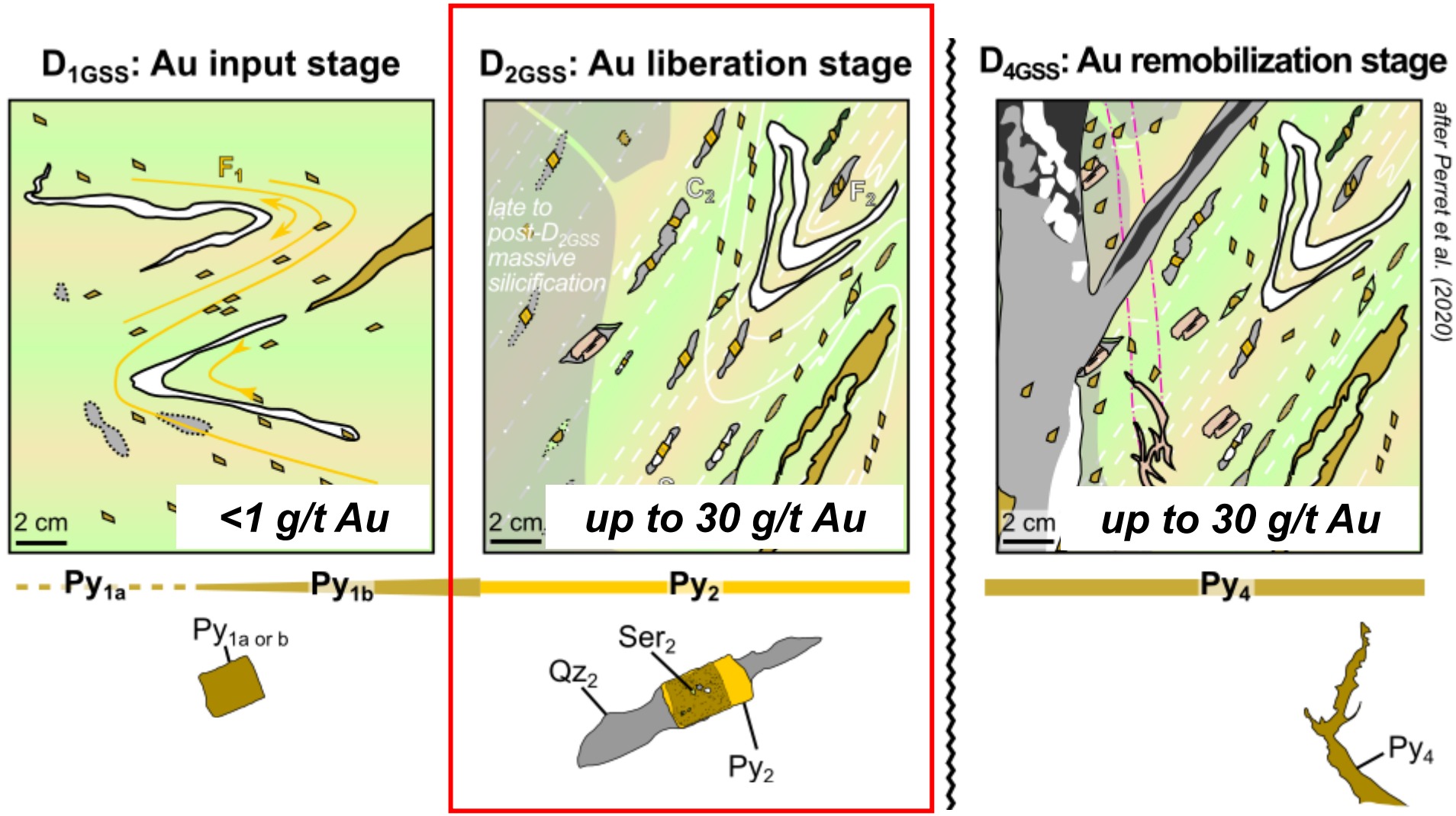
Integrated approach: towards P-T-t-d constraints



✓ **Need for *P-T-t* constraints to better unravel relationships between GSS gold mineralization and the province-scale tectonic evolution.**

III. *P-T-t-d* constraints on GSS gold mineralisation

Focus on the economic ore mineral assemblage



III. *P-T-t-d* constraints on GSS gold mineralisation

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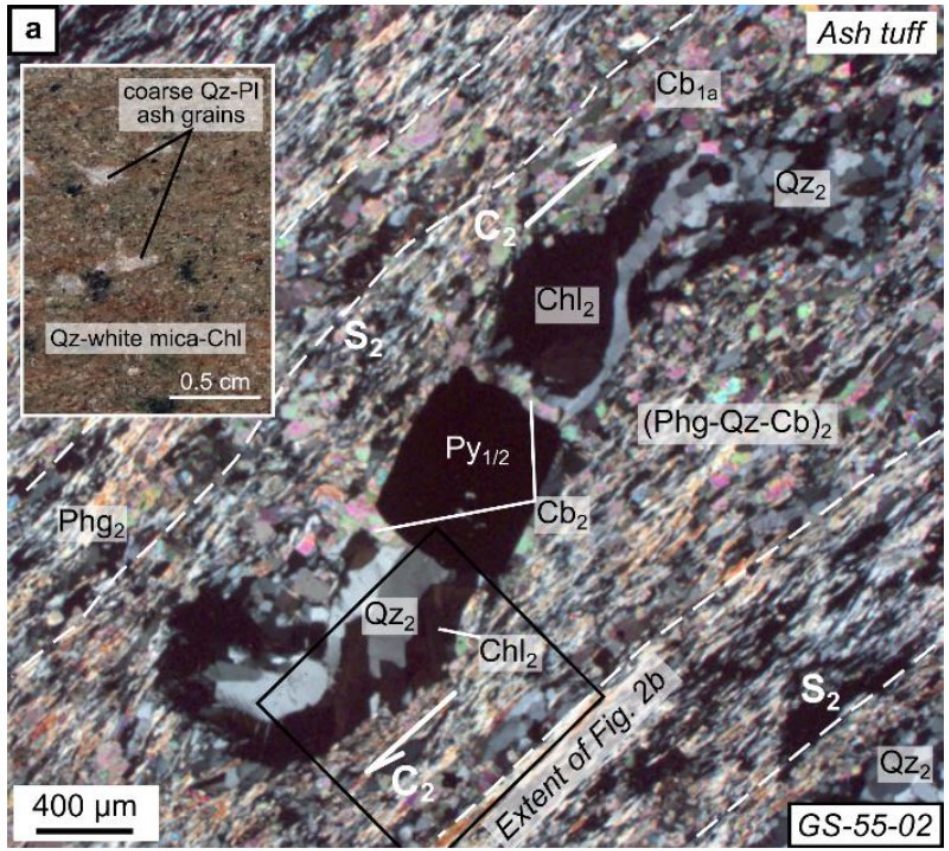
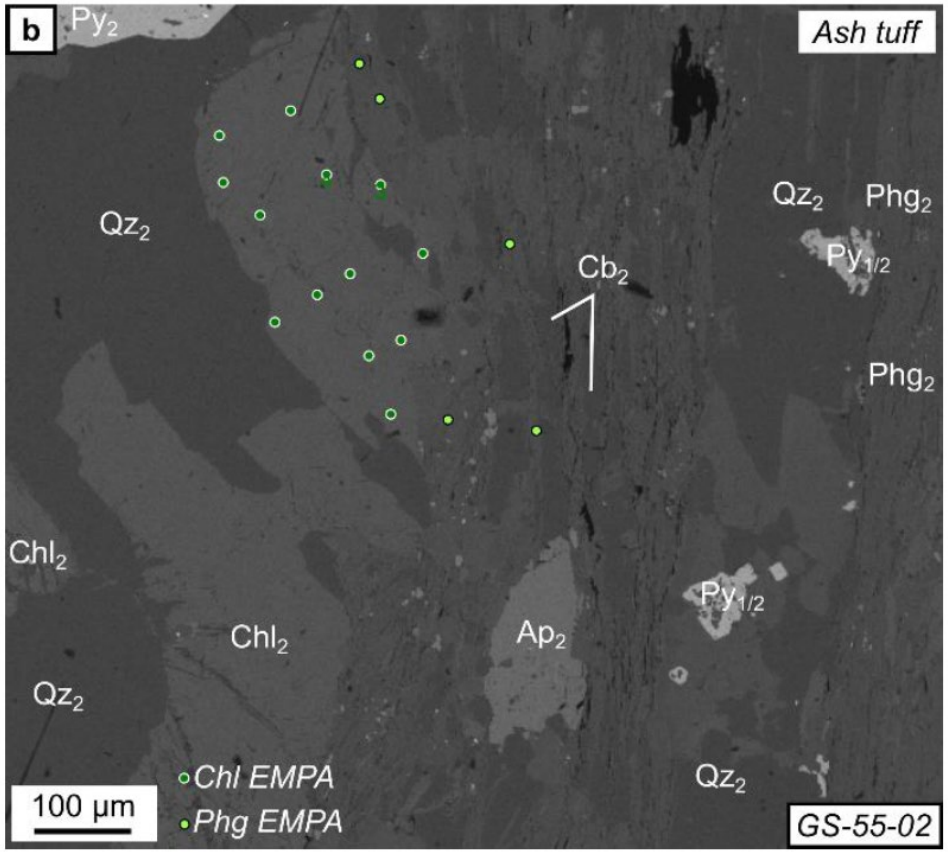
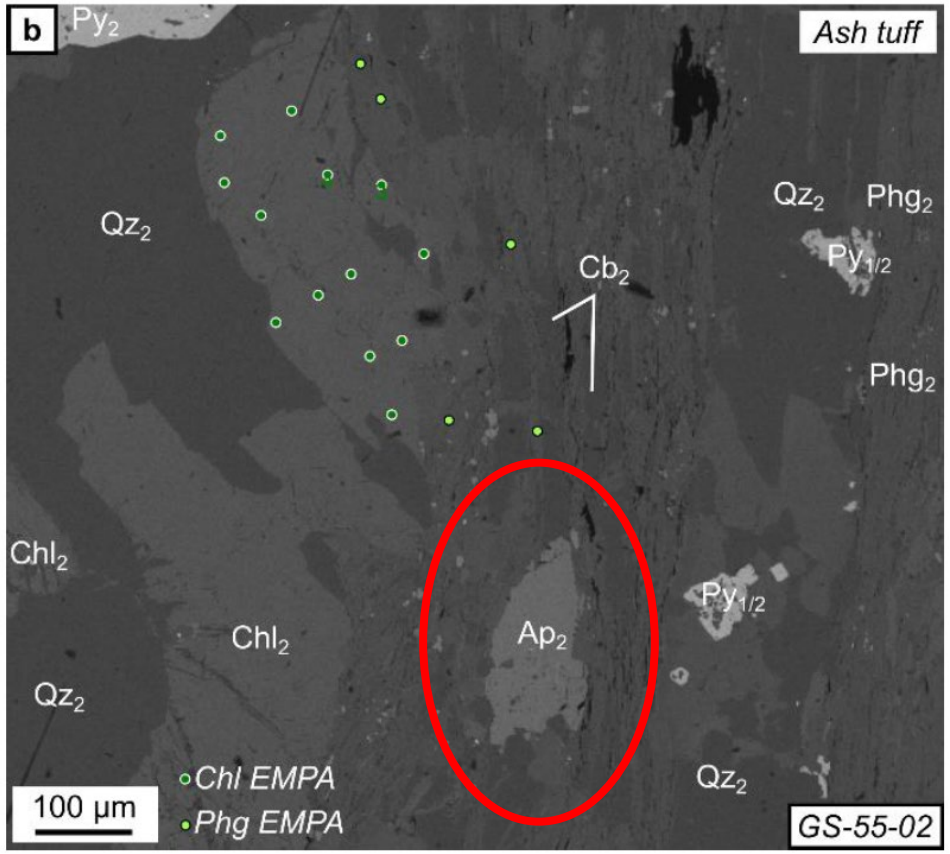


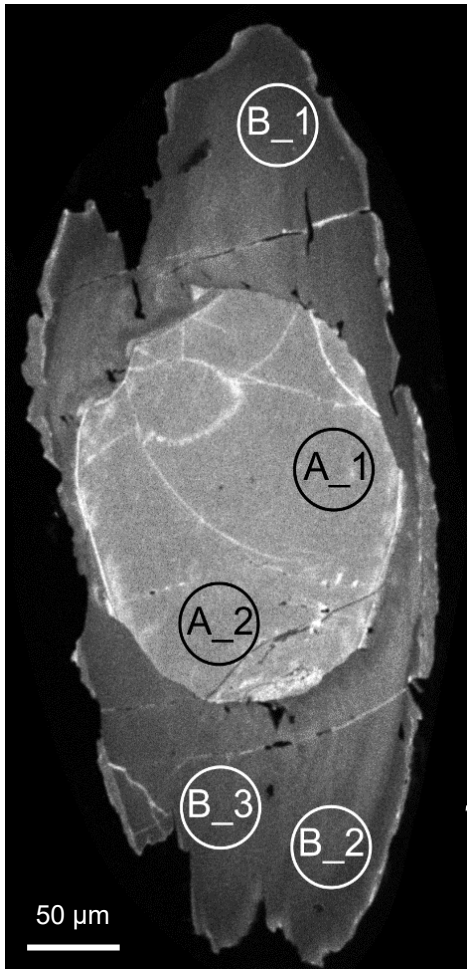


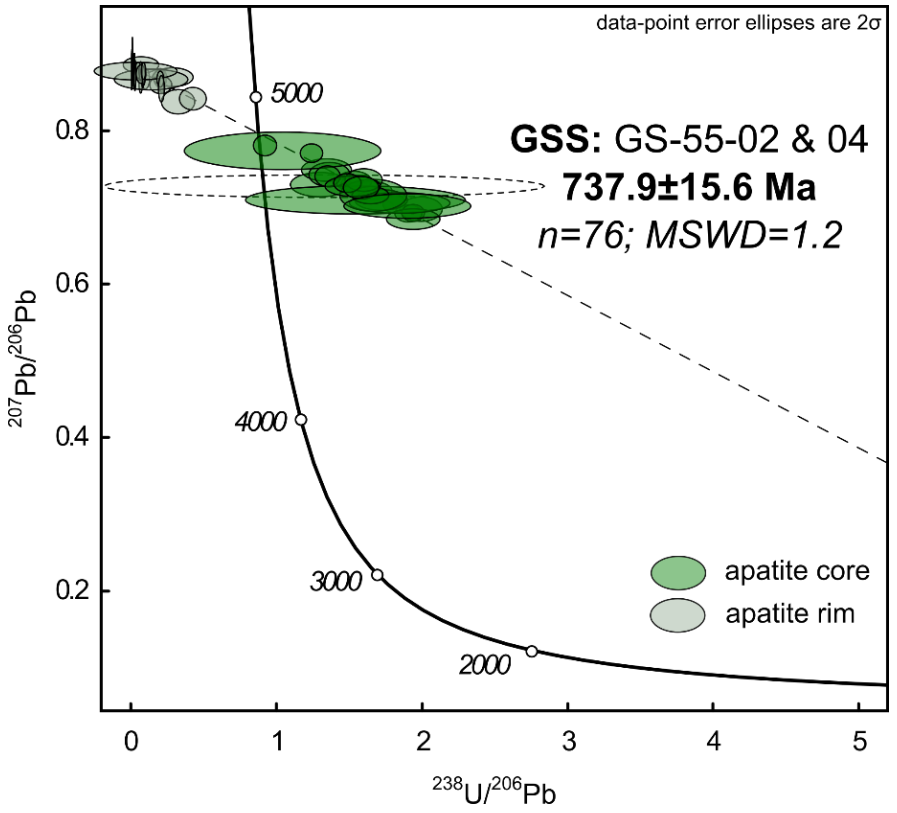
✓ Syn-ore mineral assemblage with quartz, chlorite **(geothermometer)**, white mica **(geobarometer)** and apatite **(geochrononometer)**.

III. *P-T-t-d* constraints on GSS gold mineralisation

t constraints



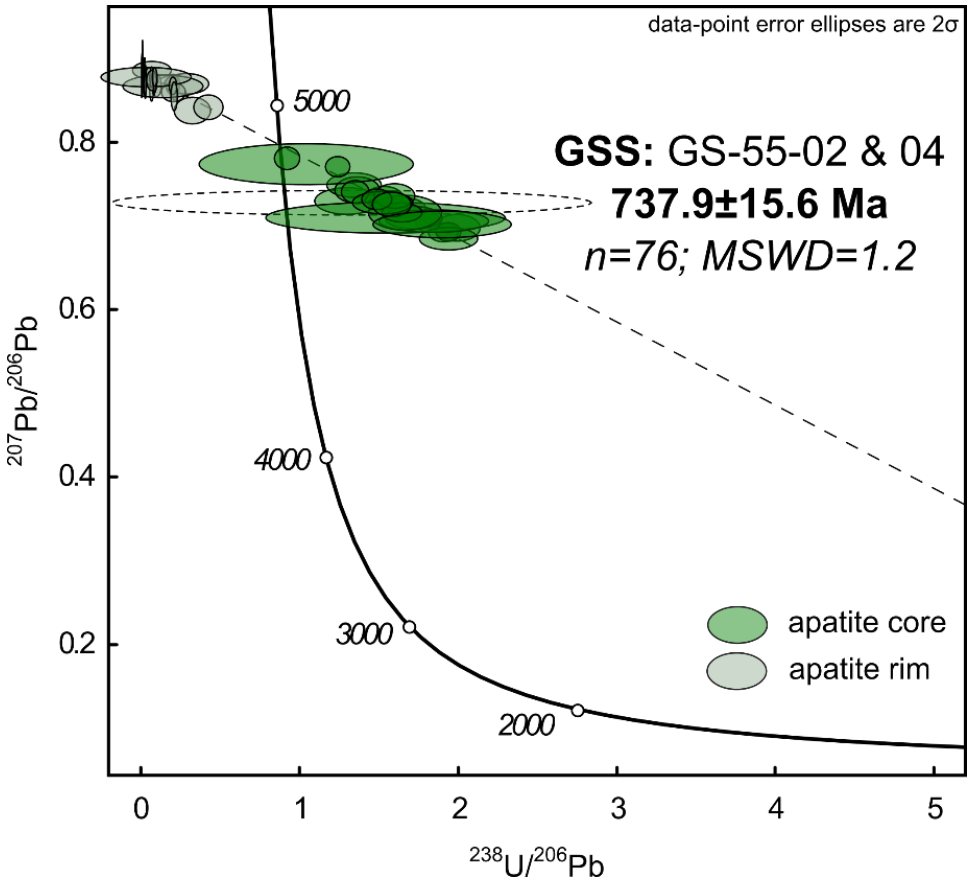


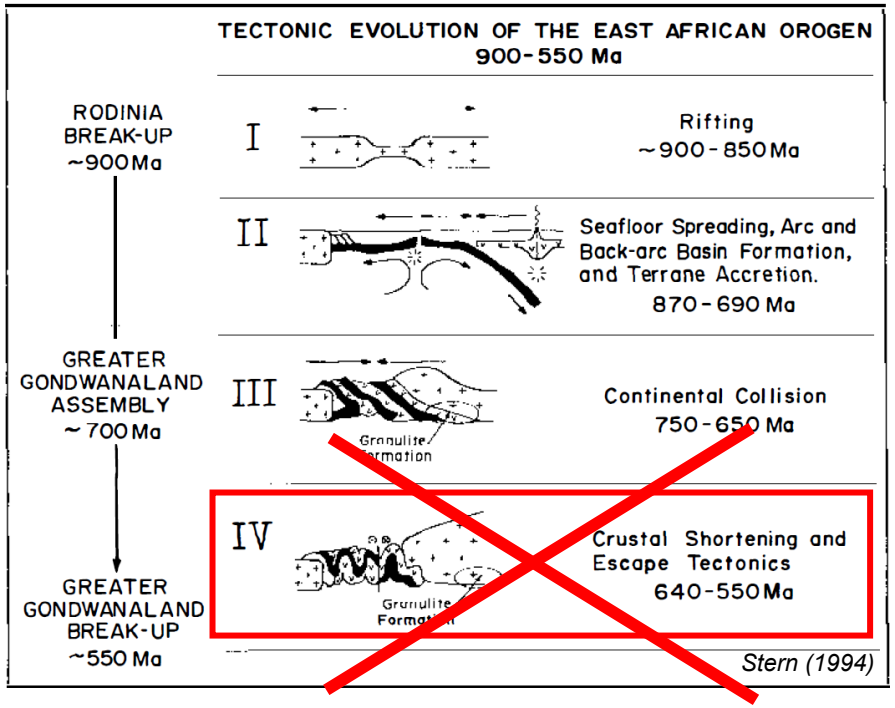


✓ *ca.* **755-725 Ma** U-Pb age of hydrothermal apatite coeval to D_{2GSS} deformation and mineralization.

III. *P-T-t-d* constraints on GSS gold mineralisation

t constraints

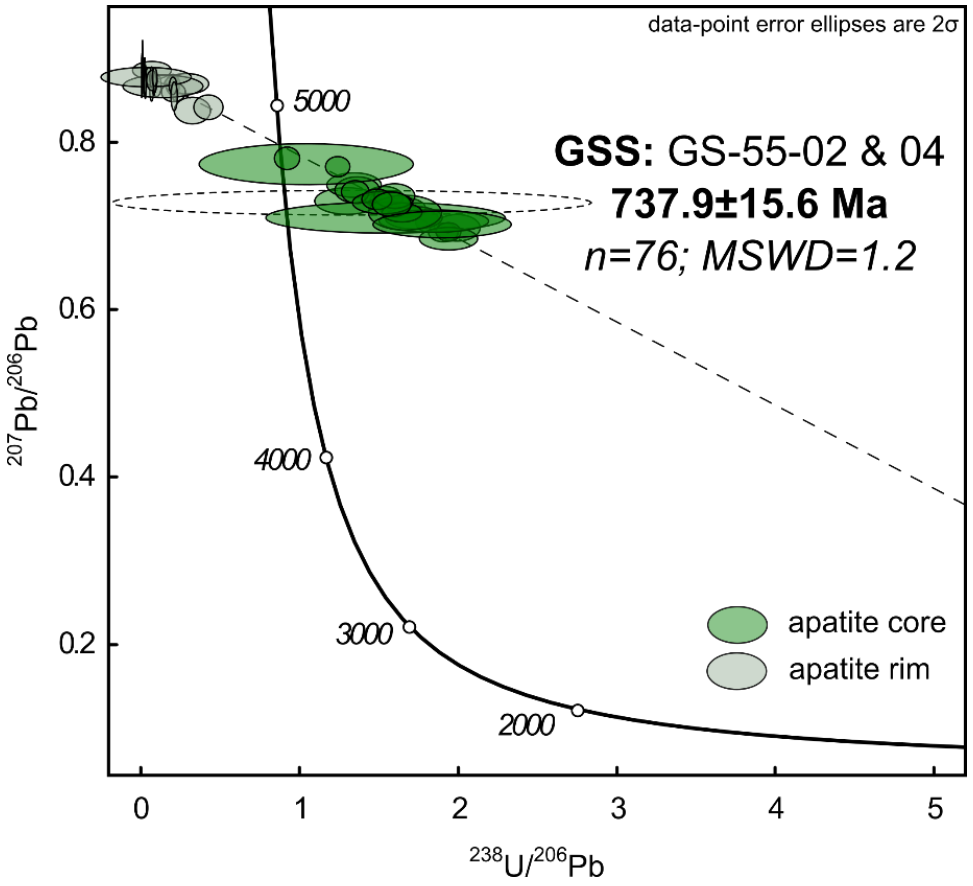


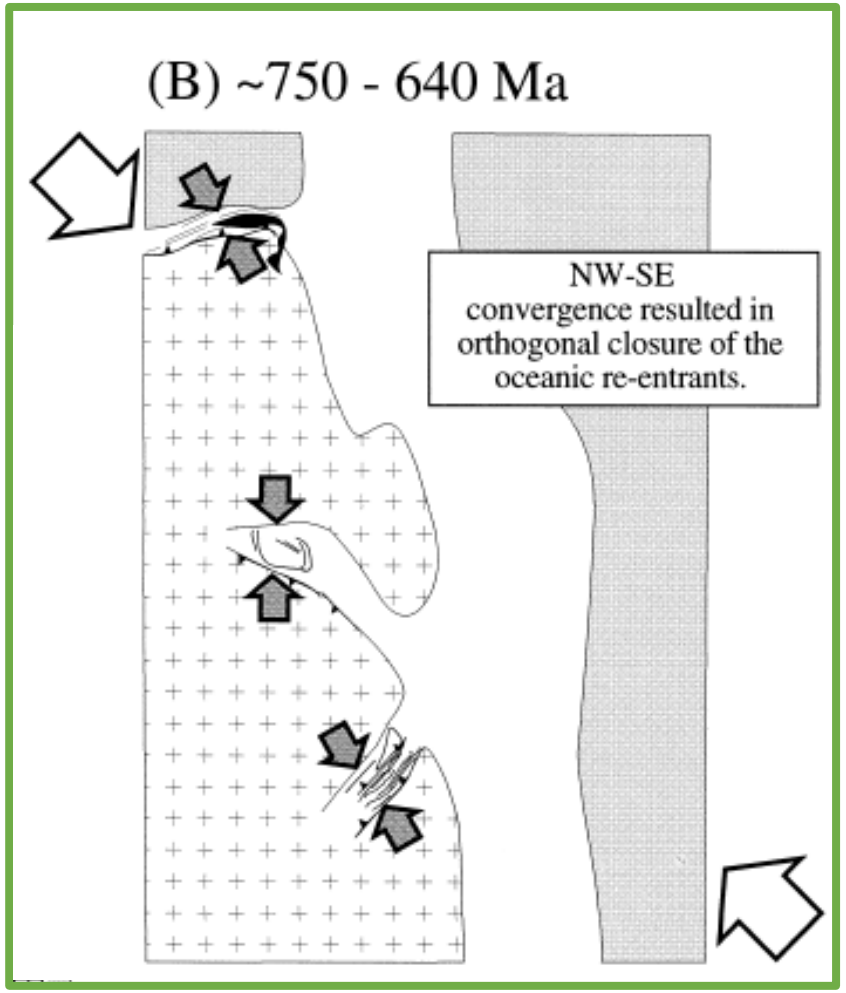


✓ **Cannot fit late collisional Keraf transcurrent reactivation...**

III. *P-T-t-d* constraints on GSS gold mineralisation

t constraints



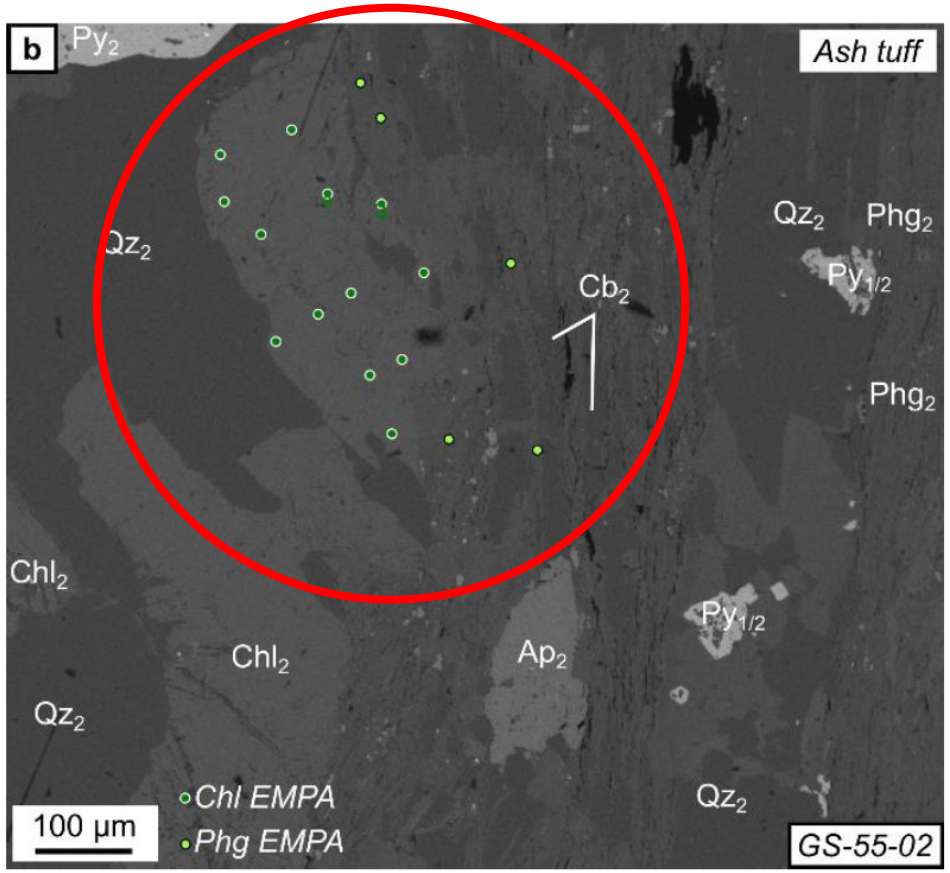


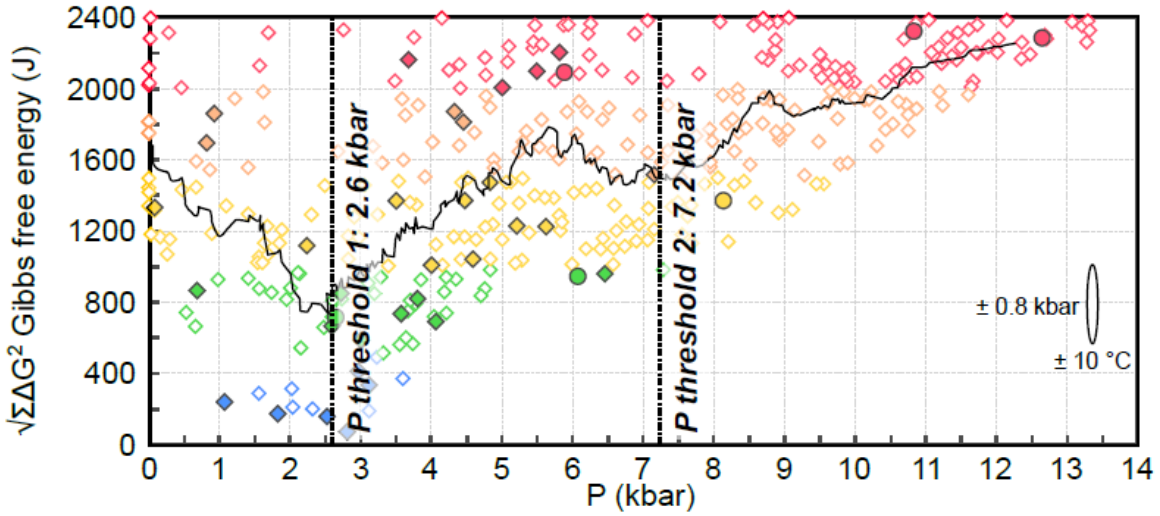
Abdelsalam et al. (1998)

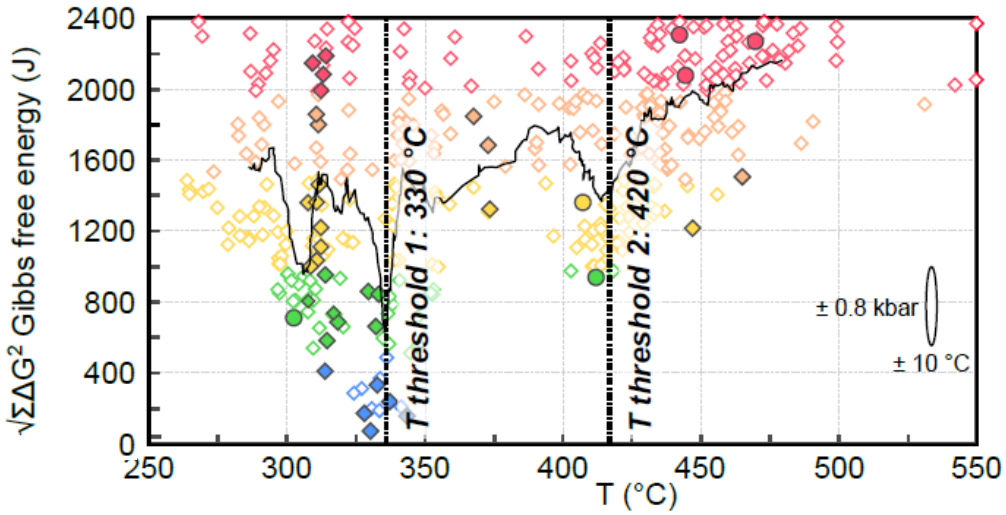
✓ **… but could fit the timing of Atmur-Delgo suturing.**

III. *P-T-t-d* constraints on GSS gold mineralisation

P-T constraints





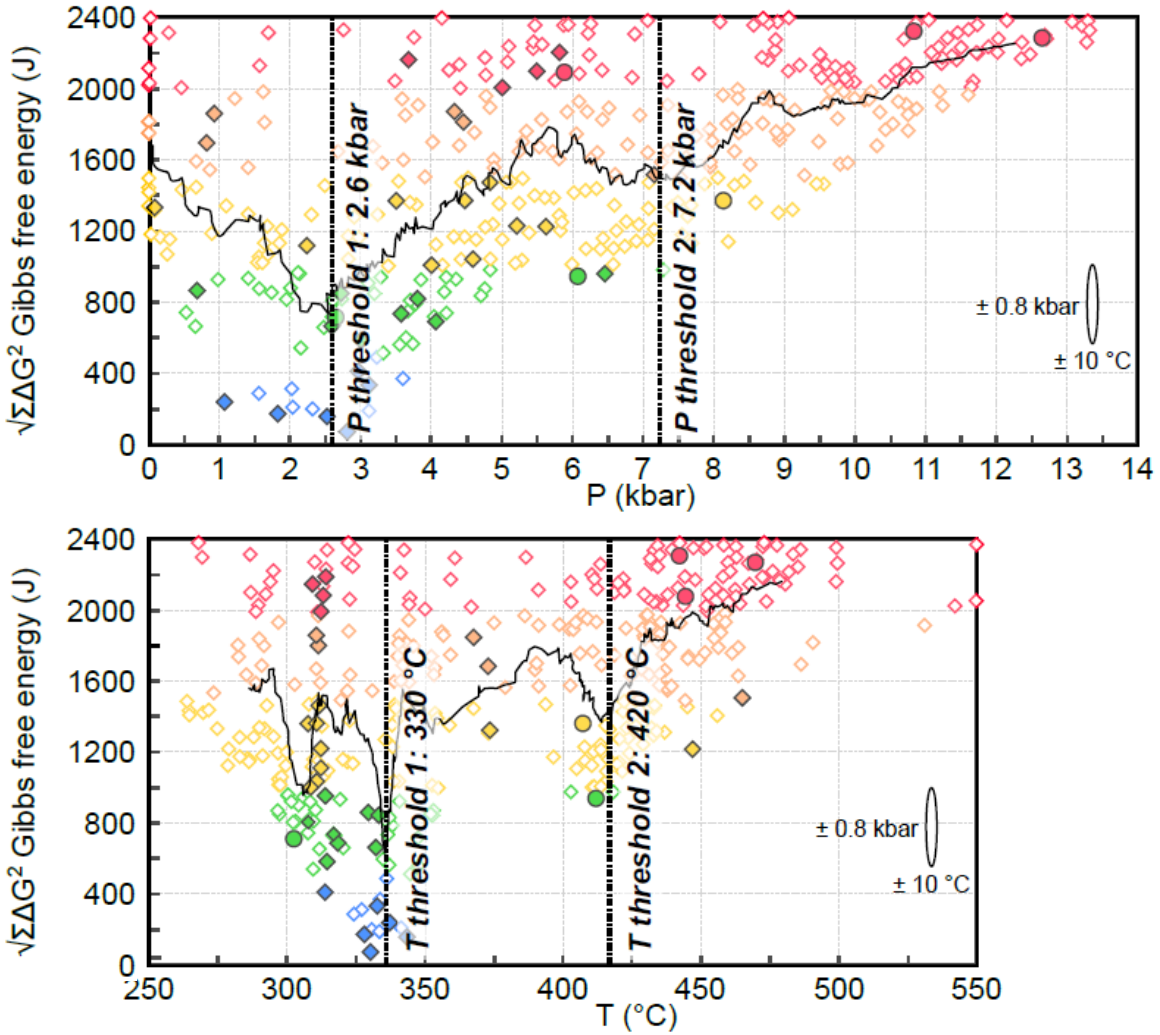


✓ Chl-Phg-Qz-H_2O multi-equilibrium calculations: **7.2 kbar** (20-25 km-depth), **420°C**.

III. *P-T-t-d* constraints on GSS gold mineralisation

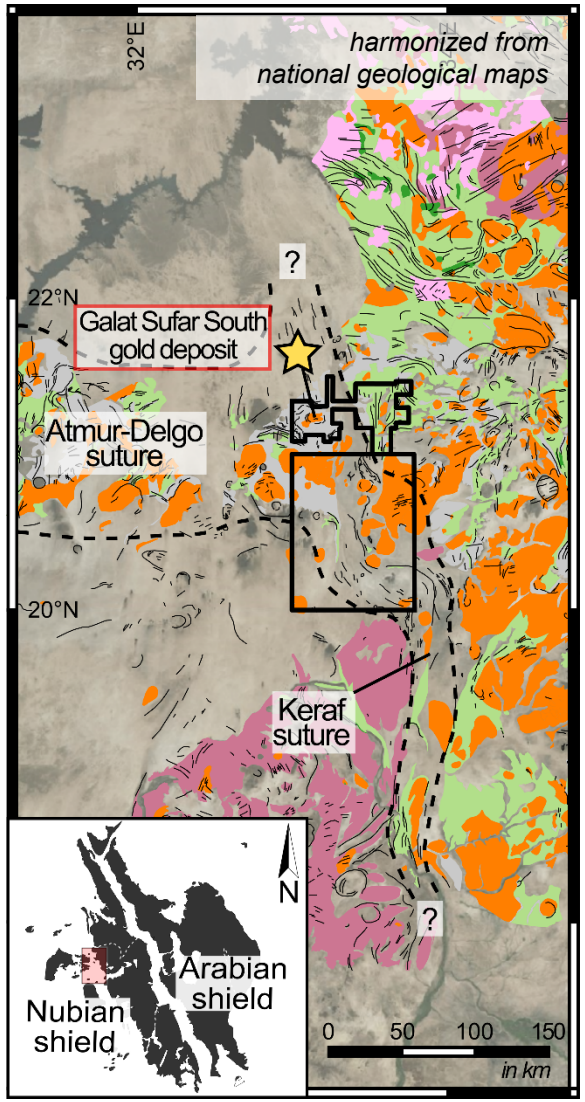
P-T constraints

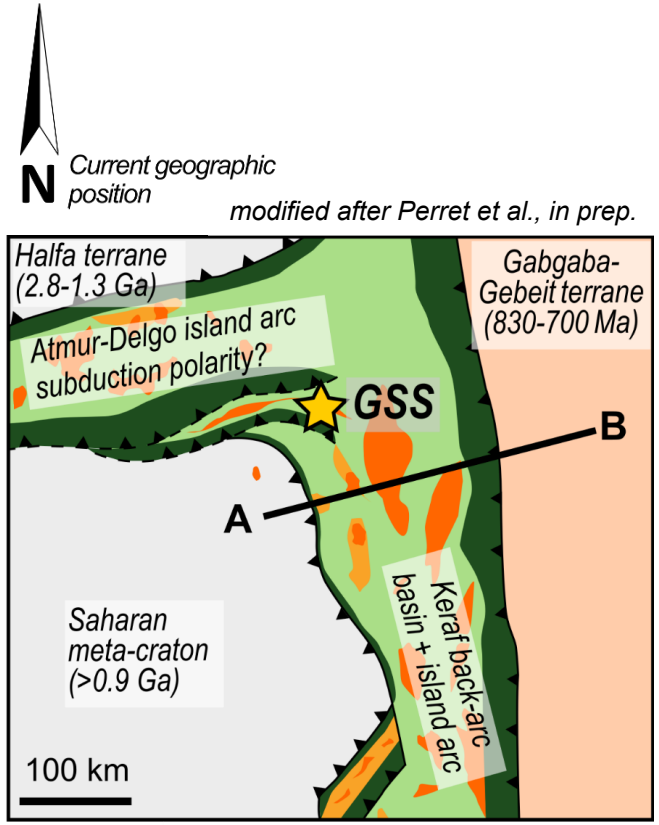
- ✓ Consistent with:
  - ✓ **prograde to peak regional metamorphism conditions** reached during suturing *(Ahmed Sulliman, 2000)*,
  - ✓ the previously documented **deformation style** *(e.g., Muir, 2002; Tomkins et al., 2004; Calderón et al., 2005)*,
  - ✓ **syn-amphibolite facies metamorphism pyrite remobilization** and gold liberation from early sulfide generations previously documented *(Perret et al., 2020, 2021)*,
  - ✓ *P-T* record of meta-volcanosedimentary-dominated **accretionary wedge** in an **accretionary-type subduction setting** *(review by Guillot et al., 2009)*.

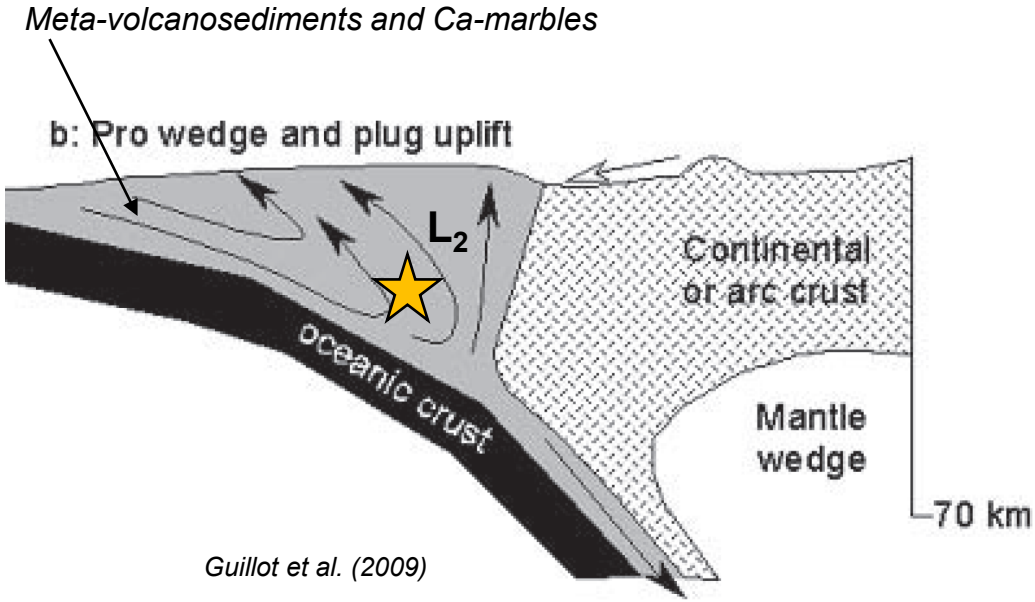


III. *P-T-t-d* constraints on GSS gold mineralisation

P-T-t constraints







Guillot et al. (2009)

✓ **7.2 kbar - 420°C - 755-725 Ma constraints on (i) GSS gold event and (ii) Atmur-Delgo tectonic accretion during Atmur-Delgo intra-oceanic subduction.**

Take-home message

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Insights from the GSS gold event

- ✓ To date, the **oldest lode gold occurrence** documented throughout the Nubian shield **(*ca.* 755-725 Ma)**, it does not relate to late tectonics…

lode gold + late collisional shear zone
≠ late collisional gold mineralization