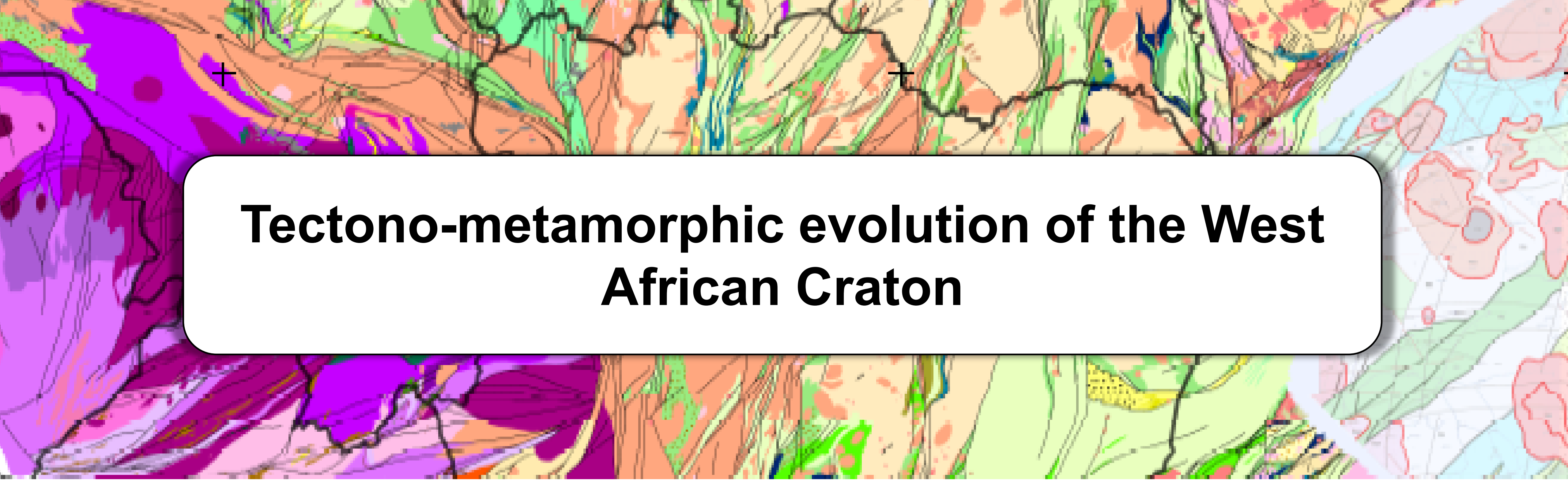


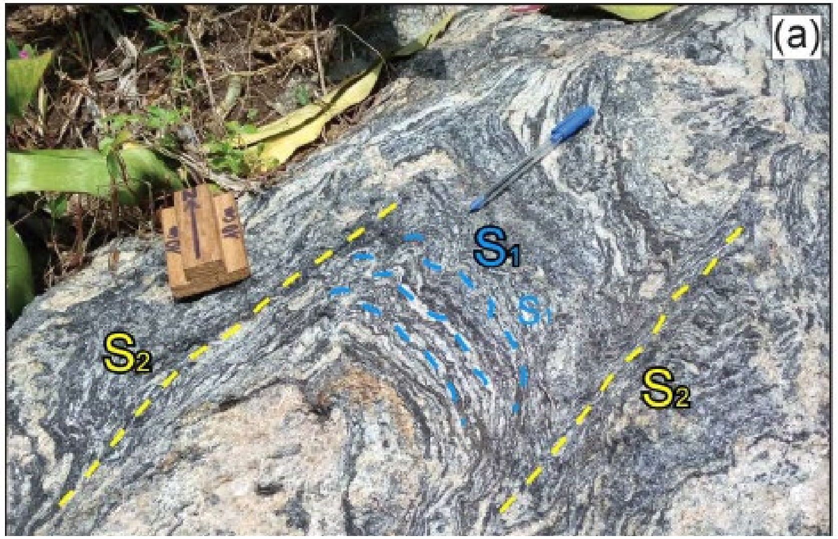
Tectono-metamorphic evolution of the West African Craton

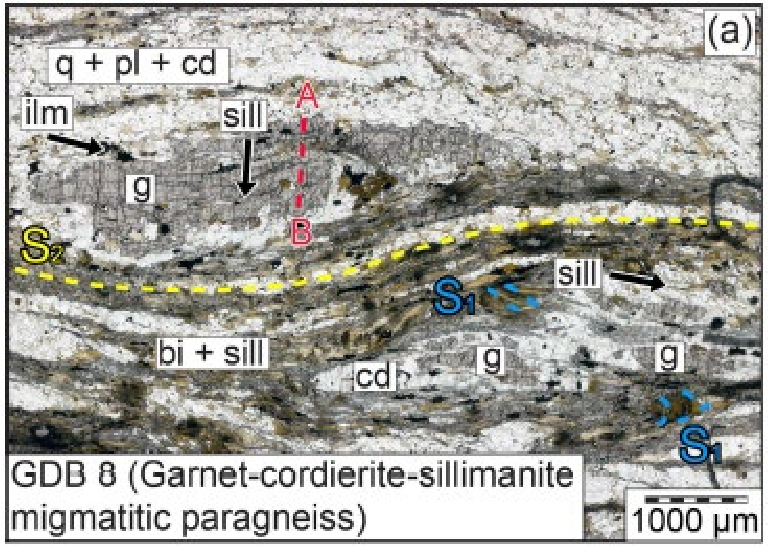
Lenka Baratoux,
M.W. Jessell, O. Vanderhaeghe, S. Naba, Y.A. Koffi, A.N. Kouamelan, V. Metelka, J. Miller, Q. Masurel, S. Perrouty, J. Kone, H. McFarlane, S. Block, M. Diallo, O. Bruguier, H. McFarlane, P. Pitra, N. Thébaud, P.O. Amponsah, P.A. Maisie, N.A. Agra and WAXI team

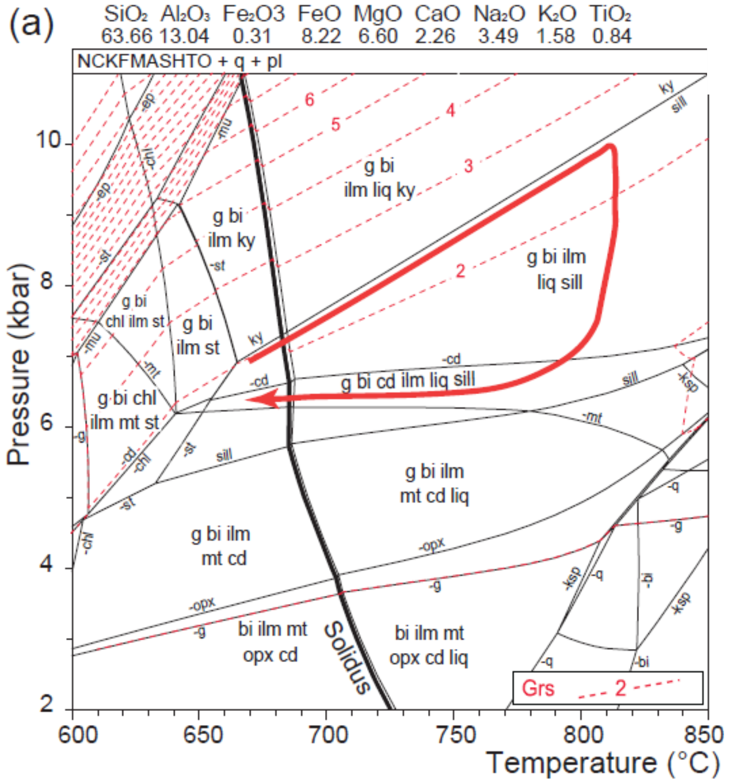
IASTG conference 2026

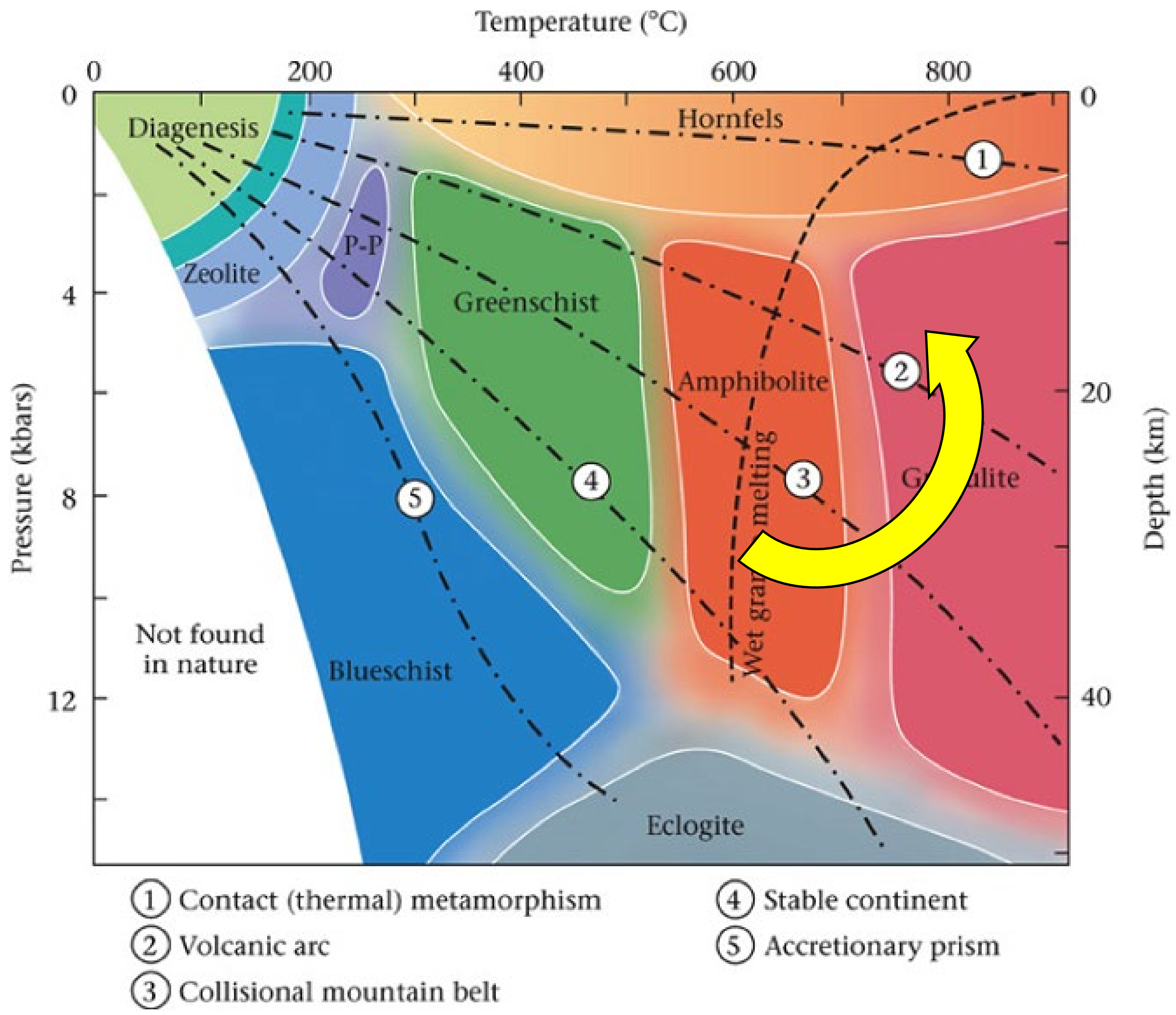
Why do we study a tectono-metamorphic evolution?

- Insight into the processes occurring in the continental and deep oceanic crust
- Estimation of the geodynamic context (depth, temperature, thermal gradient, P-T-t-d path)
- Assessment of whether conditions are favorable (or not) for mineralization
- Absolute and relative chronology of events
- Fluid activity, hydrothermal activity







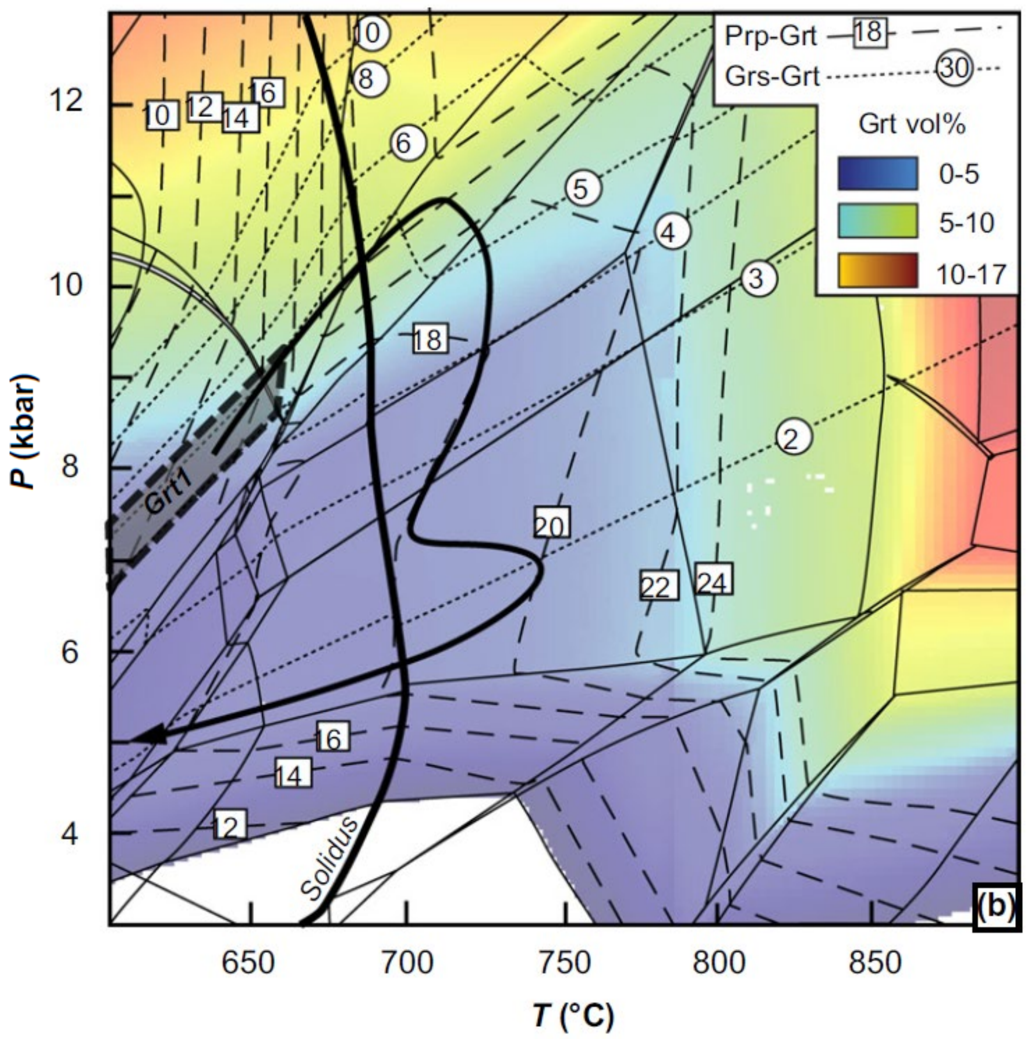


Metamorphic conditions

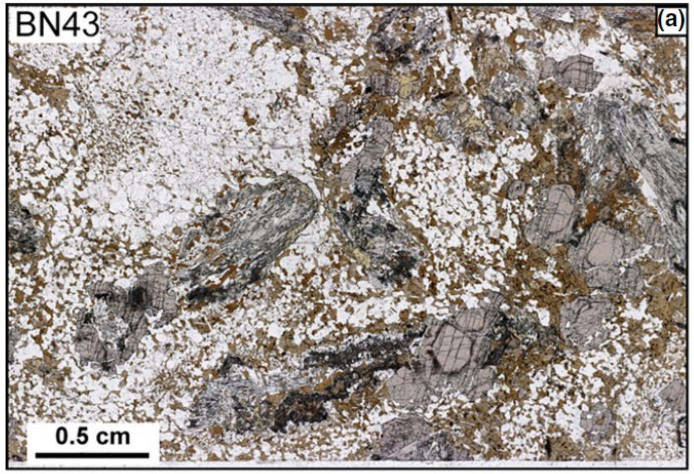
Estimation of:

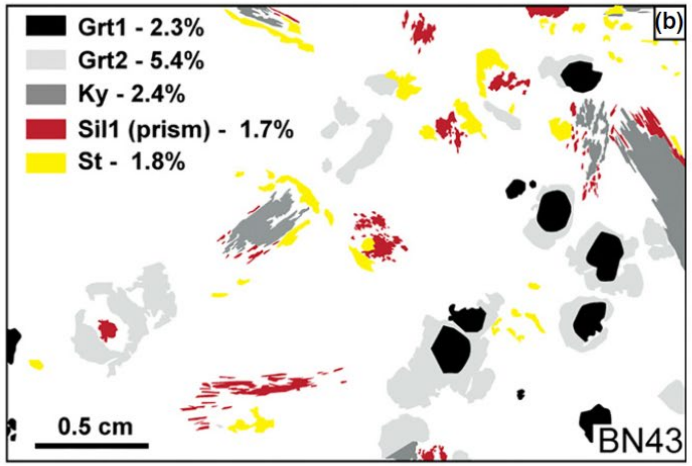
- Depth ($P=\rho gz$)
  - *(pb – local overpressure)*
- Temperature
  - *(pb – frictional heating)*
- Apparent thermal gradient
  - *(pb – incomplete record)*
- Geodynamic context
  - *(pb – based on today's contexts; Precambrian????)*

Pseudosection

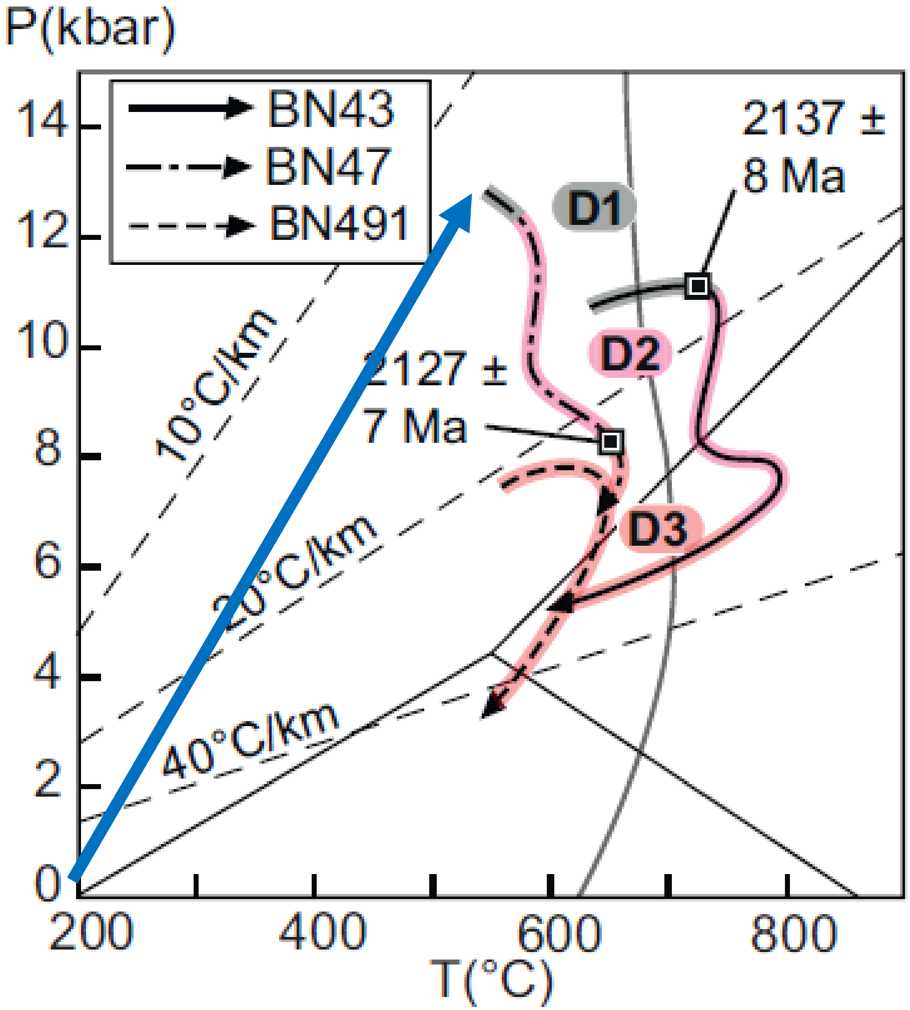


- Bulk rock composition
- Calculation of theoretical fields of stability of mineral assemblages in a PT diagram
- Comparing to a real sample assemblages and their chemistry



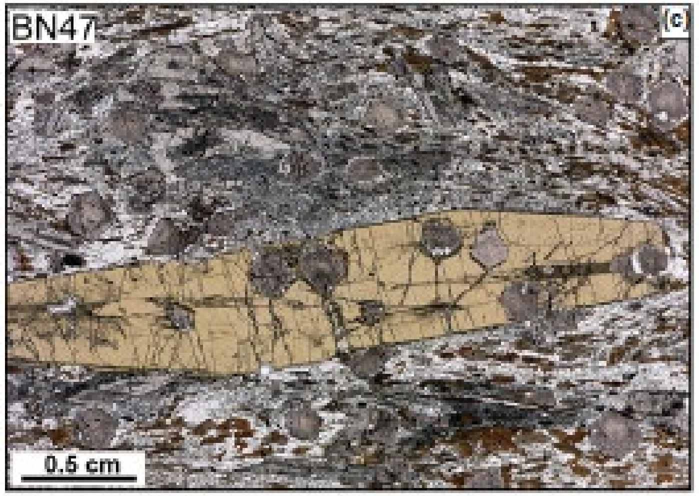


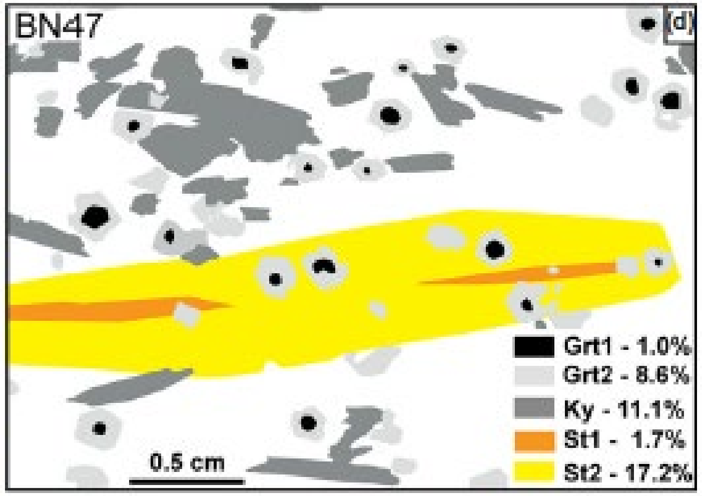
Pressure – Temperature – time – deformation path

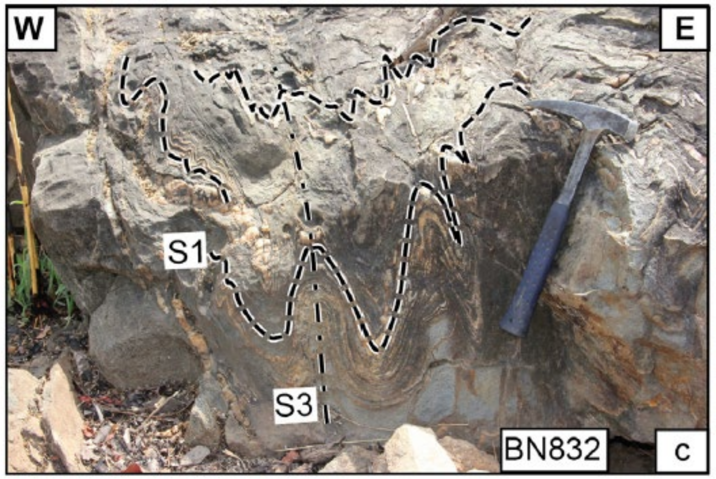


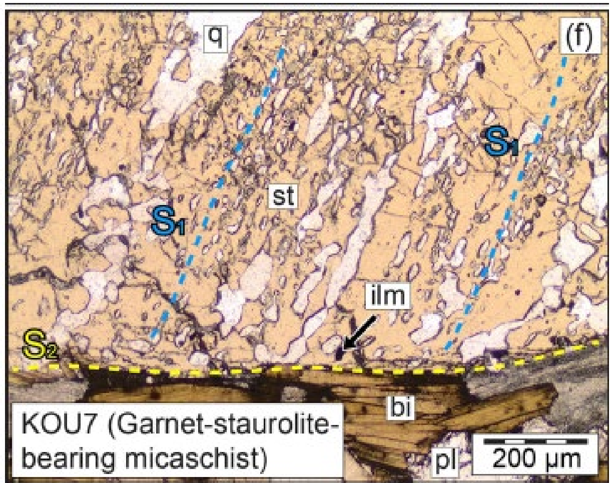
Block et al., 2016; NW Ghana

Polyphase deformation and metamorphism



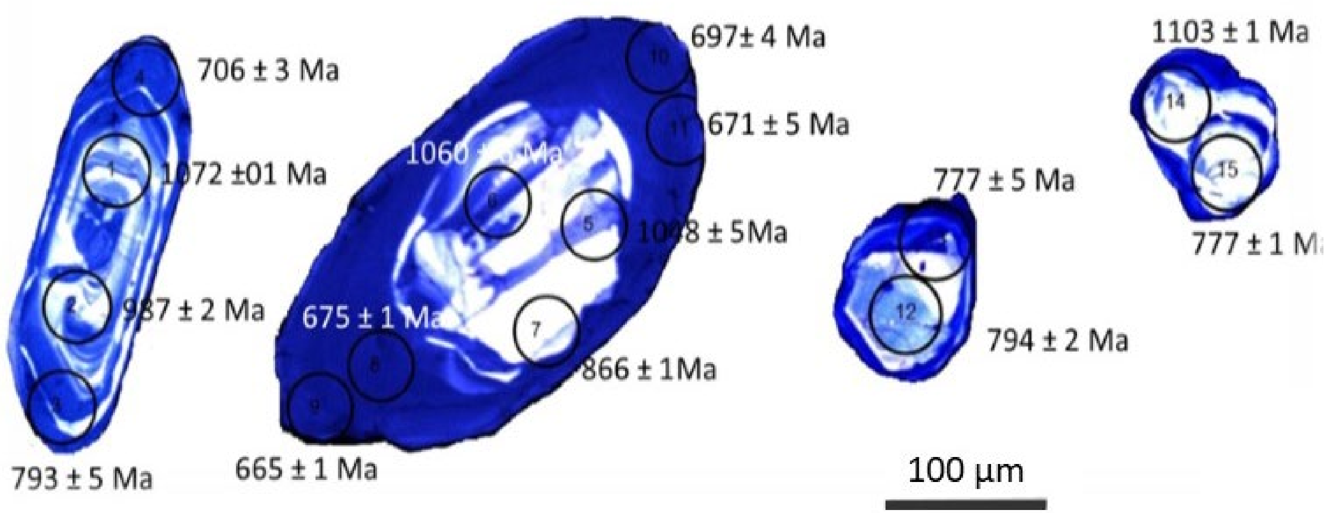






- **What do I date ?**
- **What is the relationship between the mineral and the structure/metamorphic assemblage?**
- U-Pb on zircon, baddeleyite, xenotime, rutile, allanite, monazite; calcite, apatite, etc…
- In-situ laser ICP-MS analyses allow date zoned minerals (potentially different ages)
- Closing T of each isotopic system needs to be lower than the peak T of the metamorphic event

Zircon U-Pb ages

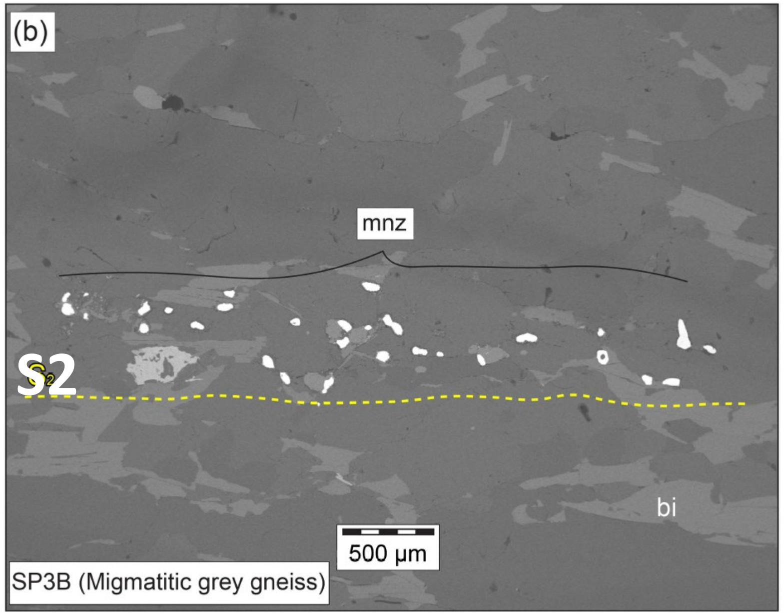


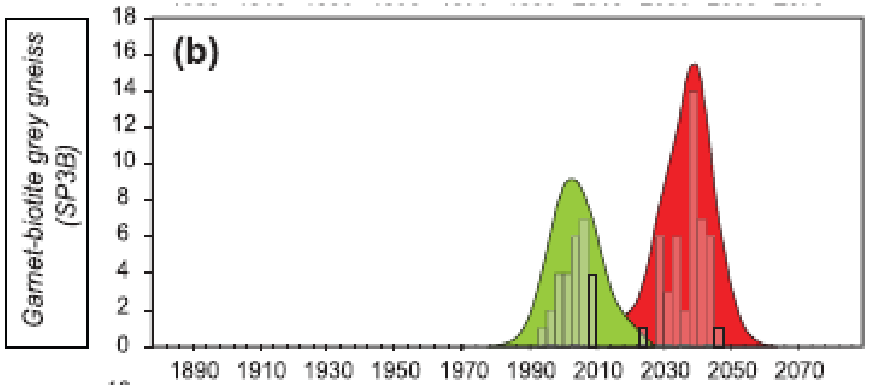
Poukesserandji, in prep.

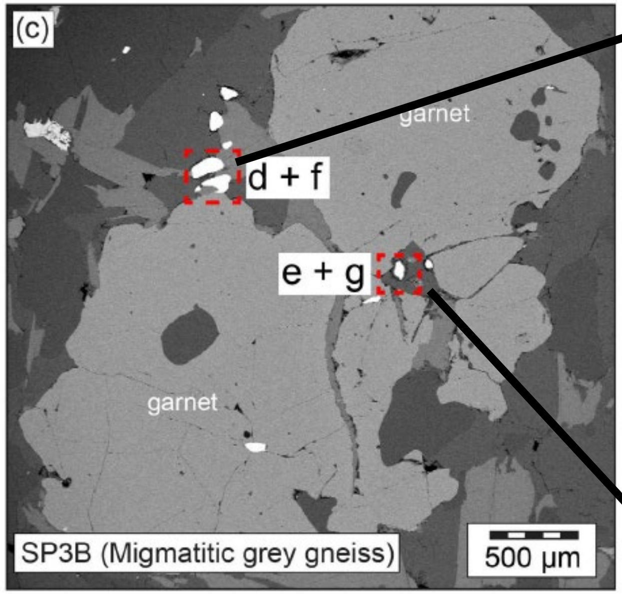
~1100 Ma – cores
~665 Ma - rims

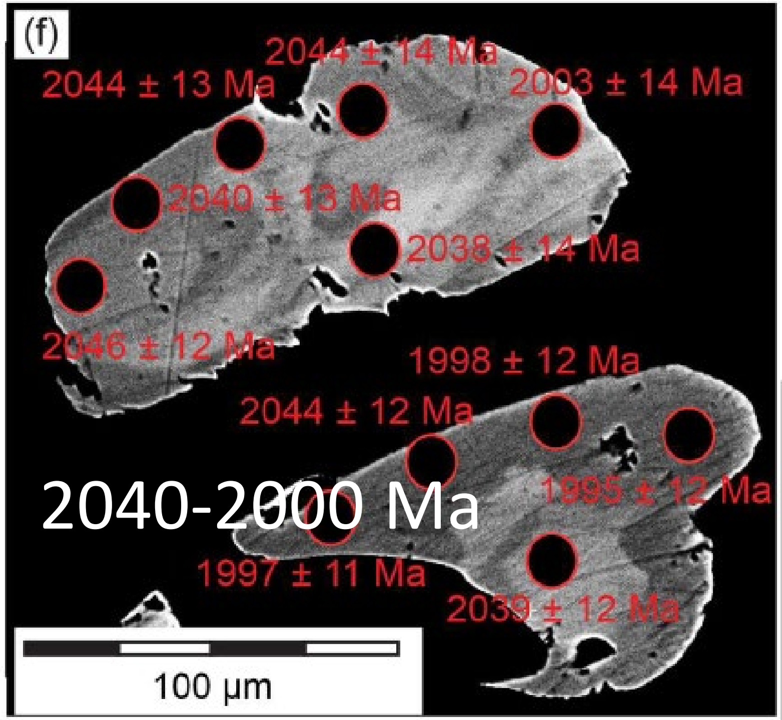
What is the relationship between the mineral and the structure/metamorphic assemblage?

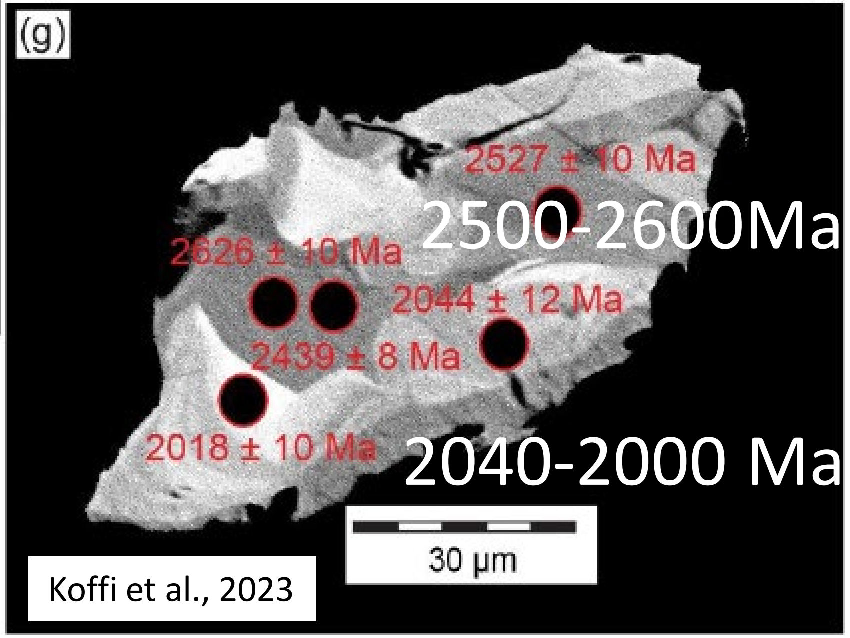
Monazite U-Pb ages







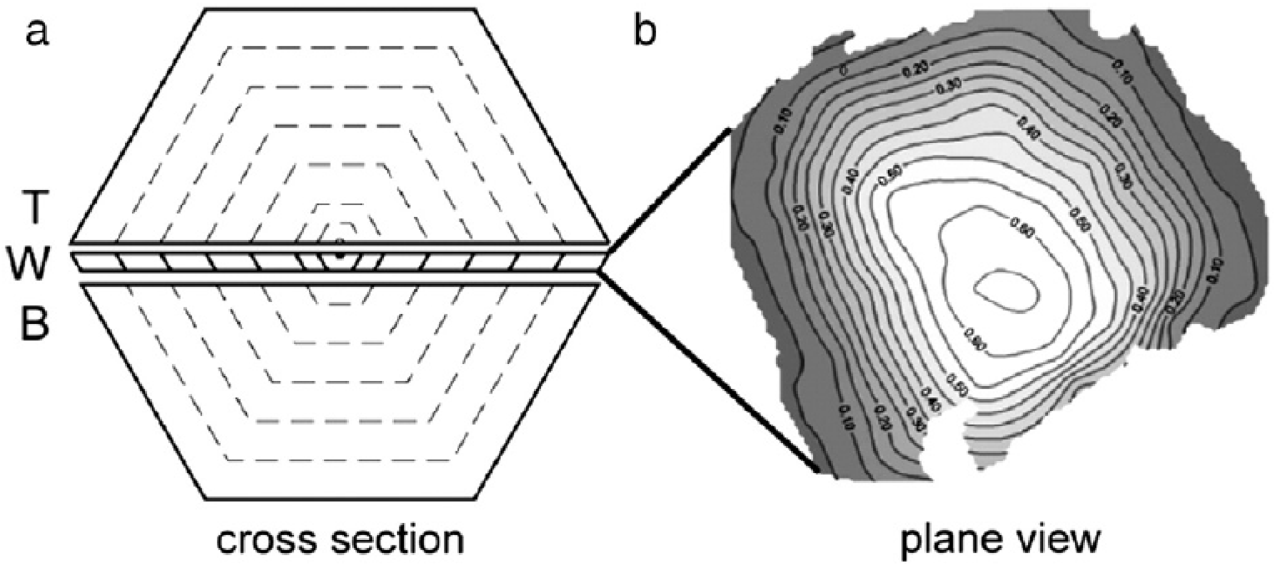


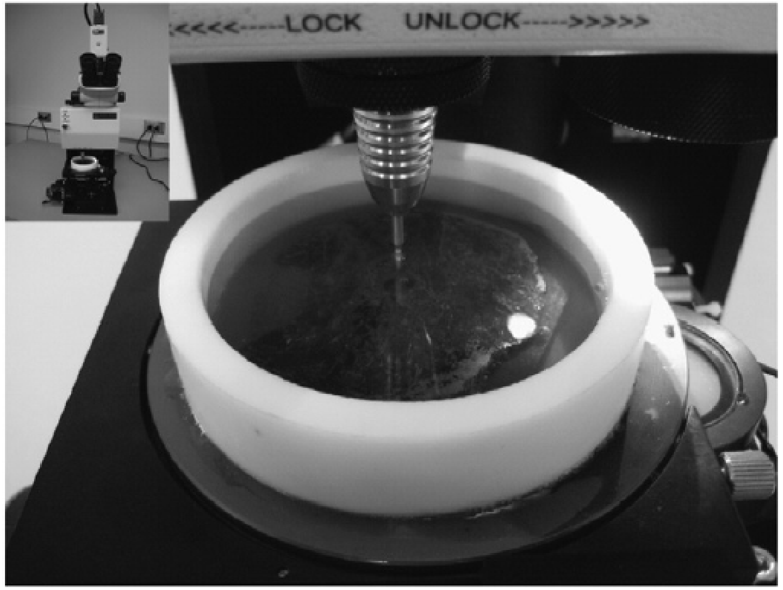


- Relict Archean ages in the cores (~2650-2500 Ma)
- D2 deformation (~2040 Ma)
- Late re-opening/disturbance of the system (~2000 Ma)

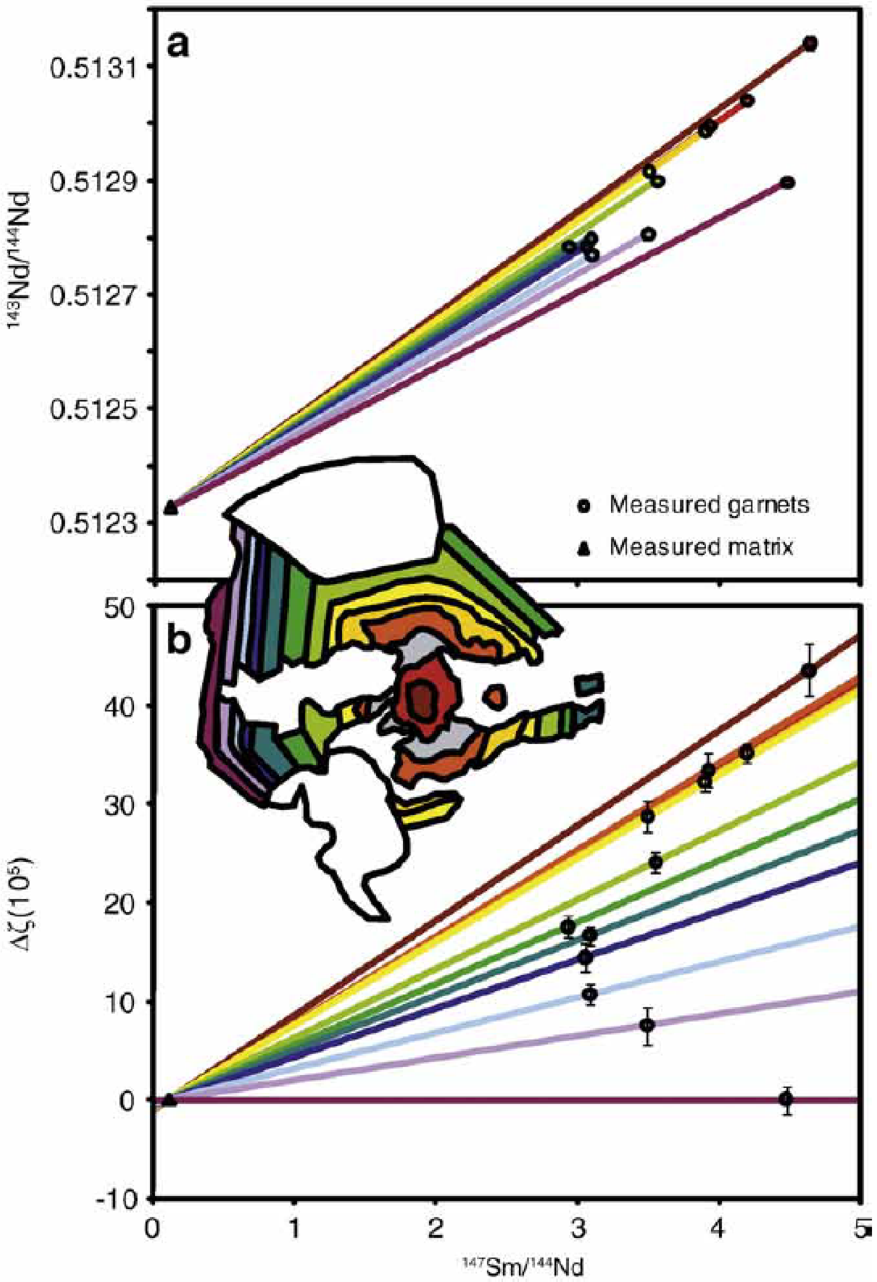
Methods for dating deformation and metamorphism

- Metamorphic minerals such as garnet, amphibole, biotite, K-feldspar, etc…
- Isotopic systems Ar-Ar, K-Ar, Sm-Nd, Lu-Hf,
- dissolution/analysis of the whole mineral or of its parts, mechanical cutting of garnet zones





Pollington and Baxter, 2011



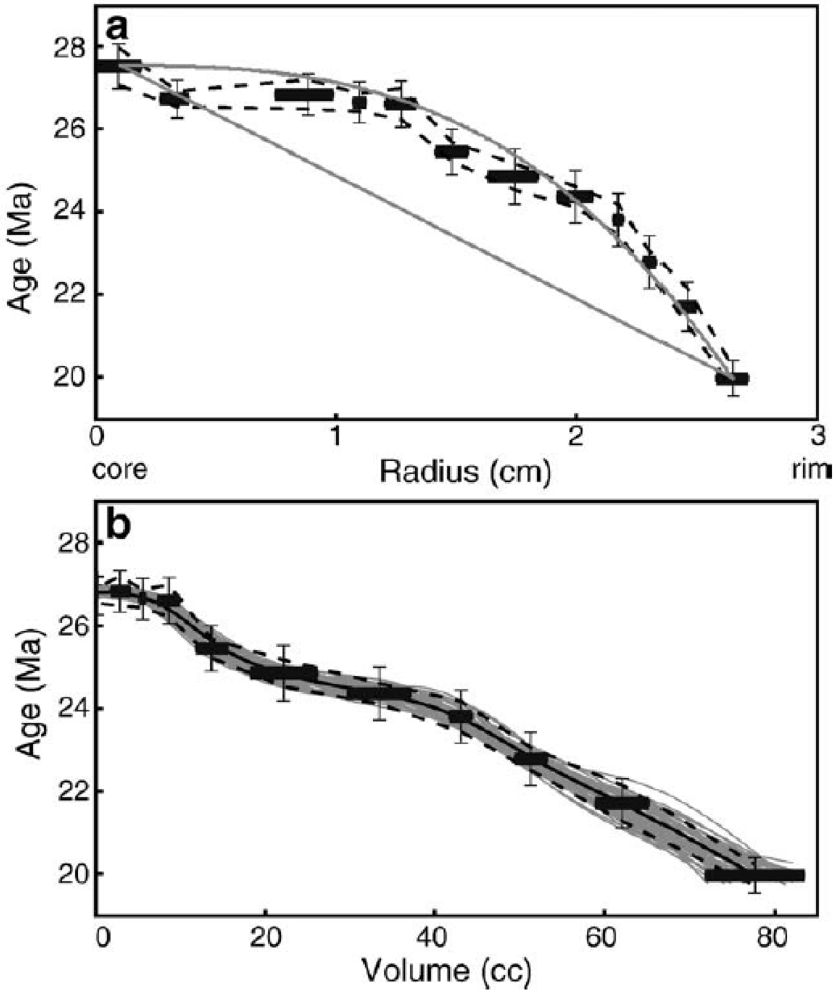
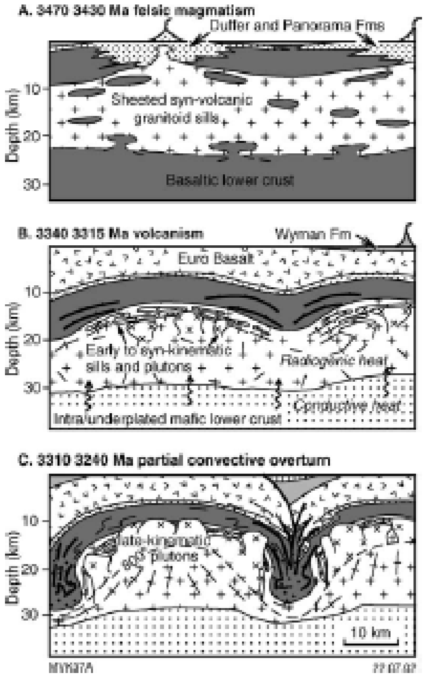


Fig. 4. Age versus garnet radius and volume. (a) Age versus radius. Horizontal bars represent the thickness of the measured annuli as measured along the white lines in Fig. 1a. Vertical black error bars represent absolute age precision (2 SD). Dashed black lines represent the relative age precision envelope between garnet ages (2 SD). Gray lines are models of constant volumetric growth rate (curved) and constant radial growth rate (straight). (b) Age versus volume. Error bars and error window are as in panel a. Black line represents best spline fit to the original data. Gray lines represent iterations from the Monte Carlo simulations.

Pollington and Baxter, 2010

Precambrian geodynamics



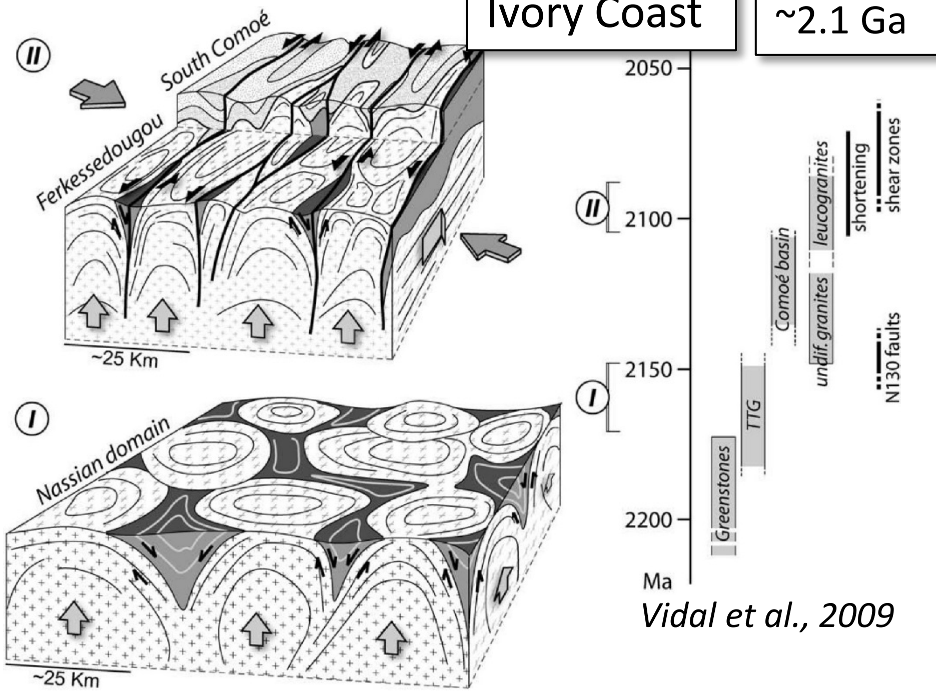
Pilbara, Australia

~3.4 Ga

Onset of the "modern" plate tectonics?

How was the tectonic style before it became "modern"?

Van Kranendonk et al., 2004



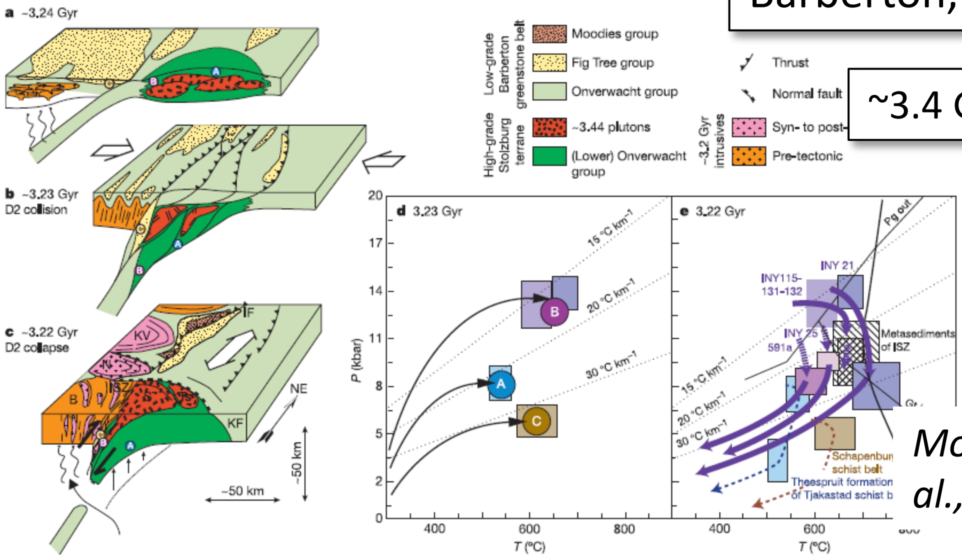
Ivory Coast

~2.1 Ga

Vidal et al., 2009

Barberton, South Africa

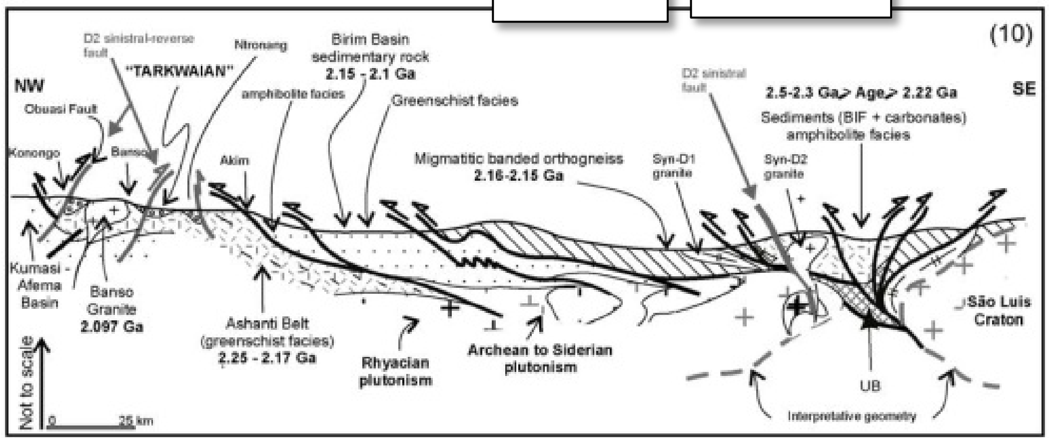
~3.4 Ga



Moyen et al., 2006

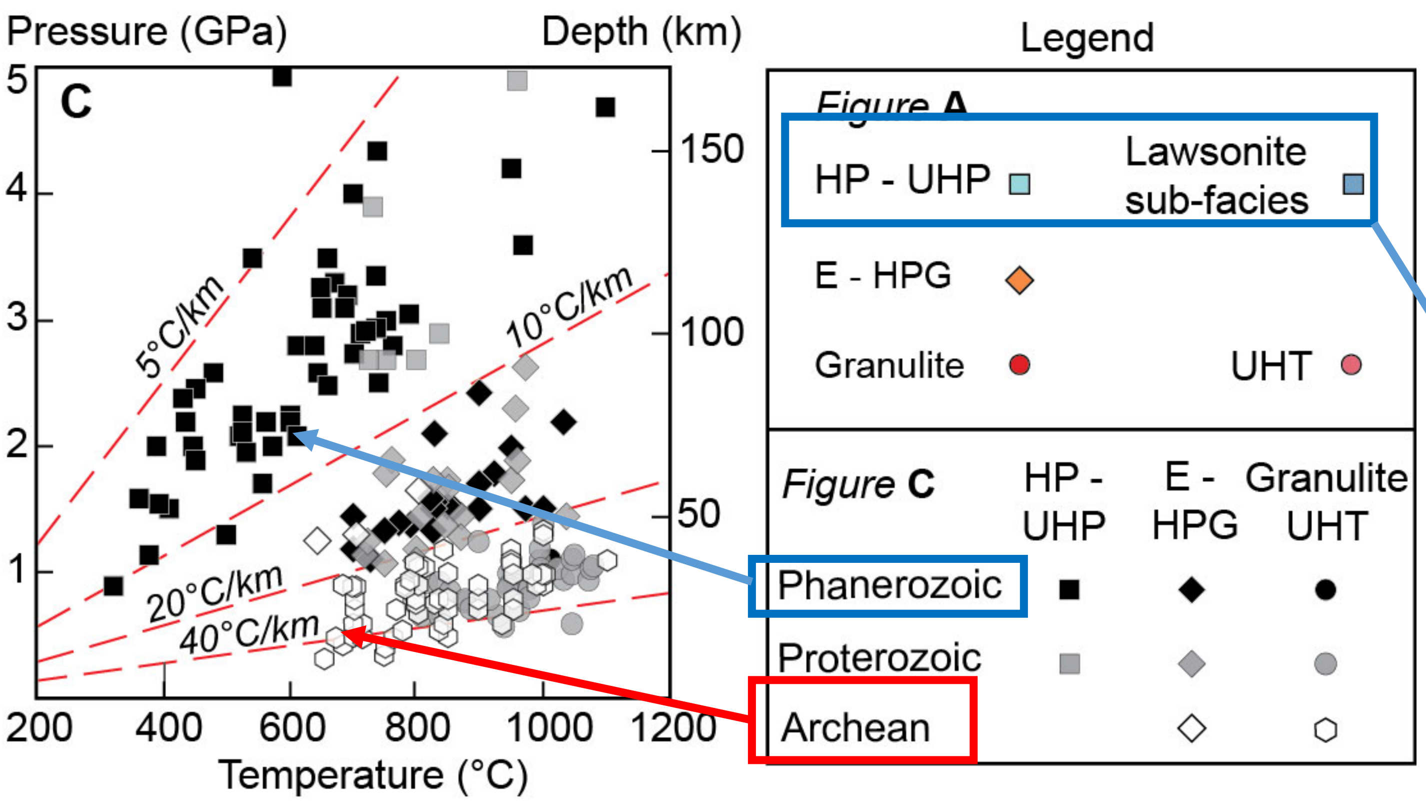
Ghana

~2.1 Ga

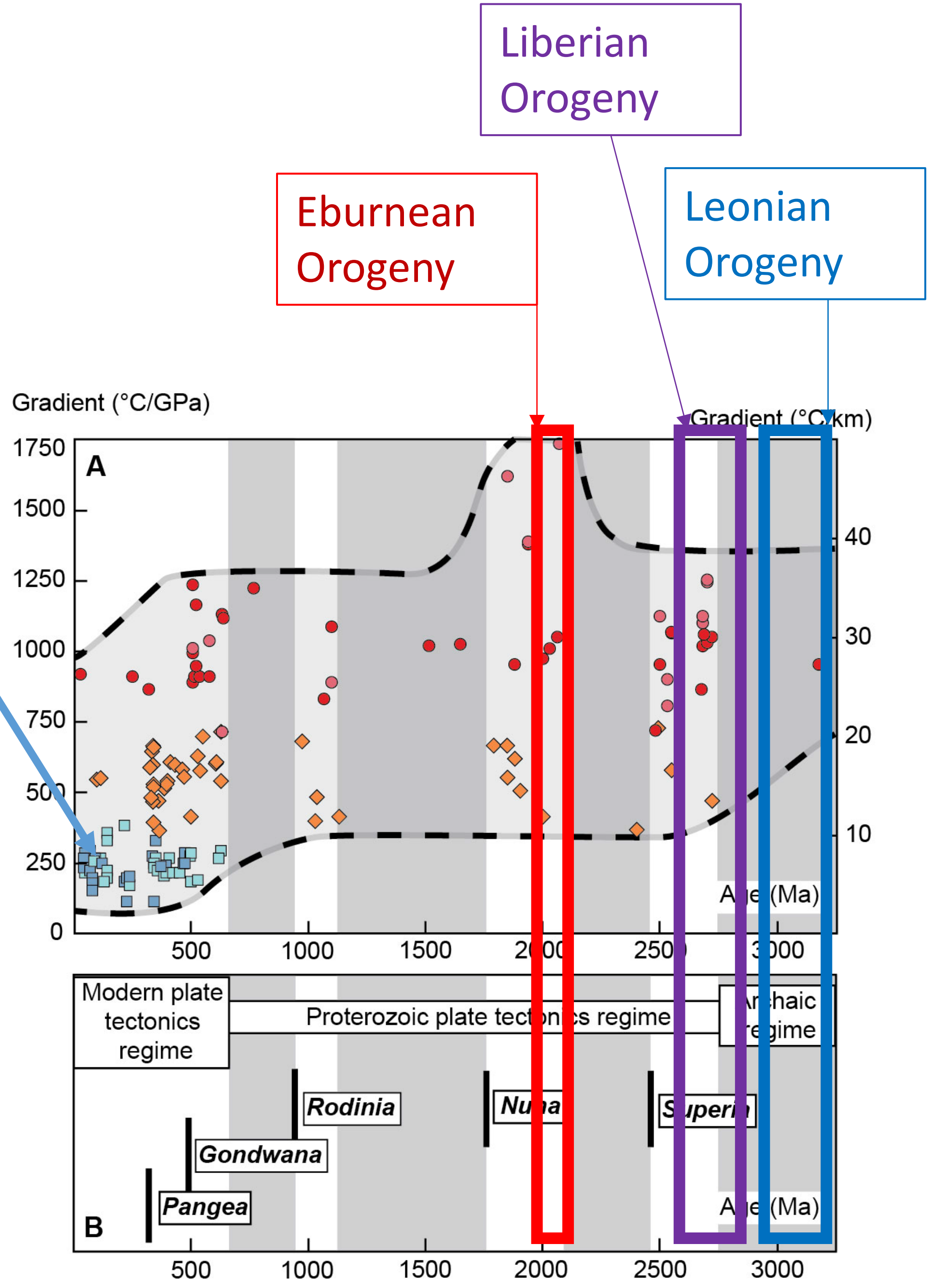


Feybesse et al., 2006

Metamorphic grade

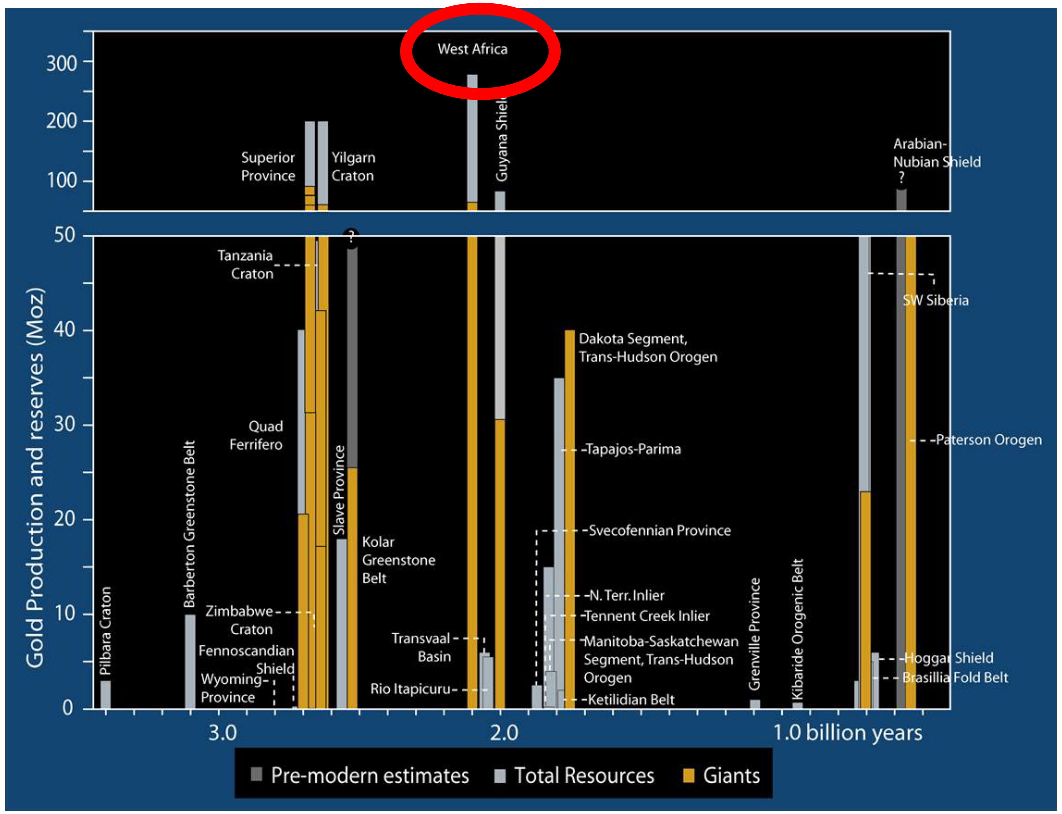


Brown, 2007



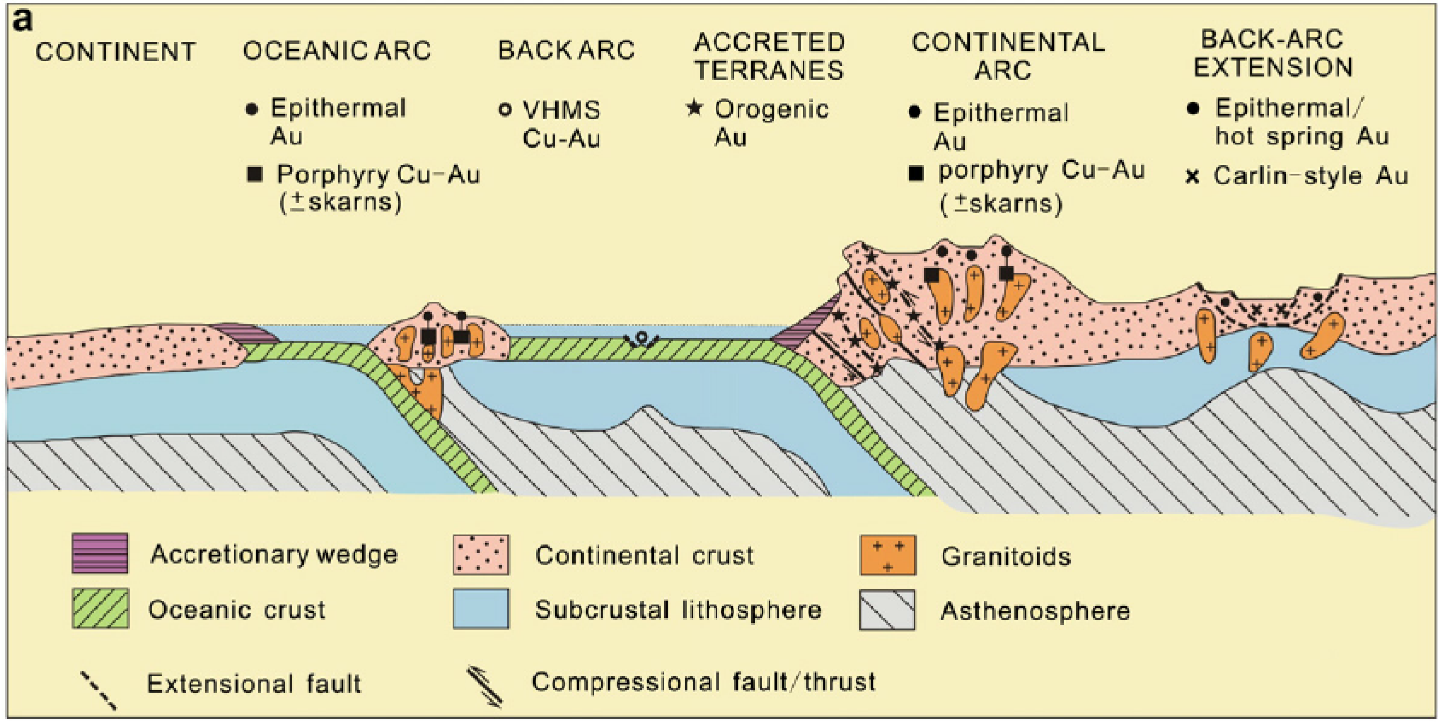
Introduction – Geodynamic setting and mineral deposits

Orogenic gold provinces through time



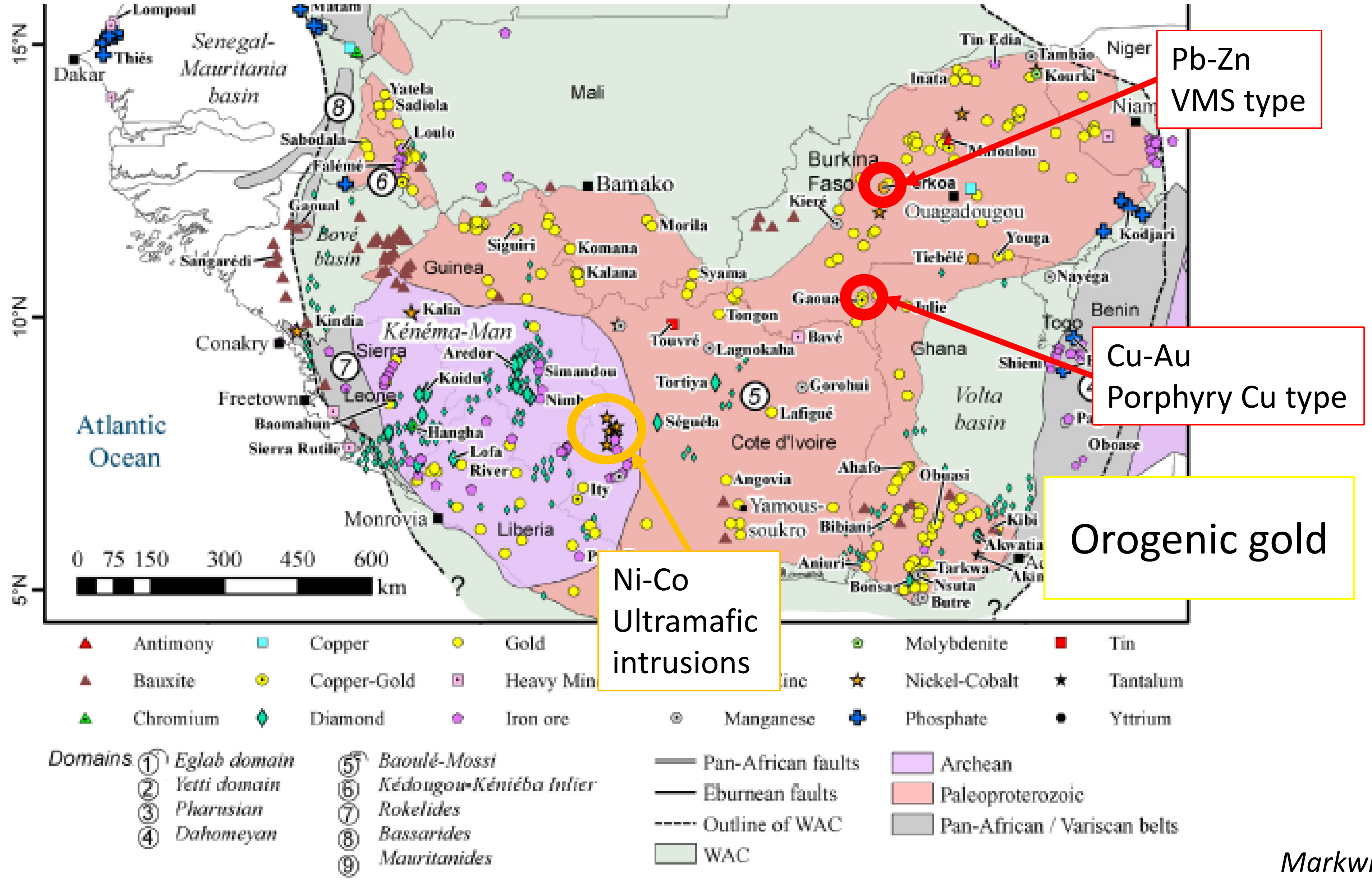
Goldfarb (2005)

Geodynamic settings for various gold deposits



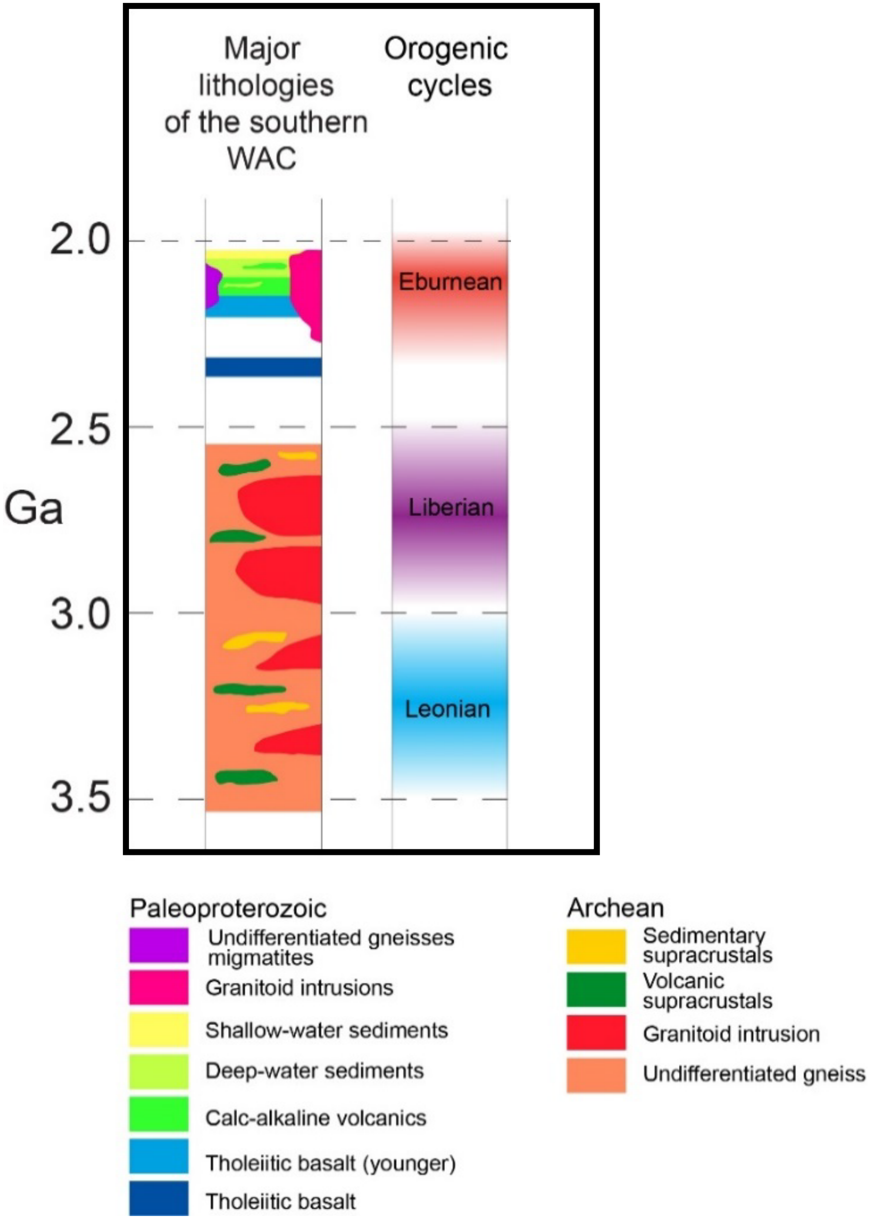
Groves et al., 2003

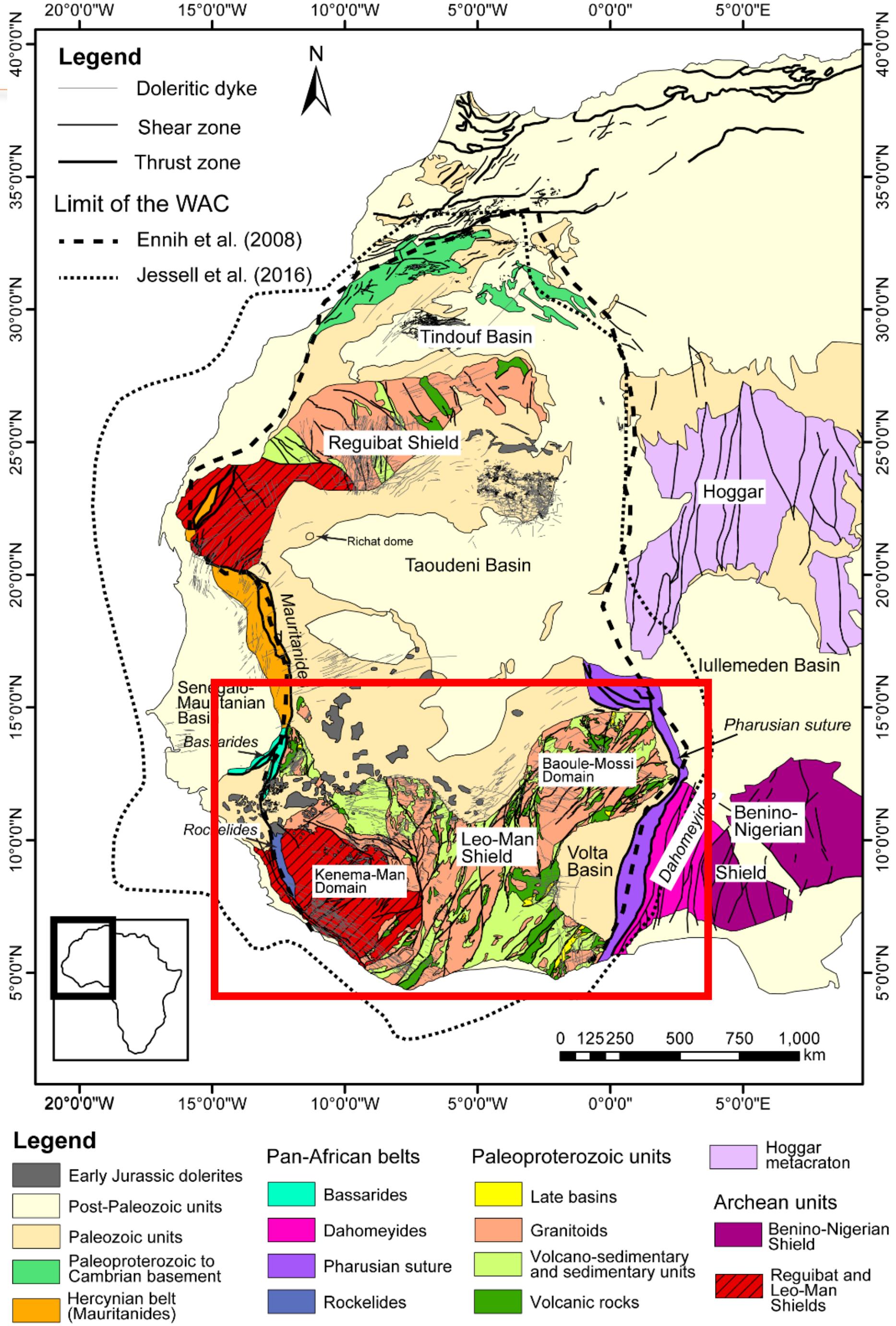
Introduction – Mineral deposits in the southern West African Craton



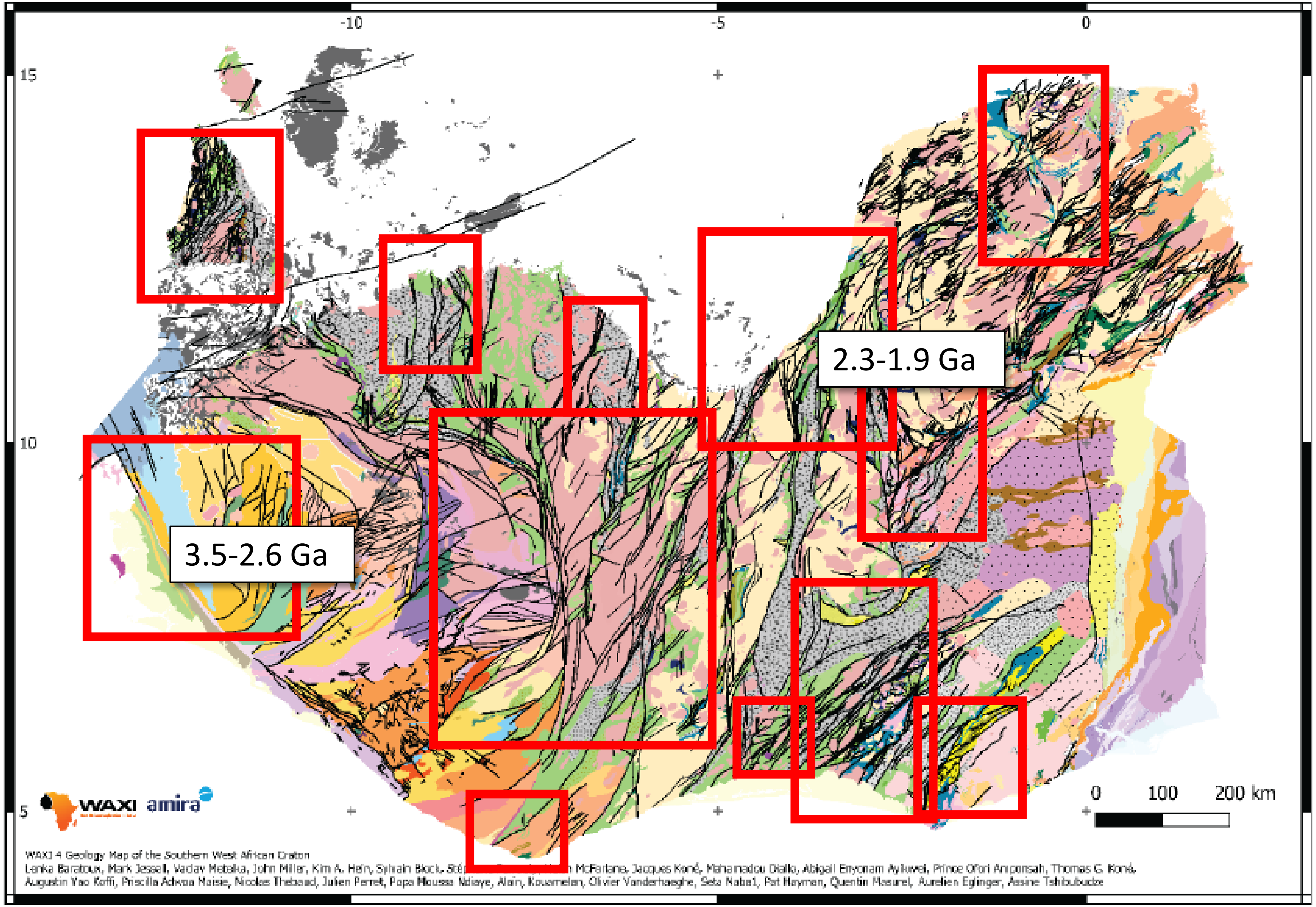
Markwitz et al., 2015

The West African Craton





The southern West African Craton



WAXI research (2006-2026)

WAXI
West African Exploration Initiative

Basement Interp.

- Volta Basin (1)

Archean

- Amphibolite
- Charnockite
- Composite gneiss
- Diorite
- Gabbro
- Granite
- Granite with pyroxene
- Granodiorite
- Iron formation
- Kasila-Magbele
- Kasila-Tapr
- Leonian domed granitoid
- Leonian gneiss
- Leonian granitoid
- Leucocratic gneiss
- Liberian gneiss
- Liberian Granitoid
- Mafic schist
- Melanocratic gneiss
- Mica schist
- Migmatite
- Mylonitised Leonian granite
- Ortho-gneiss
- Quartzite
- Rokotolon
- Shear zone
- Simandou formation
- Transitional granitoids
- Transitional gneiss
- Undifferentiated granitoid
- Undifferentiated schist

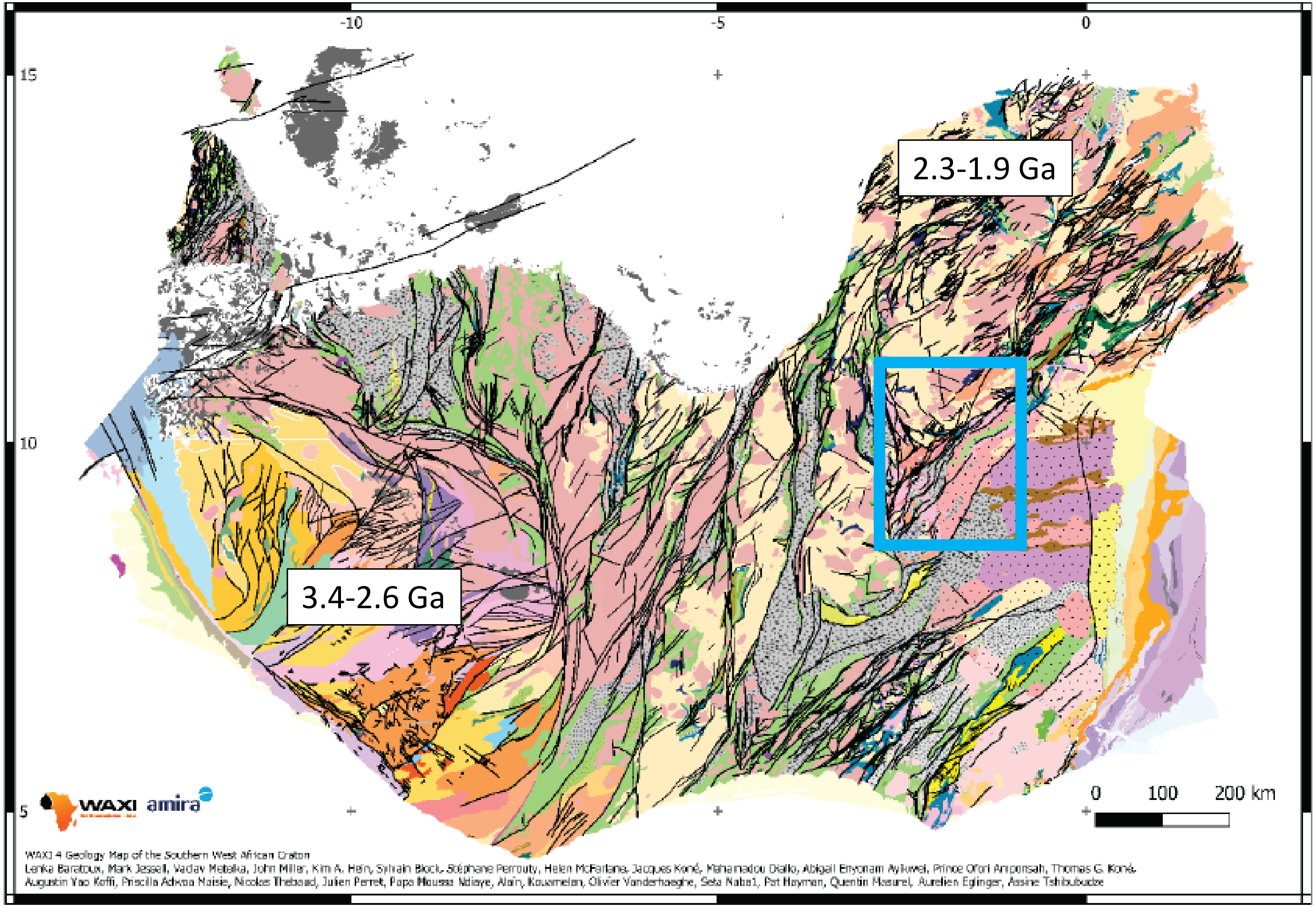
Paleo-Proterozoic

- Amphibolite
- Andesite
- Andesite, pyroclastic flow
- Argillite, pelitic schist
- Basalt
- Basalt, andesite
- Basalt, andesite, pyroclastic flow
- Basalt, gabbro
- Basalt, volcano-sedimentary, andesite, sediment
- Biotite gneiss
- Carbonate units
- Charnockite
- Composite gneiss
- Detrital sediments, Birimian formation
- Detrital sediments, conglomerate, minor sandstone
- Detrital sediments, conglomerate, sandstone
- Detrital sediments, Huni formation
- Detrital sediments, Kawere formation
- Detrital sediments, phyllite
- Detrital sediments, sandstone, minor conglomerate
- Detrital sediments, sandstone, minor siltstone
- Detrital sediments, Tarkwaian-type
- Detrital sediments,highly magnetic
- Diorite
- Dolerite
- Dolerite
- Dolerite
- Freetown Complex
- Gabbro
- Gabbro norite
- Gabbro, pyroxenite
- Gondite
- Granite
- Granodiorite
- Granodiorite, diorite
- Granodiorite, granite
- Graywacke
- Graywacke, sandstone, argillite, pelitic schist
- Iron skarn
- Ironstone placer
- Komatiite and high Mg basalt
- Lamproite
- Late-stage Kfs granite
- Leucocratic gneiss
- Mafic conglomerate
- Mica schist
- Migmatite
- Ortho-gneiss
- Para-gneiss
- Quartzite
- Rhyolite, dacite
- Tapr
- Tonalite, trondhjemite, granodiorite
- Ultramafic rock
- Undifferentiated granitoid
- Undifferentiated sediment
- Undifferentiated sediment
- Volcano-sedimentary schist
- Volcano-sedimentary schist, andesite, pyroclastics

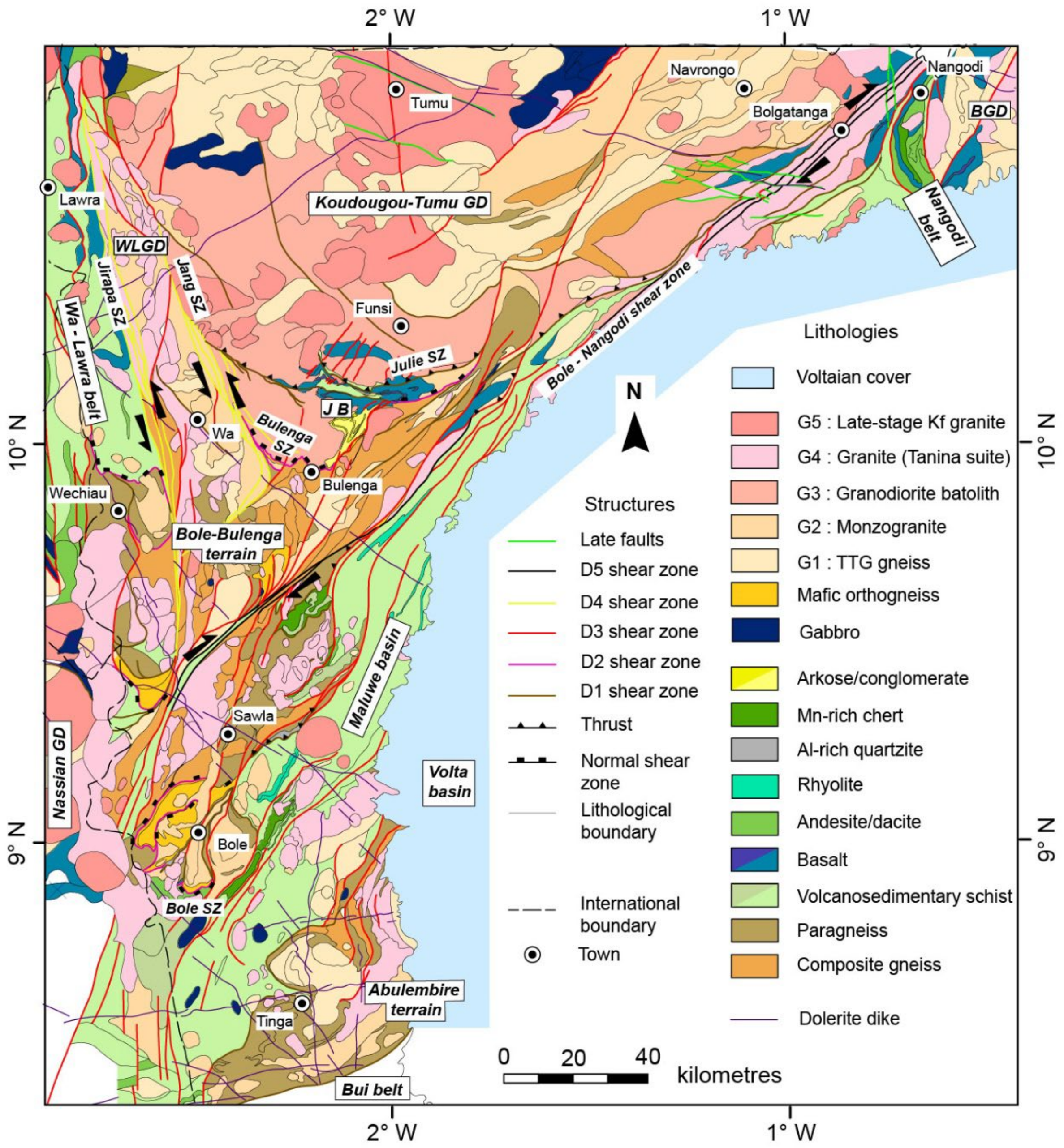
Phanerozoic

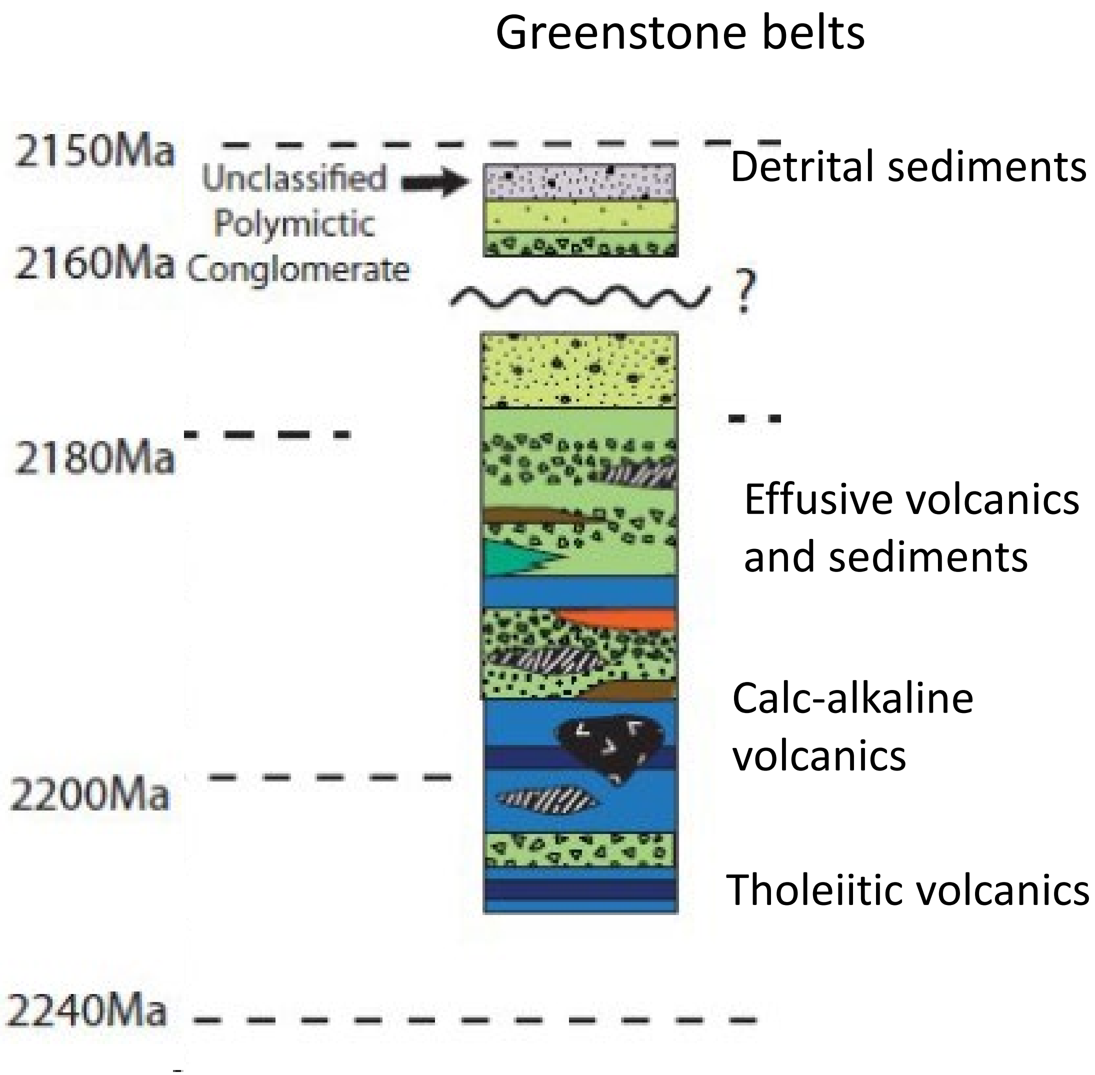
- Rokel River
- Rokel River-Tapr
- Undifferentiated sediments

Paleoproterozoic terrains – example of NW Ghana



NW Ghana

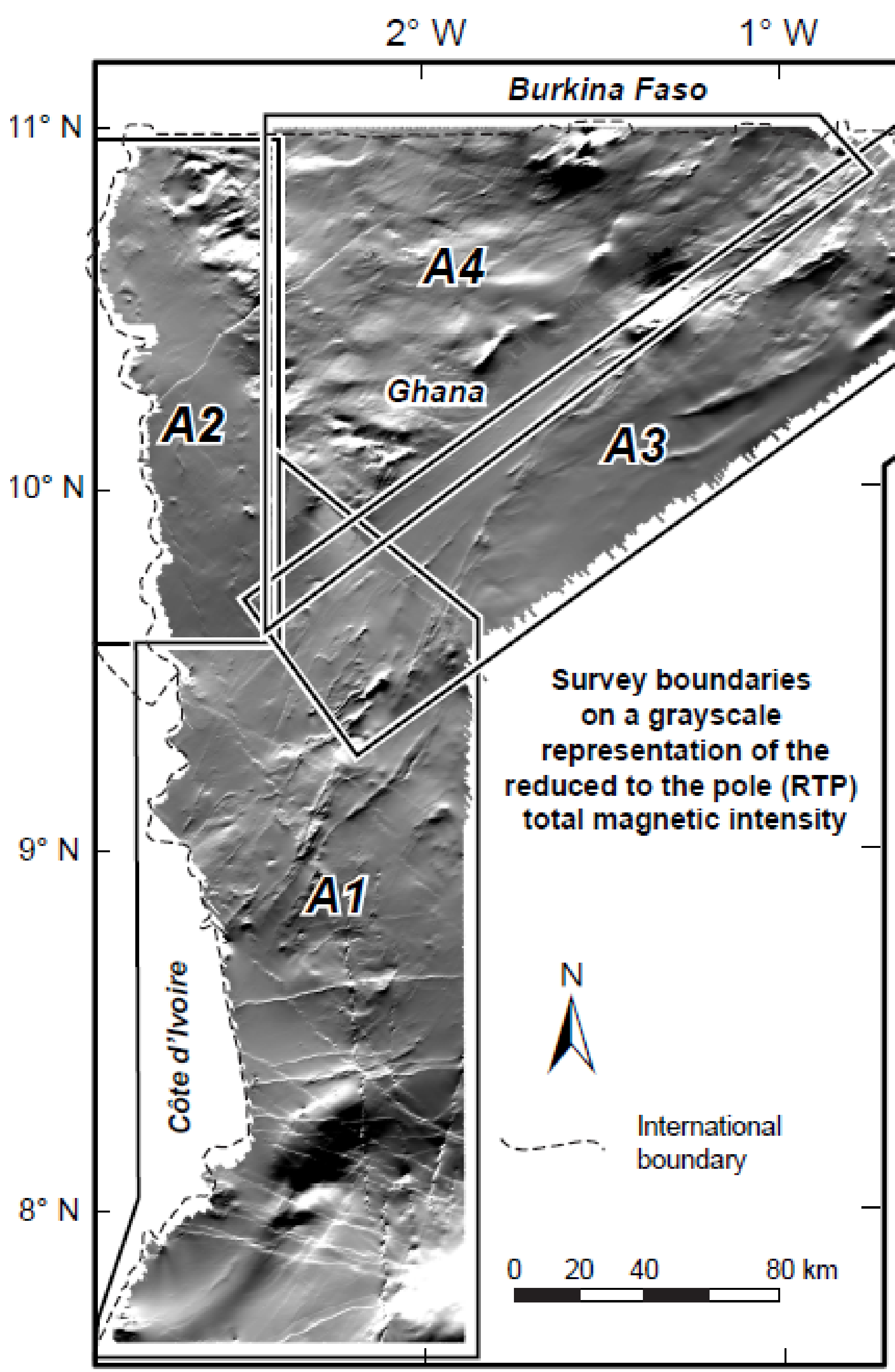


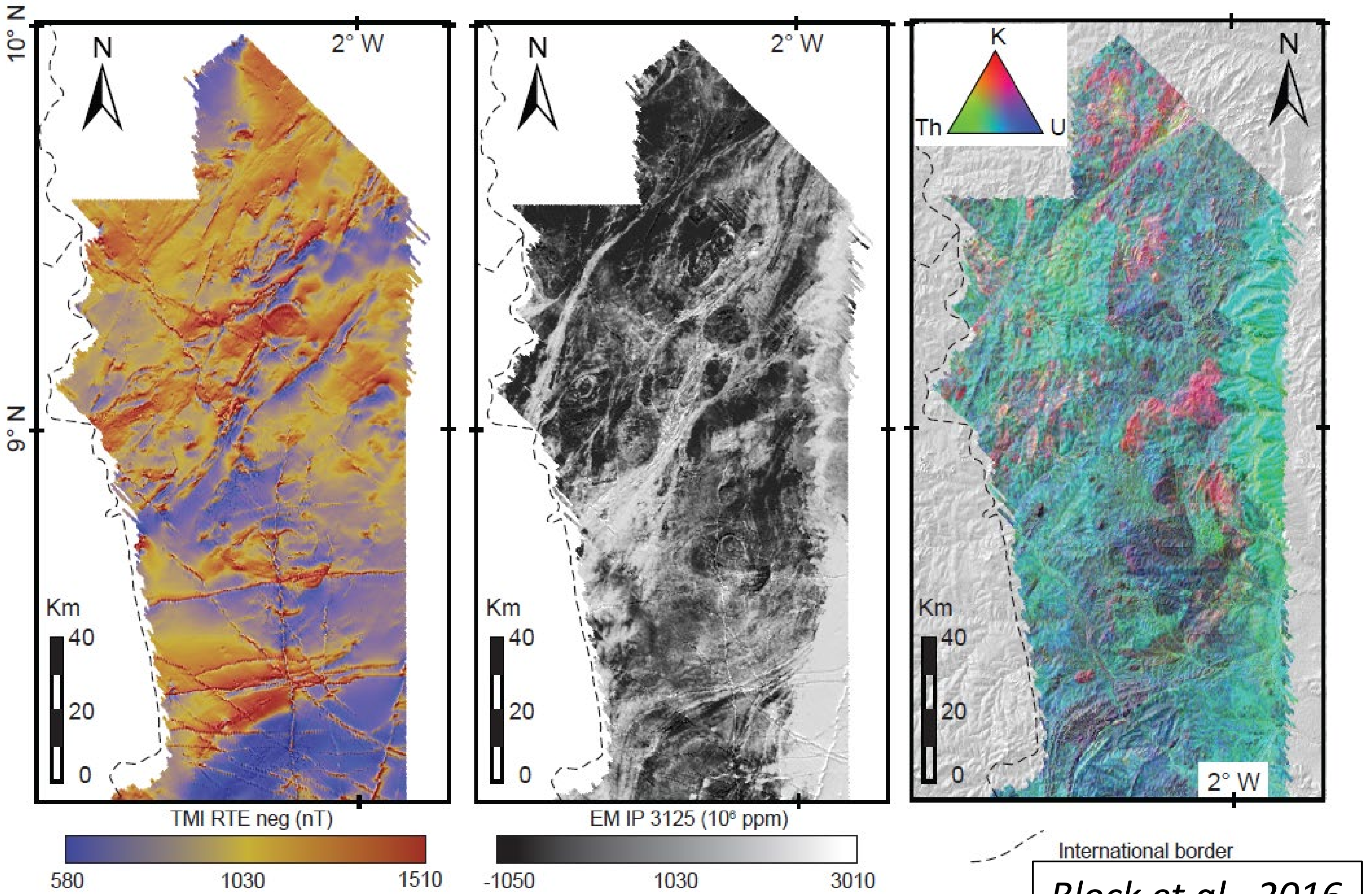


Block et al., 2016

High resolution geophysical data – NW Ghana

Azumah Resources
flight height of 40 m and line spacing of 100 m





Block et al., 2016

Geophysical data interpretation – NW Ghana

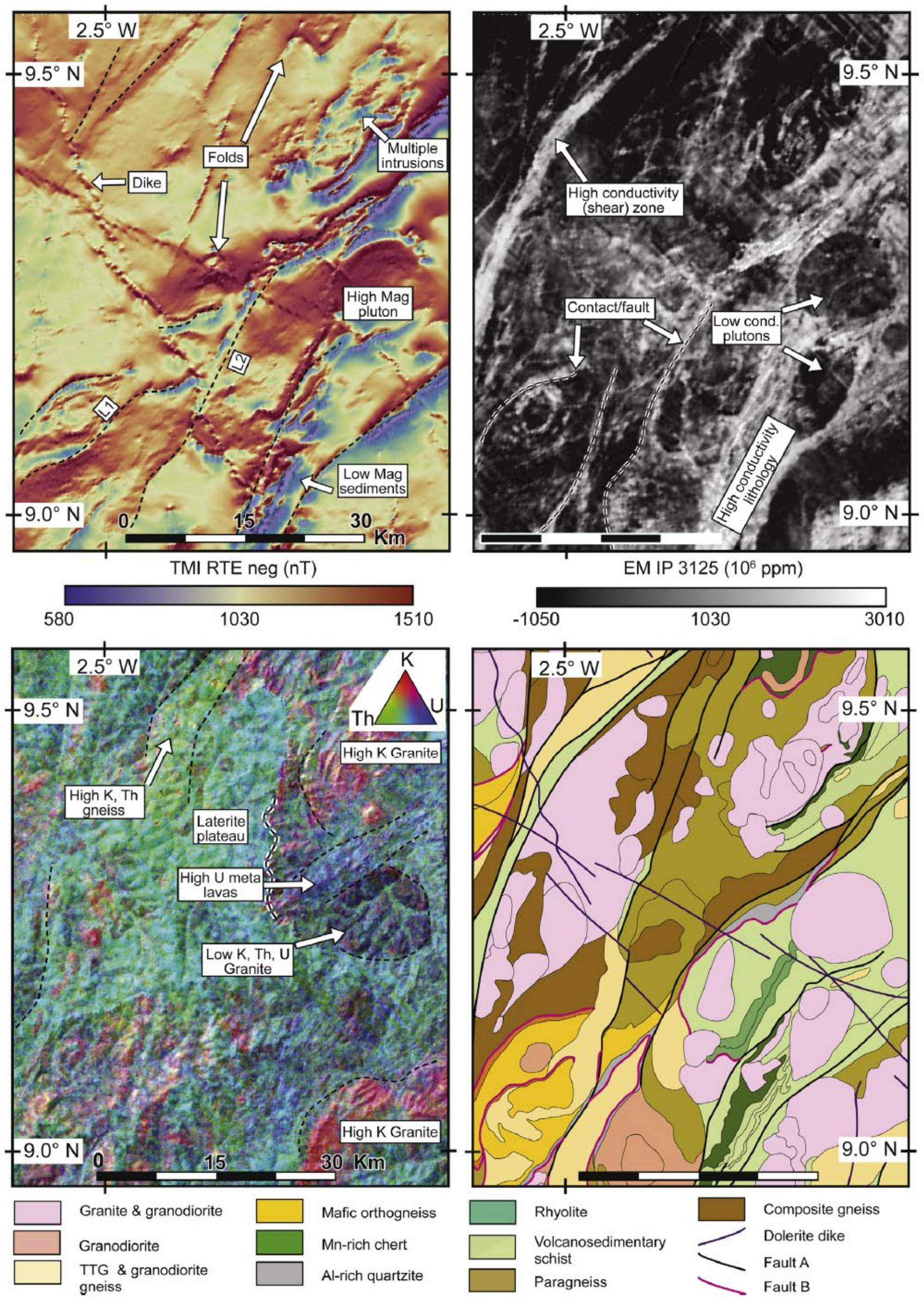
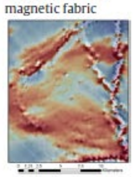
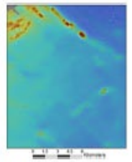
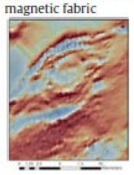
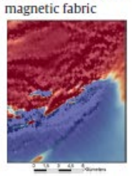
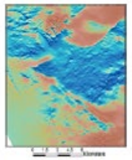
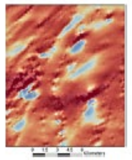
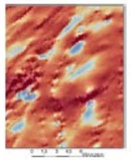
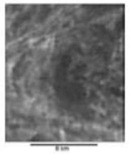
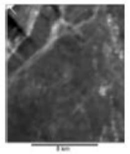
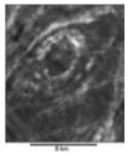
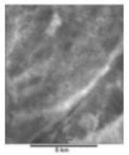
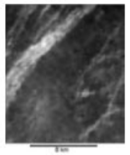
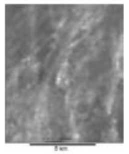
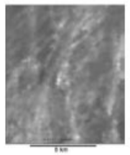
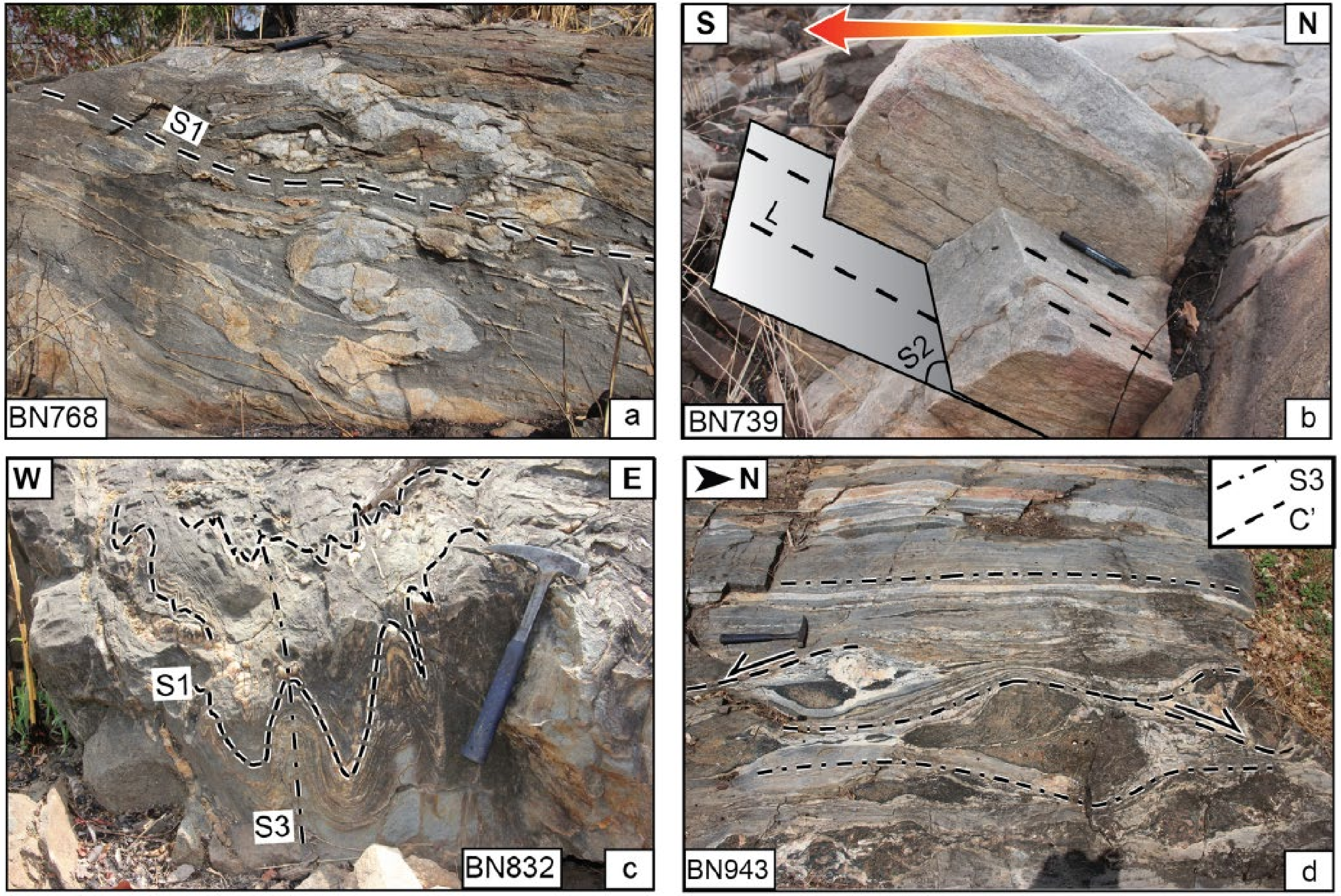


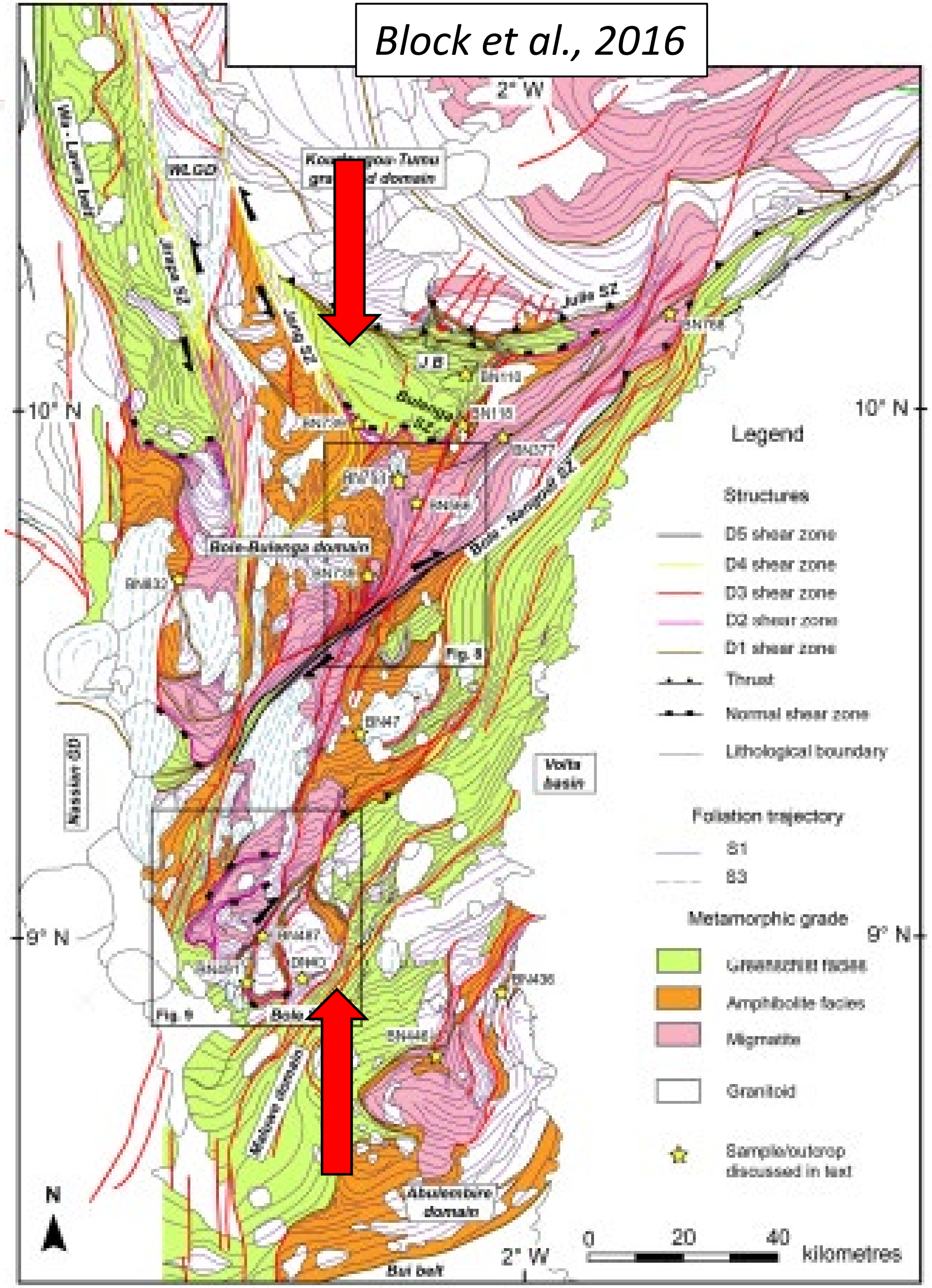
Table 1
Synthesis of the petrophysical properties and geophysical signatures of the lithologies represented on the geological map (Fig. 3). Thumbnails represent subsets of geophysical datasets of 12 × 18 km processed according to the same method as the images presented in Fig. 2. The geophysical responses of the lithological types served as criteria for mapping. Whole rock geochemical analyses were conducted by A.L.S. Mineral Laboratory, Sevilla, Spain.

Lithology	G1: TTG & granodiorite gneiss	G2: granodiorite & diorite	Mafic orthogneiss	G3: granodiorite	G4: biotite granite & granodiorite	G5: potassic granite	Andesite/dacite	Basalt/metabasalt
Mineralogy	qz, pl, hbl, bt	qz, pl, kf, hbl (±ep)	qz, pl, hbl, ilm (±gt)	qz, pl, hbl, bt	qz, pl, kf, bt	qz, kf, pl, bt (±ep)	qz, pl, hbl, sph,	act, chl, qz, ep, cal
Magnetic susceptibility (10^{-3} SI)	0.05, 0.30–0.40, 4–10, multimodal	0.10–0.30	0.10–0.5, 1.0–10 (bimodal)	1.0–55	0.005–0.15	0.10–8.0, bimodal	0.30–0.40	No data
Sample	BN261	BN092	BN506	BN380	BN112	BN083	BN02	BN101
U (ppm)	0.29	2.15	0.81	0.46	1.55	4.45	0.810	0.075
Th (ppm)	3.79	3.49	2.26	1.16	12.85	13.9	2.2	0.2
K_2O (%)	0.92	3.07	0.56	1.48	2.03	5.16	0.51	0.14
Map								
Airborne magnetic response	Moderate to high intensity, marked magnetic fabric	Low to moderate, homogeneous.	Low to high, heterogeneous, strong magnetic fabric	Very high, heterogeneous, strong magnetic fabric	Low intensity, homogeneous interlocked bodies	Low to high intensity.	Low to moderate intensity, variable	High intensity layers
Magnetic image								
Airborne radiometric response	K, Th, U poor (dark)	Moderate to high K, moderate U, low Th (red)	Moderate K, moderate U, low Th (red to blue)??	Low to moderate K Th, U poor (dark to red)	Moderate K, high Th, low U (green, yellow, orange)	Very high K, high Th, moderate U (red–yellow)	moderate U (blue), low Th, K.	K, Th, U poor (dark)
Radiometric + shaded DTM								
Airborne electro-magnetic signal	Heterogenous	Low intensity, homogeneous	Heterogeneous	Heterogeneous	Low intensity, homogeneous	No data	Low intensity, homogeneous	Moderate to high intensity
Electro-magnetic image						No data		

Block et al., 2016

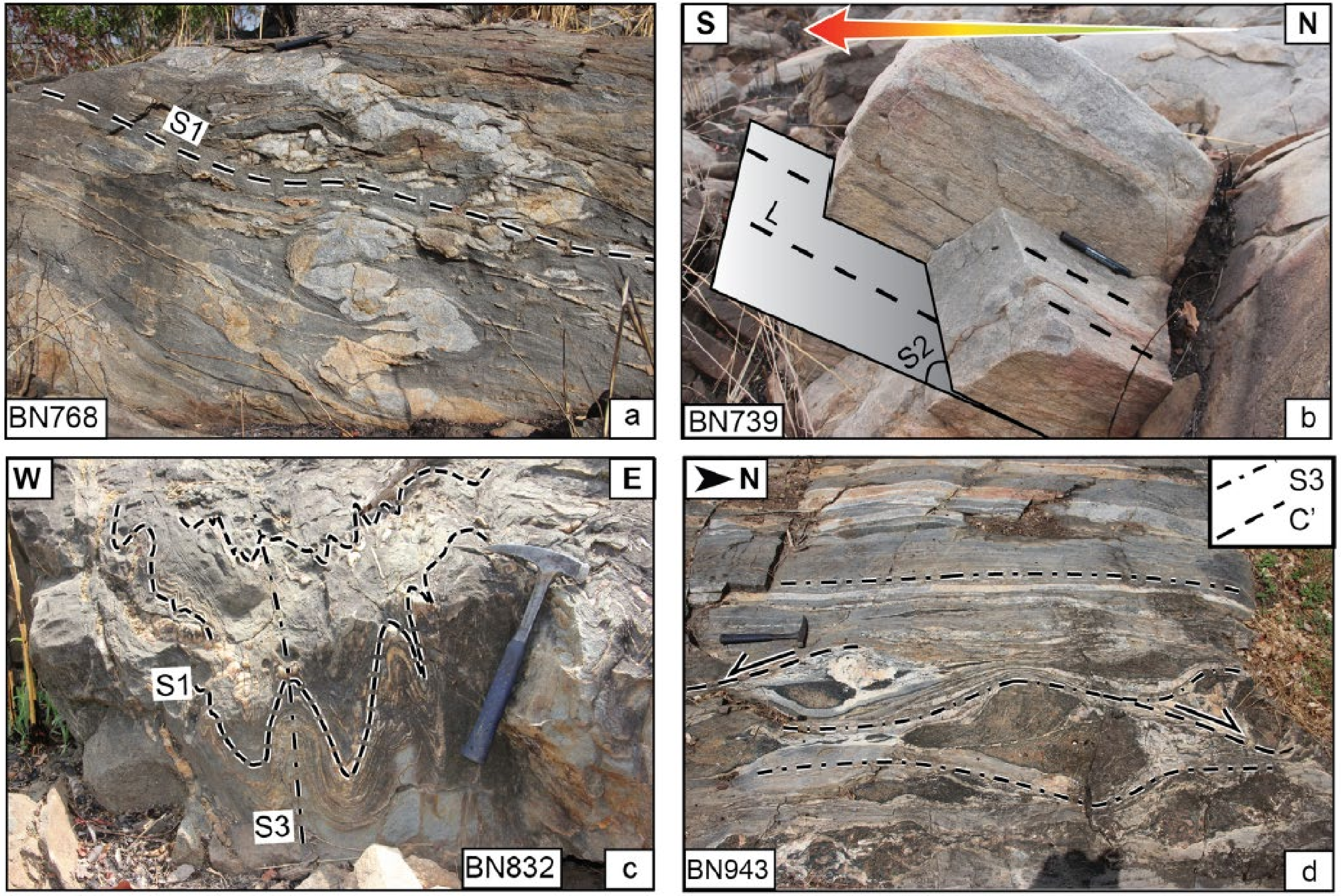
Field structural data



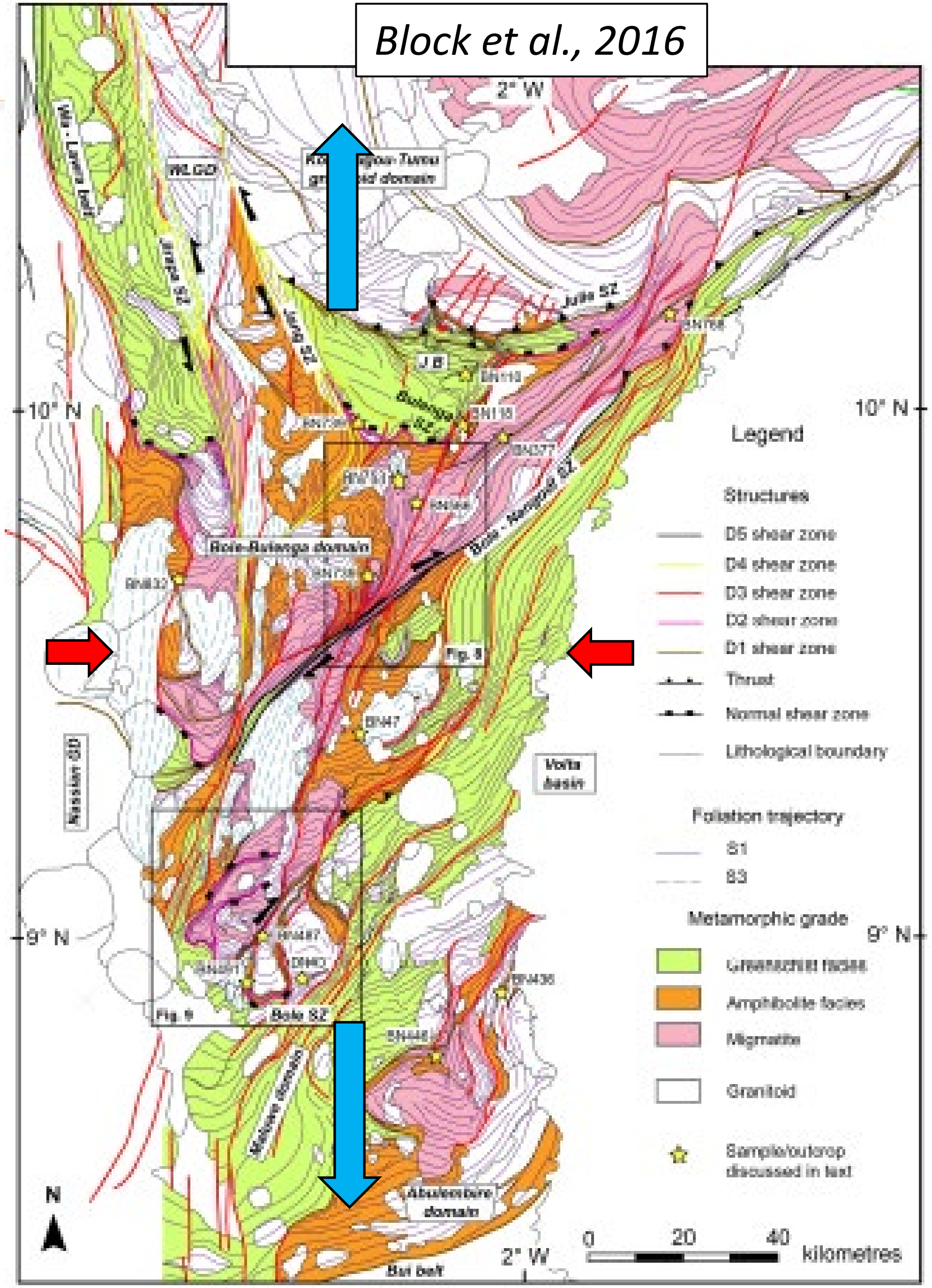


D1 – N-S shortening

Field structural data

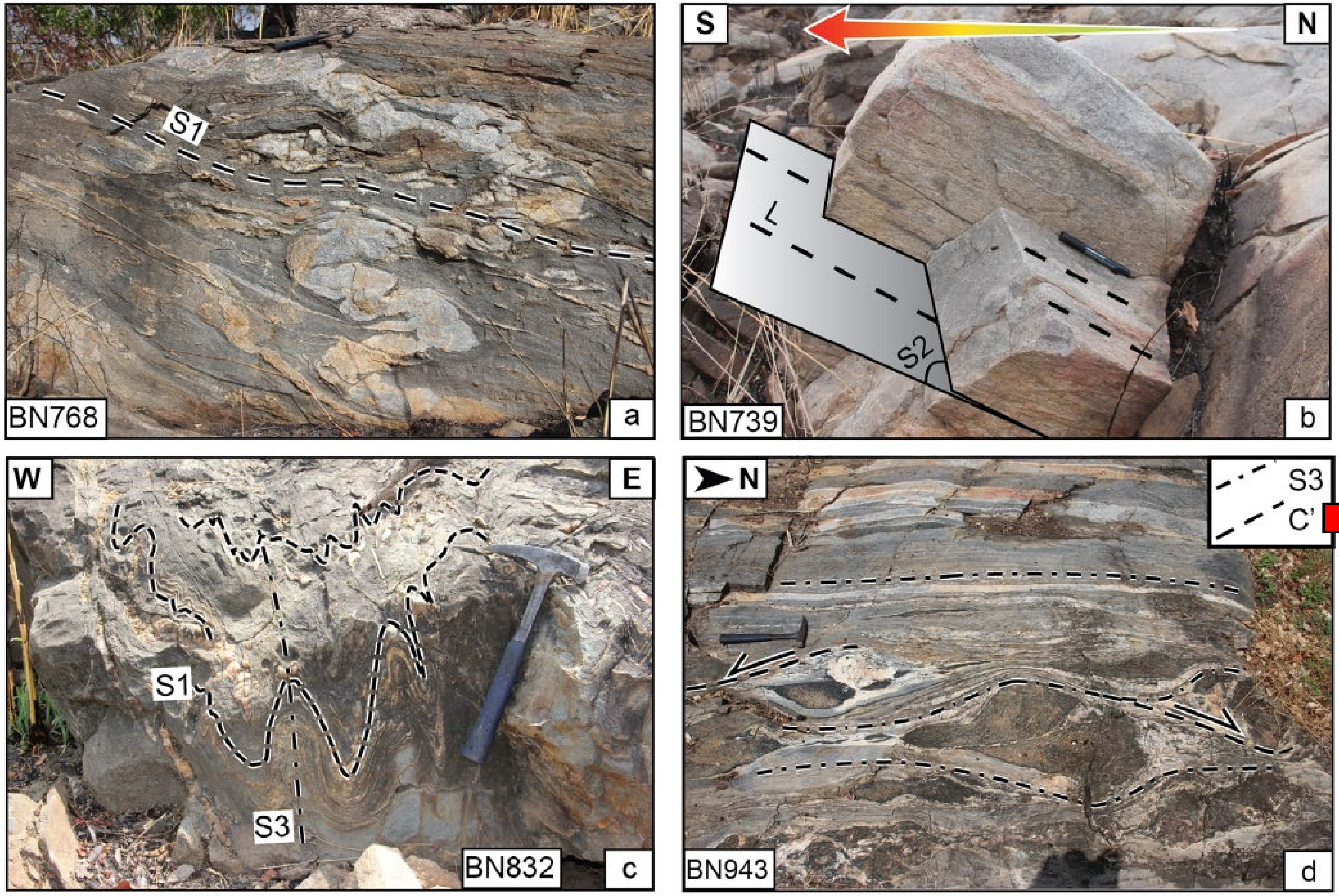


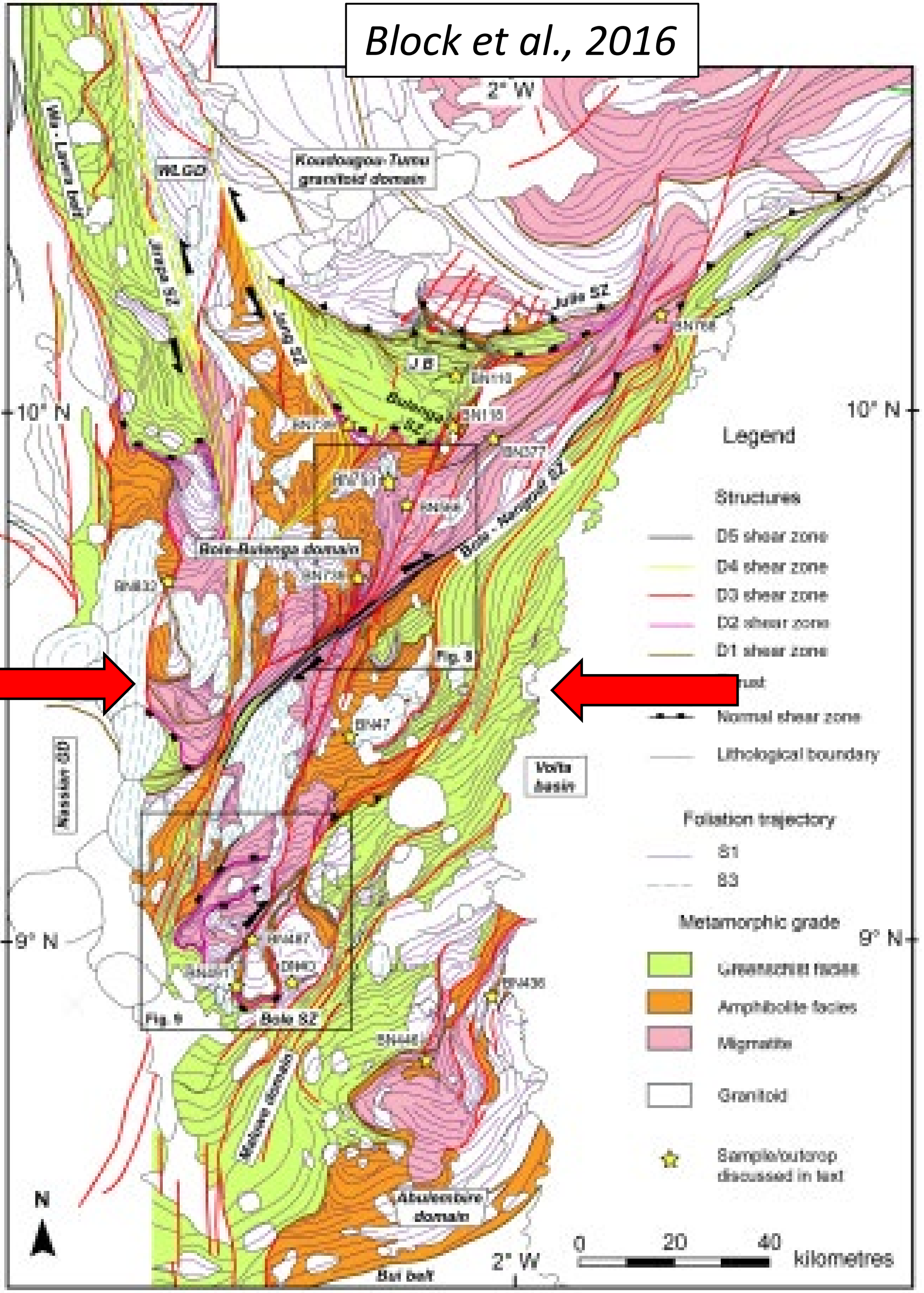
Block et al., 2016



D2 – N-S extension

Field structural data

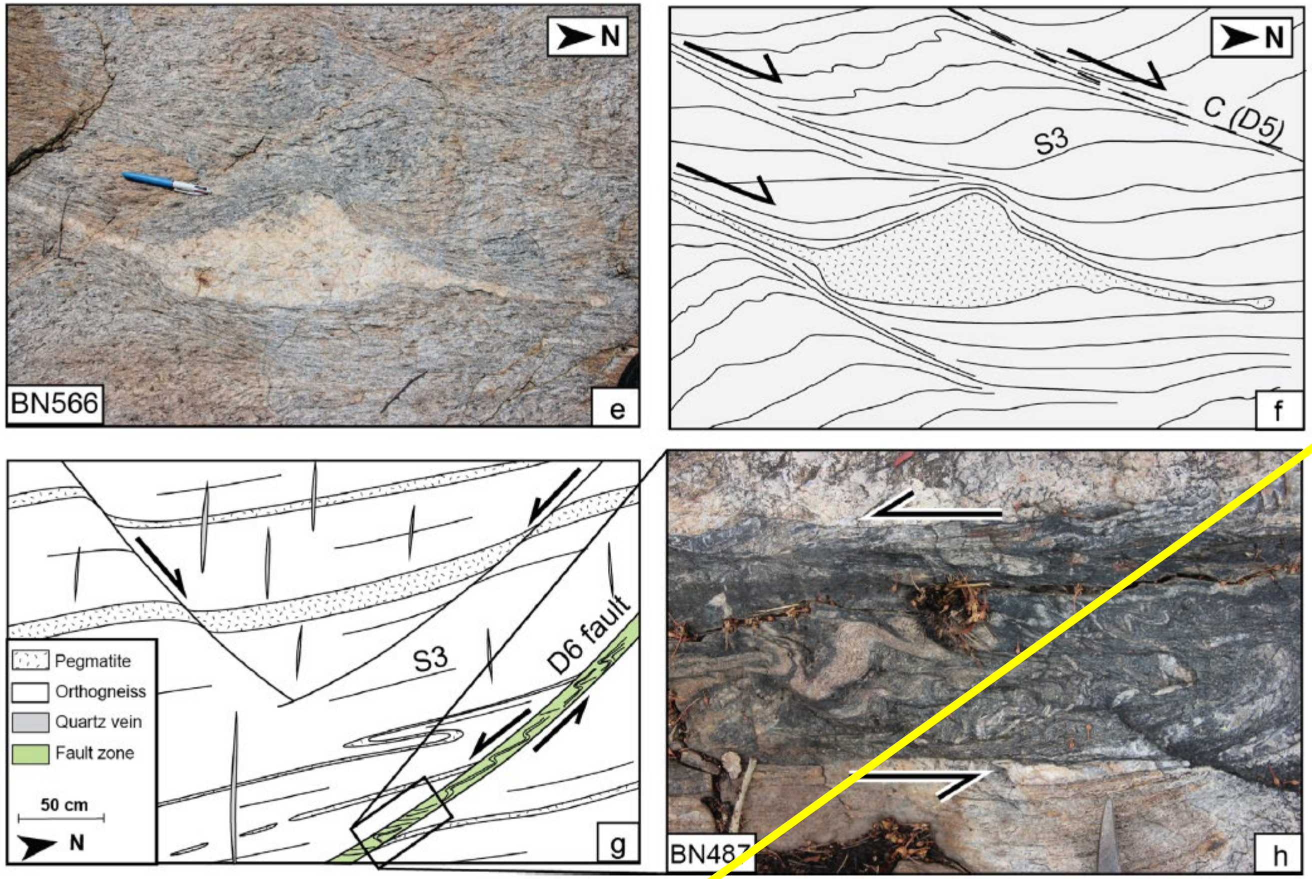


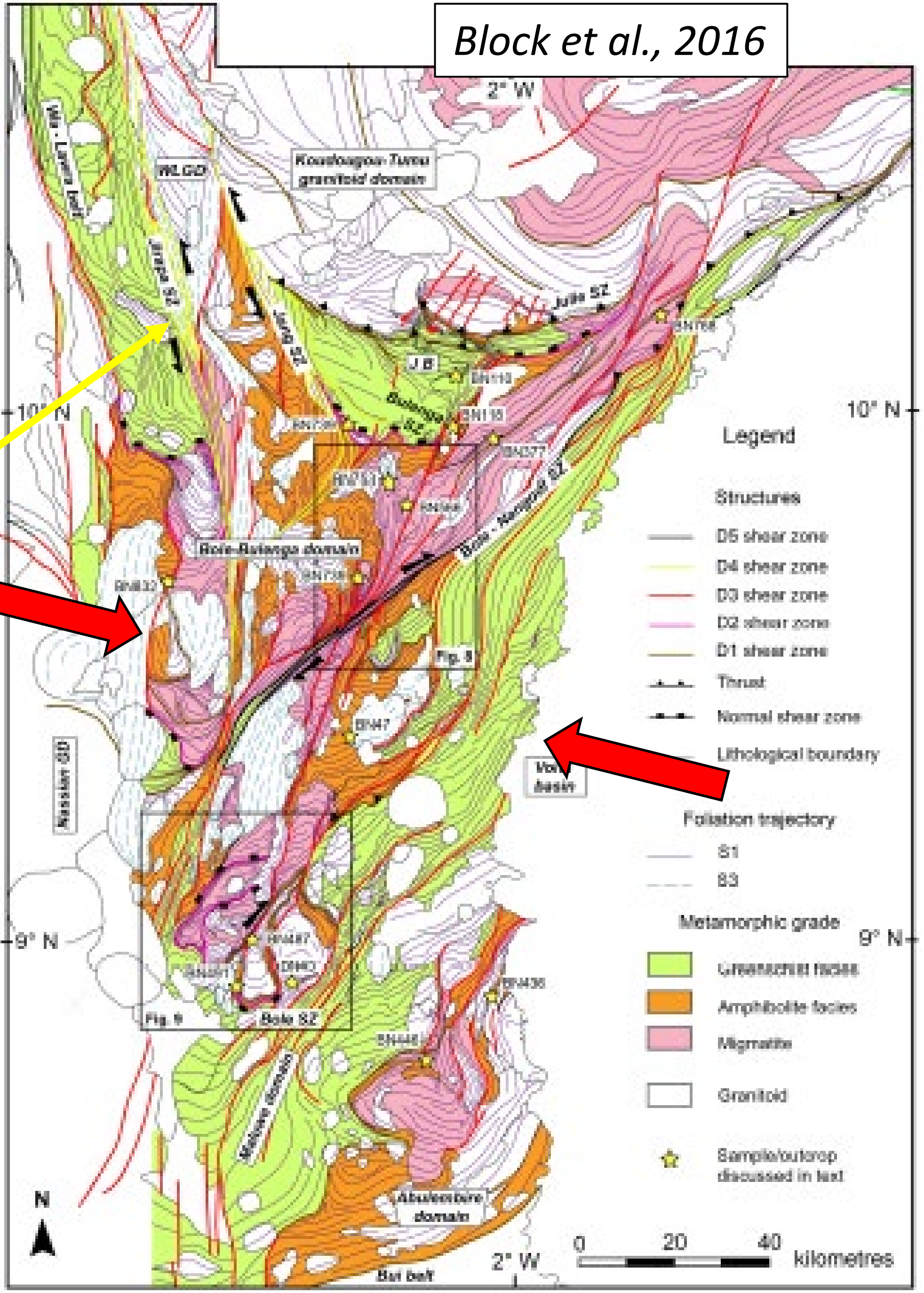


D3 – E-W to WNW-ESE shortening

Field structural data – NW Ghana

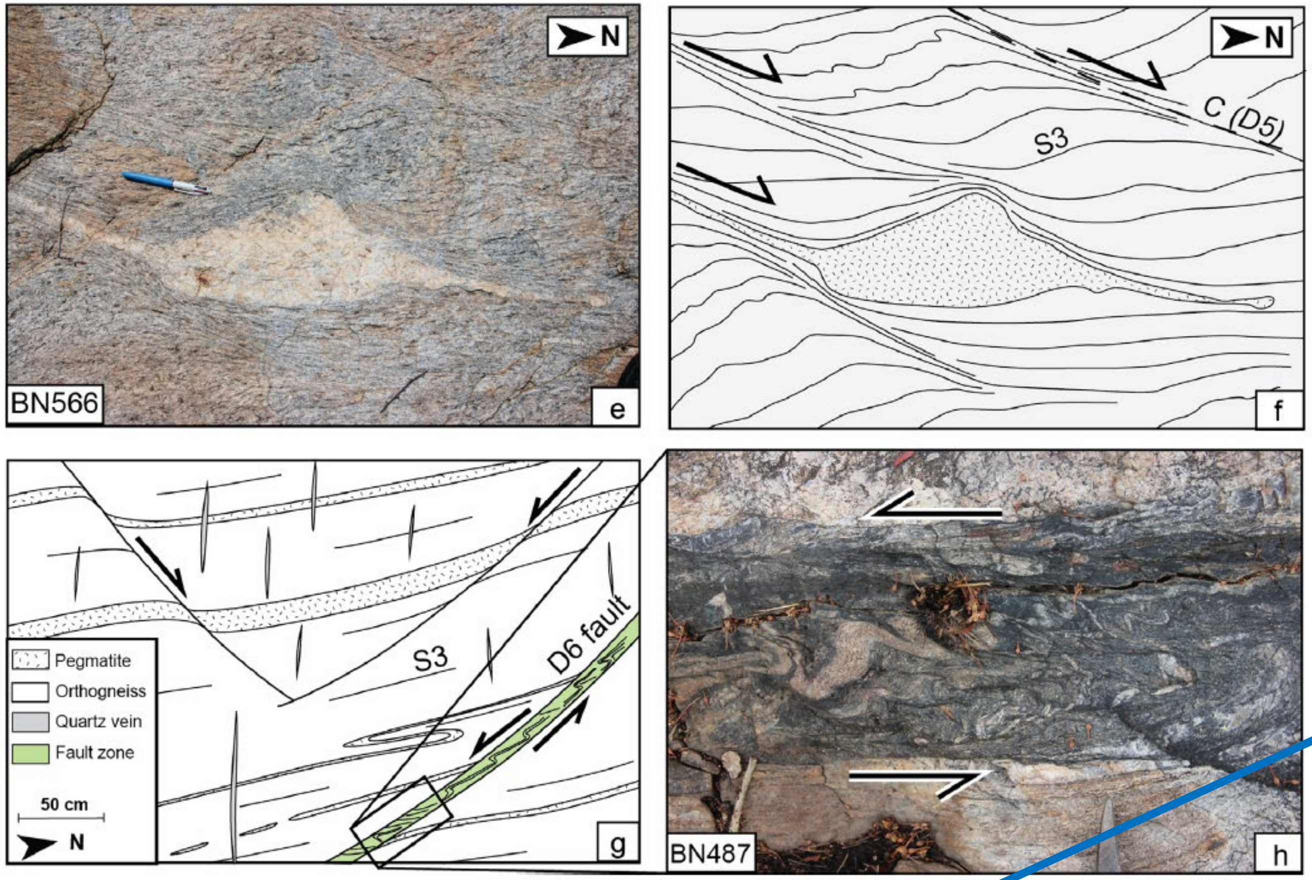
Block et al., 2016



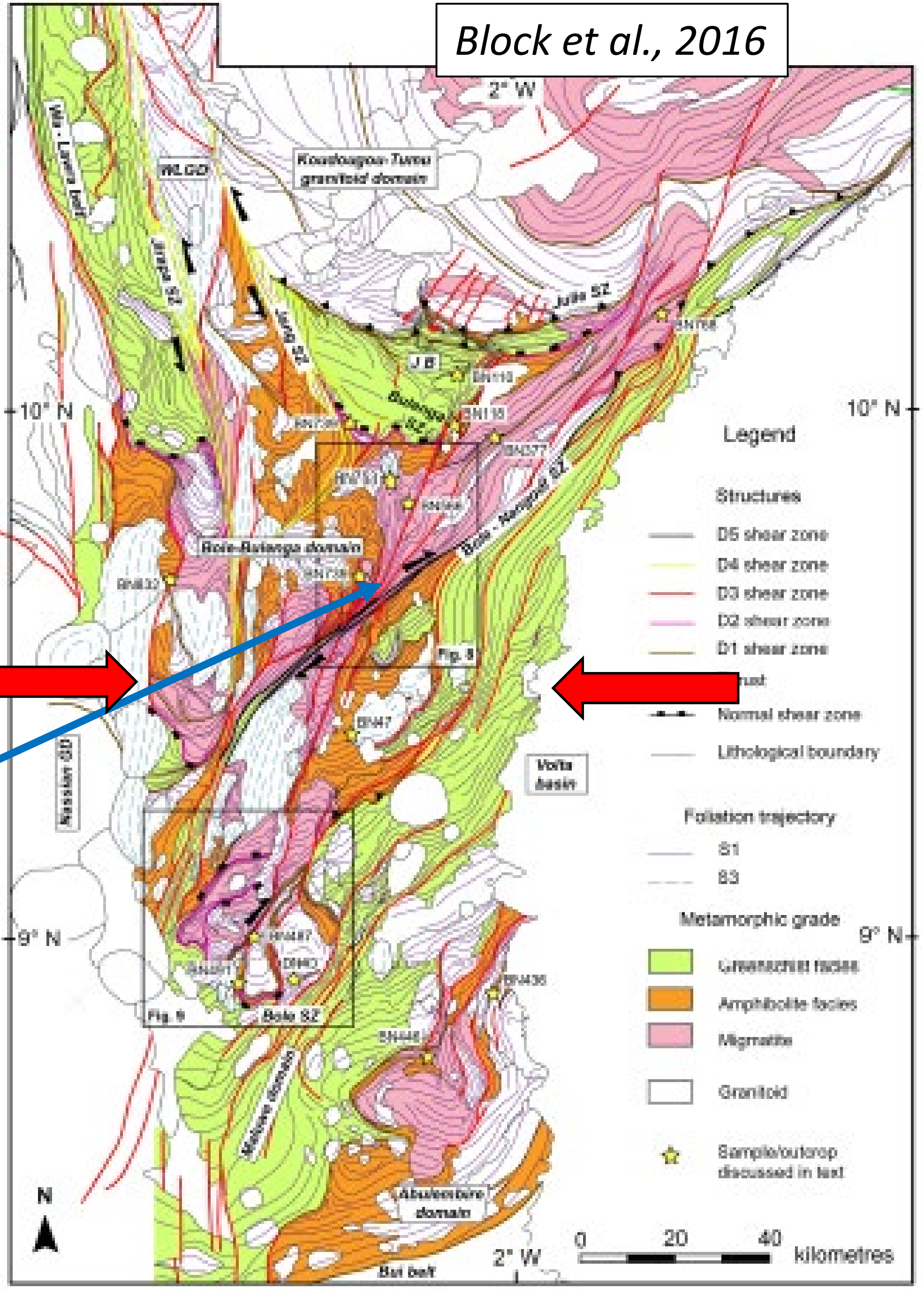


D4 – WNW-ESE shortening

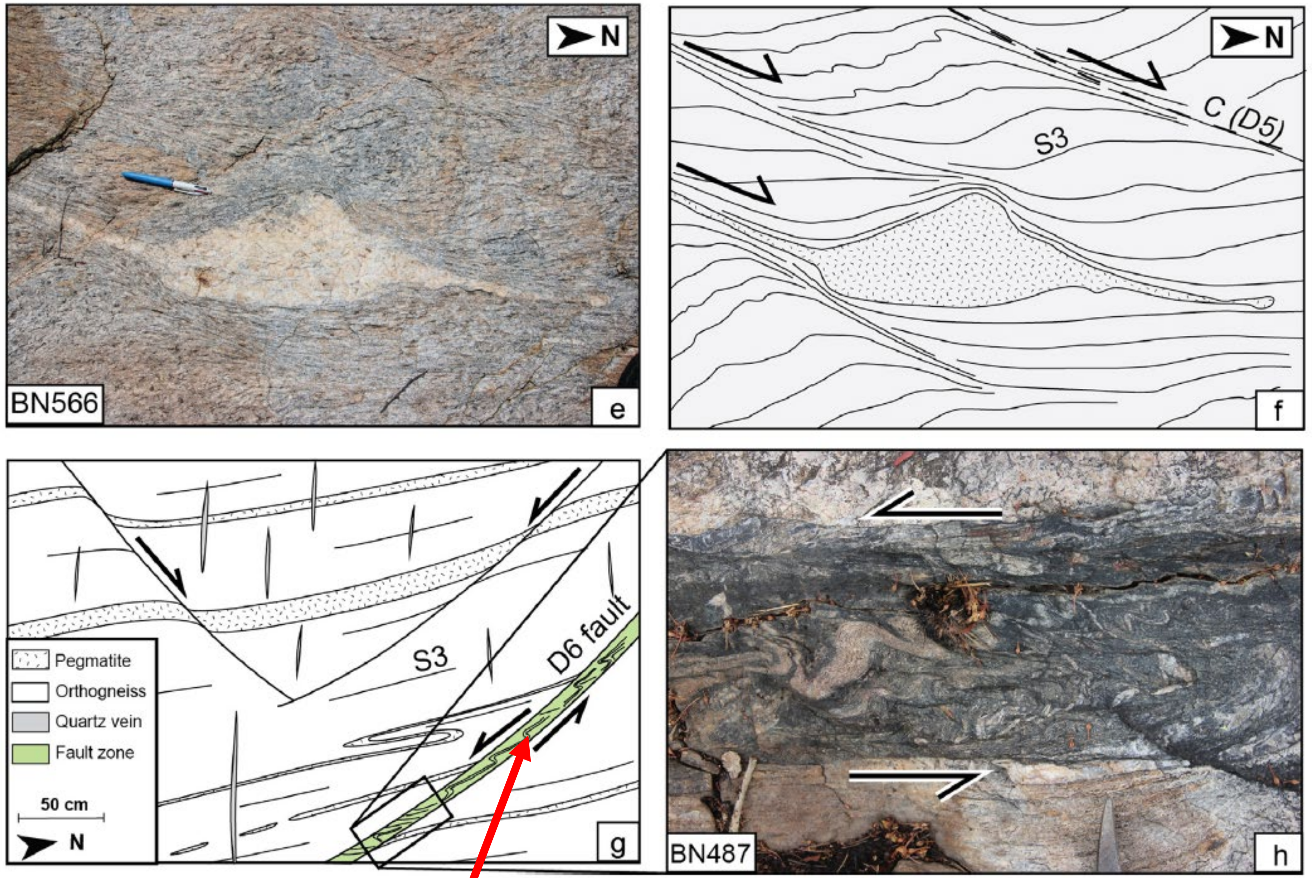
Field structural data – NW Ghana

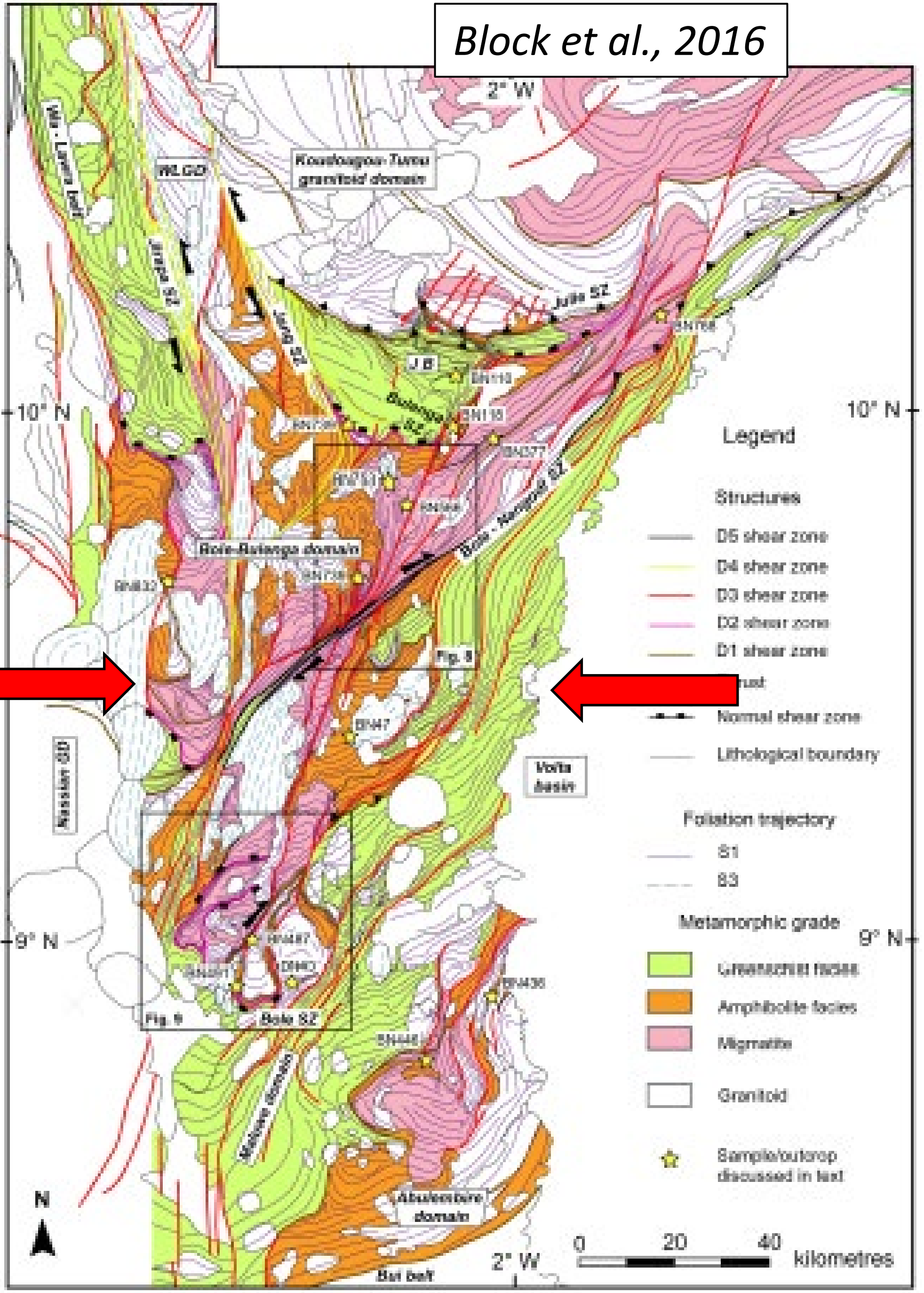


D5 – E-W shortening (ductile)



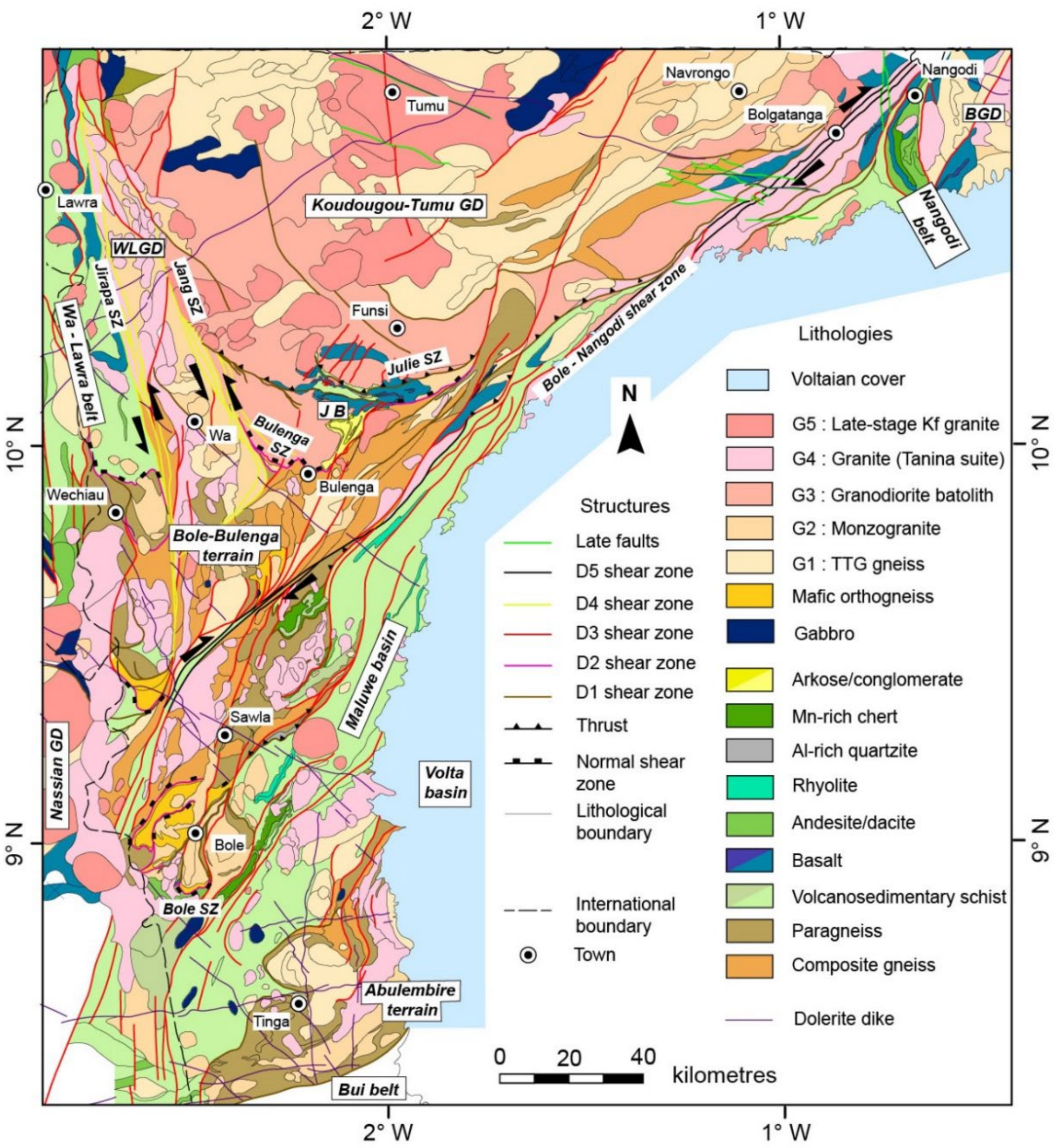
Field structural data – NW Ghana



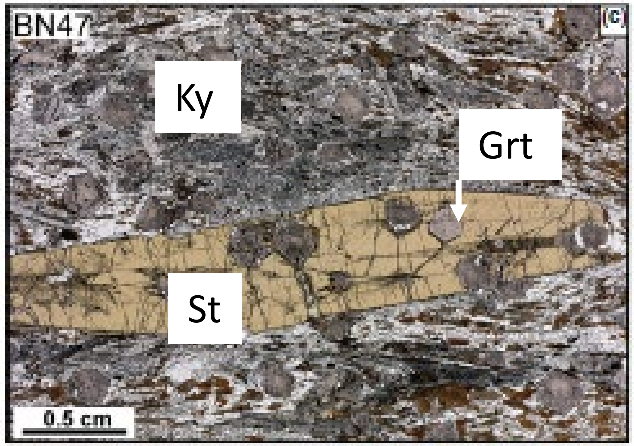


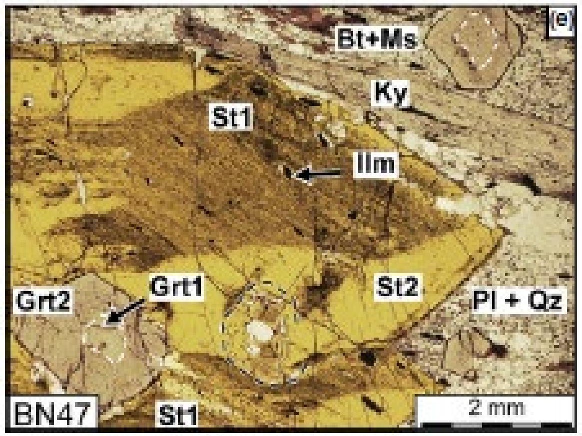
D6 – E-W shortening (brittle)

Metamorphic assemblages – NW Ghana

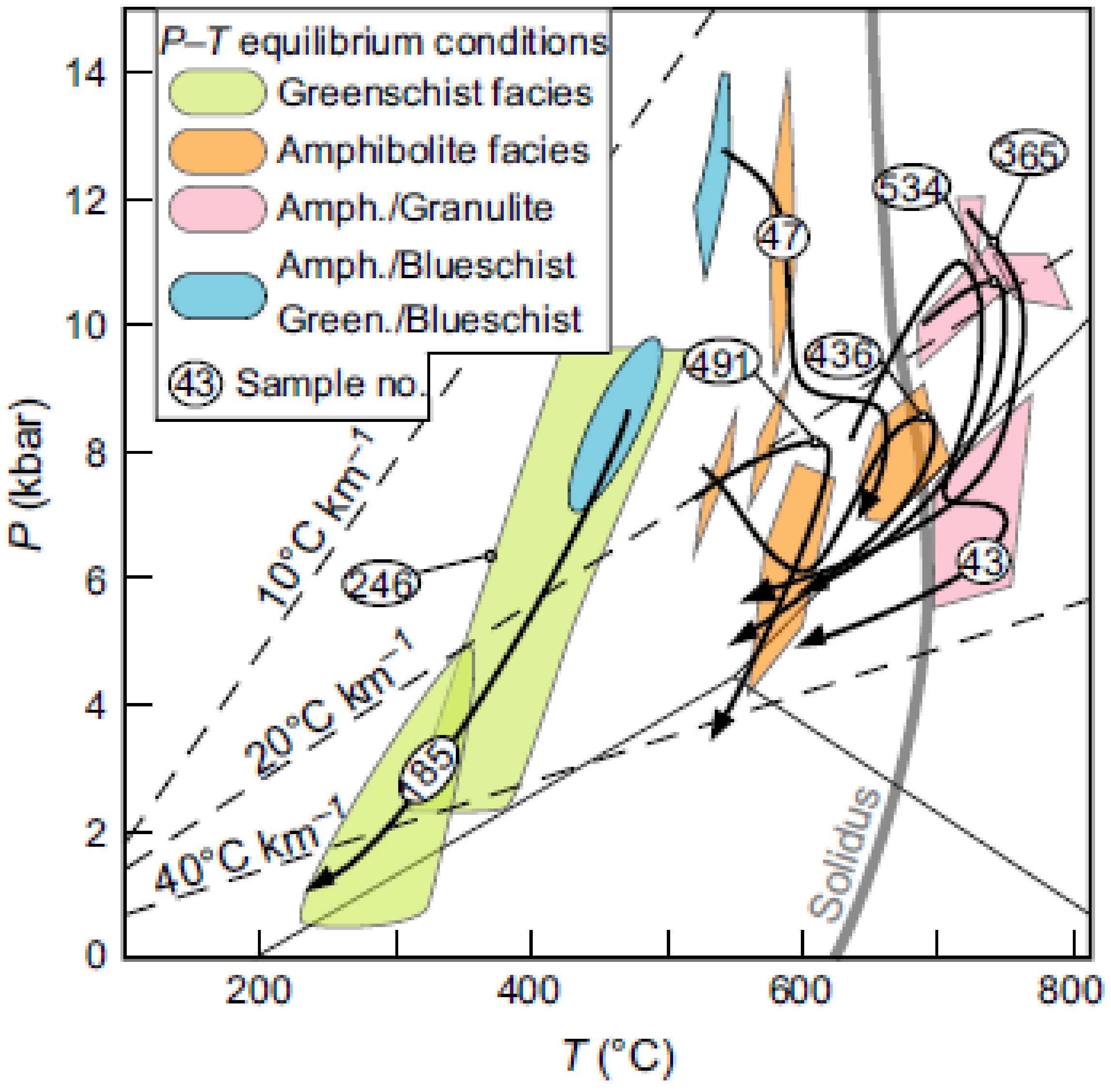


Block et al., 2015

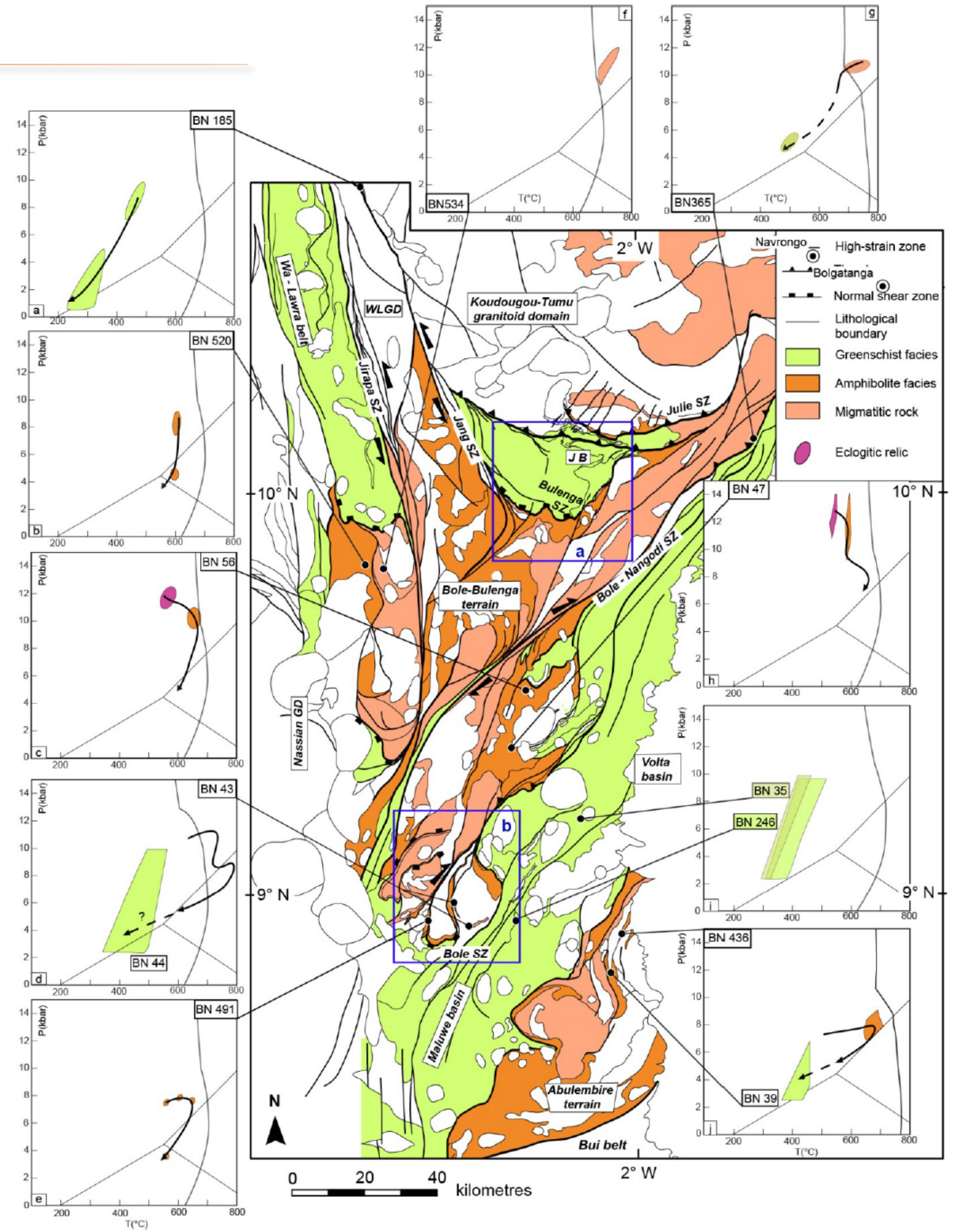




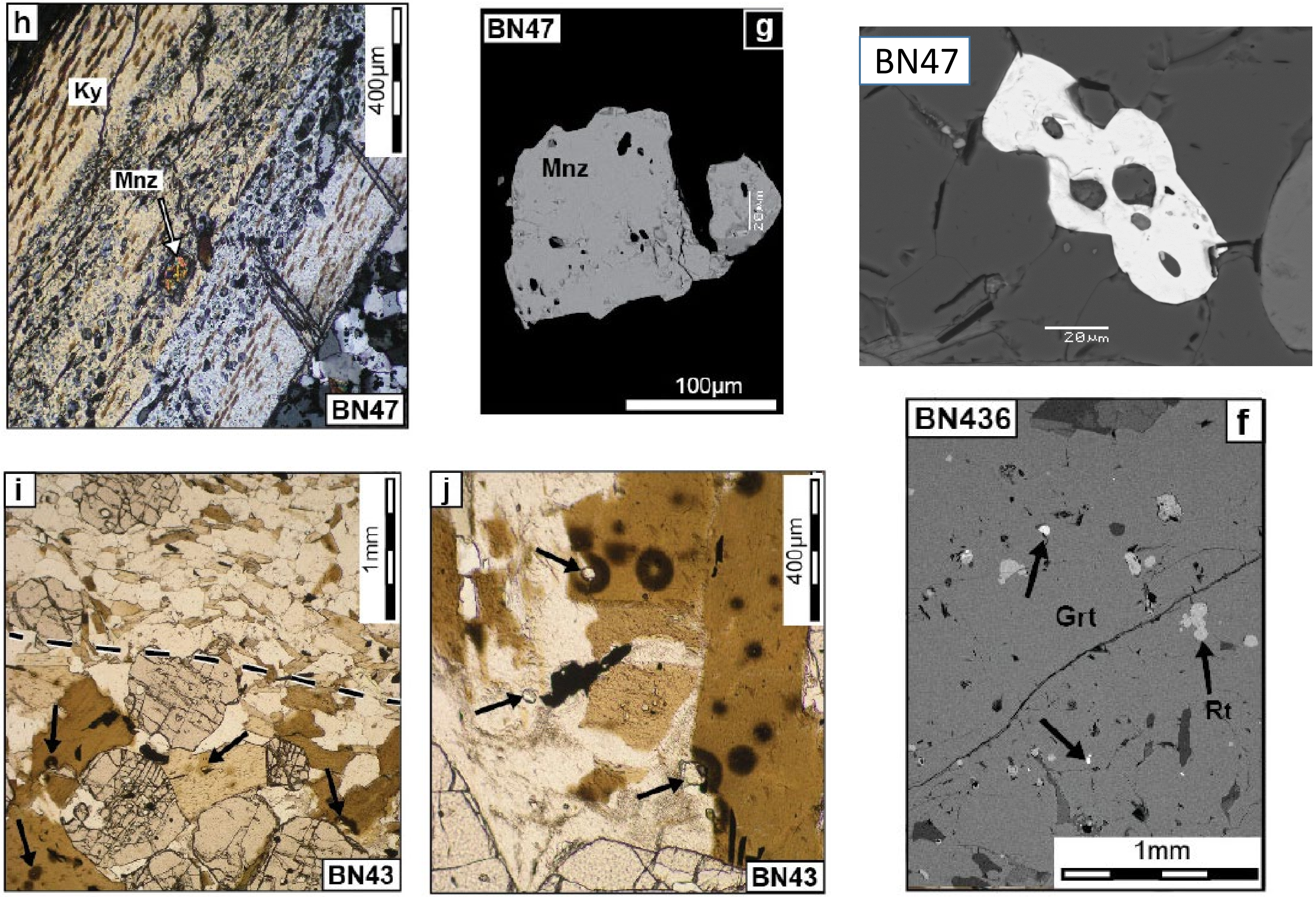
Metamorphic conditions – NW Ghana



Block et al., 2015



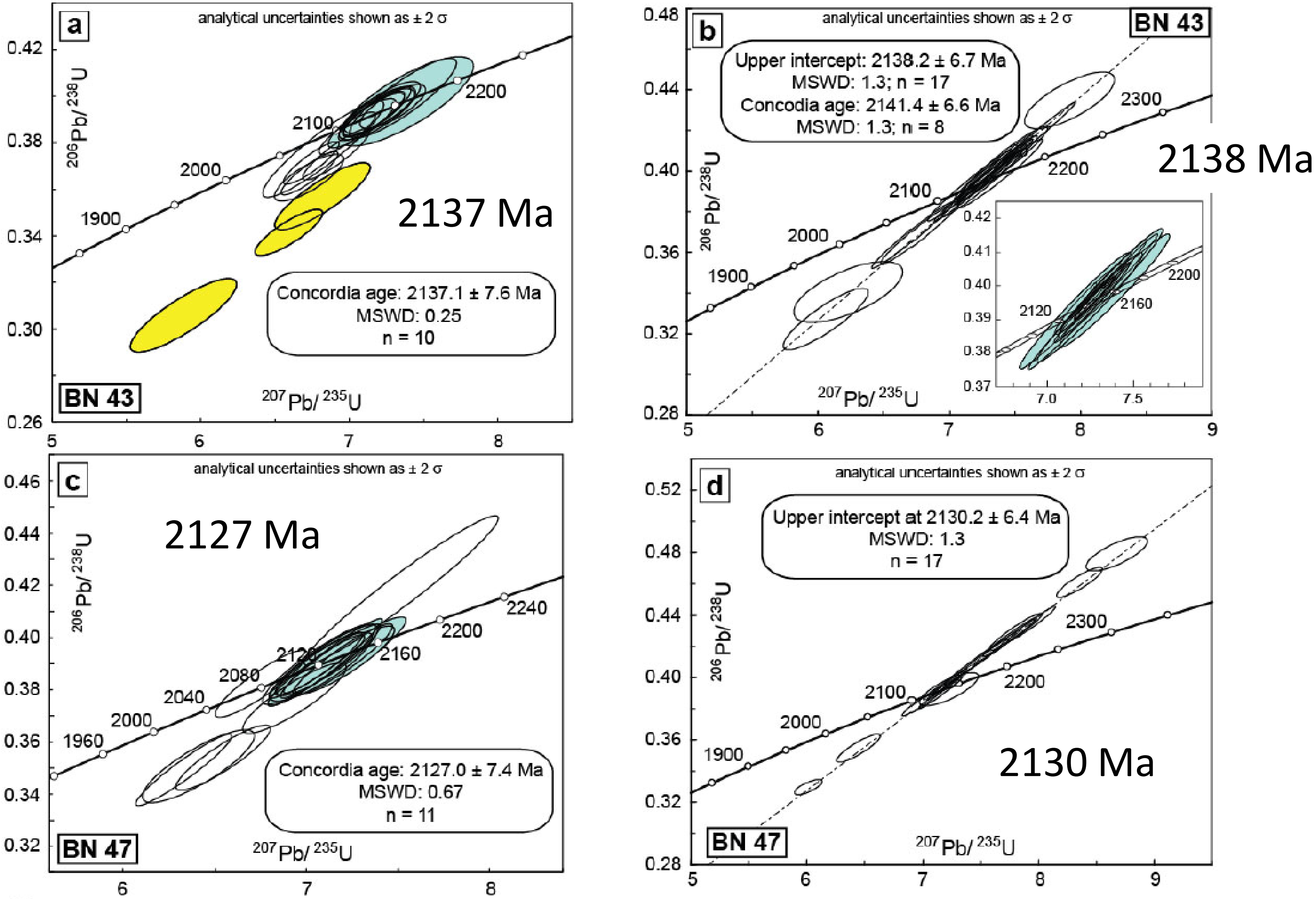
U-Pb monazite dating - NW Ghana



U-Pb monazite dating - NW Ghana

In situ LA ICP-MS

In situ SHRIMP



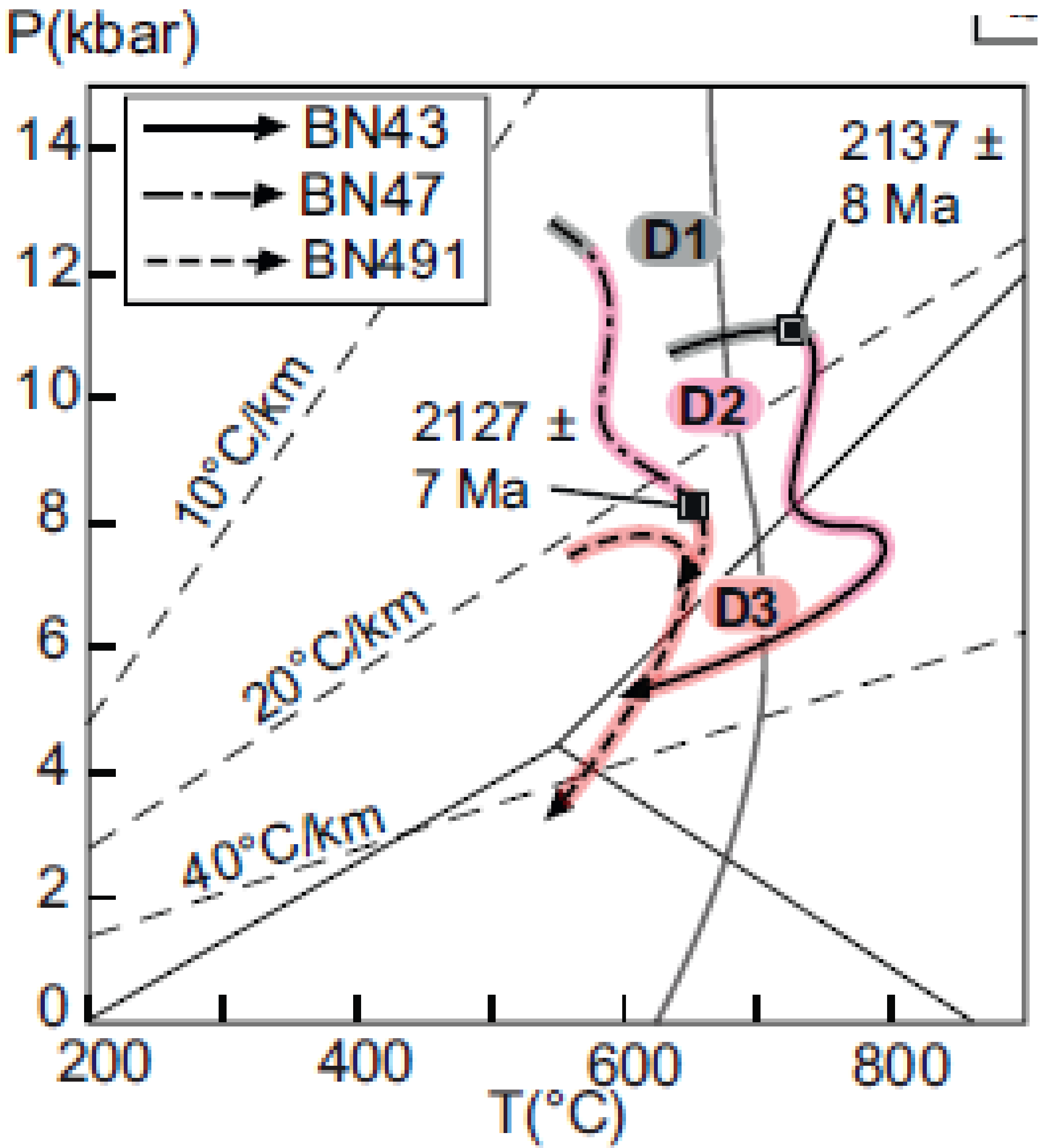
Timing of metamorphism and deformation

P-T-t-d paths
Polyphase metamorphism – deformation phases

U-Pb on monazite

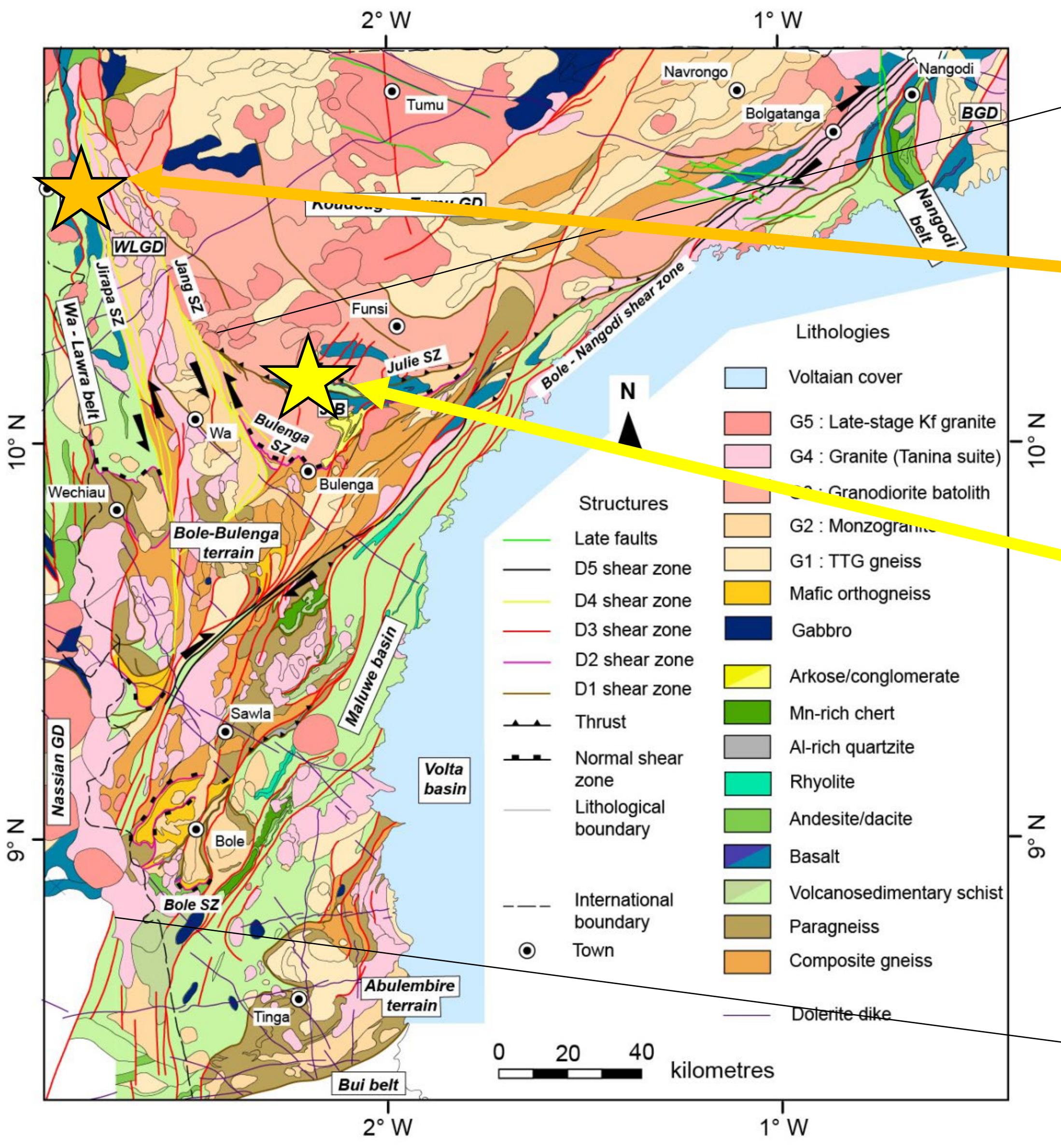
- BN43 – 2137 ± 8 Ma ; 2138 ± 7 Ma
- BN47 – 2127 ± 7 Ma ; 2130 ± 6 Ma
- BN436 – 2131 ± 6 Ma

-> age of HT metamorphic phase



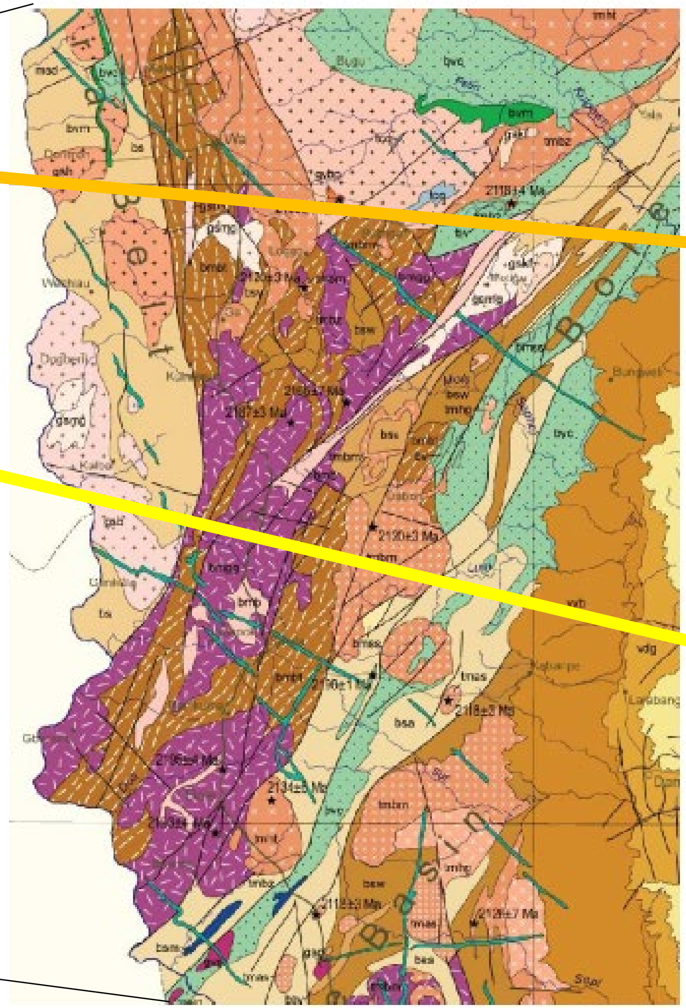
Block et al., 2015, JMG
Block et al., 2015, PR

Lithostructural map – NW Ghana



Block et al., 2016

Agyei Duodu et al., 2009



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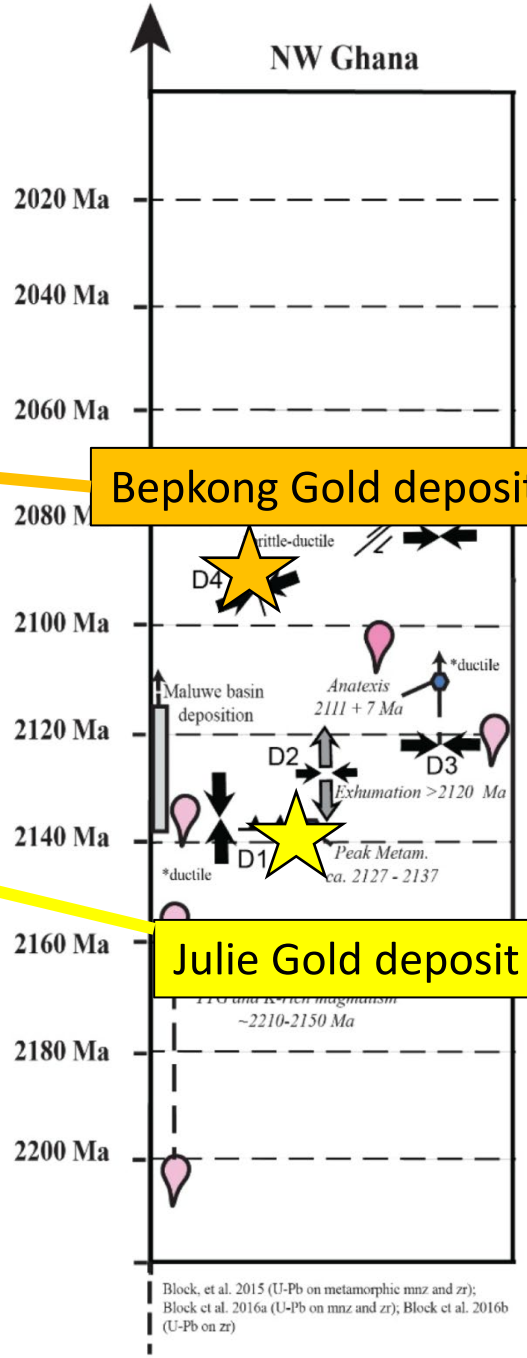
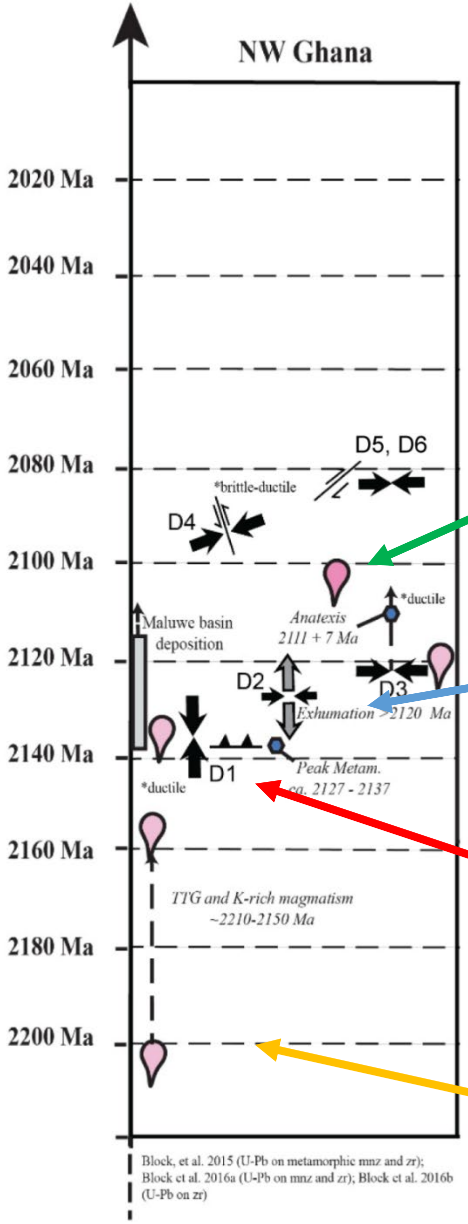


Bepkong Gold deposit

Julie Gold deposit

Geodynamic interpretations – NW Ghana



Important changes in the orientation of the shortening direction, which is hardly consistent with vertical tectonics

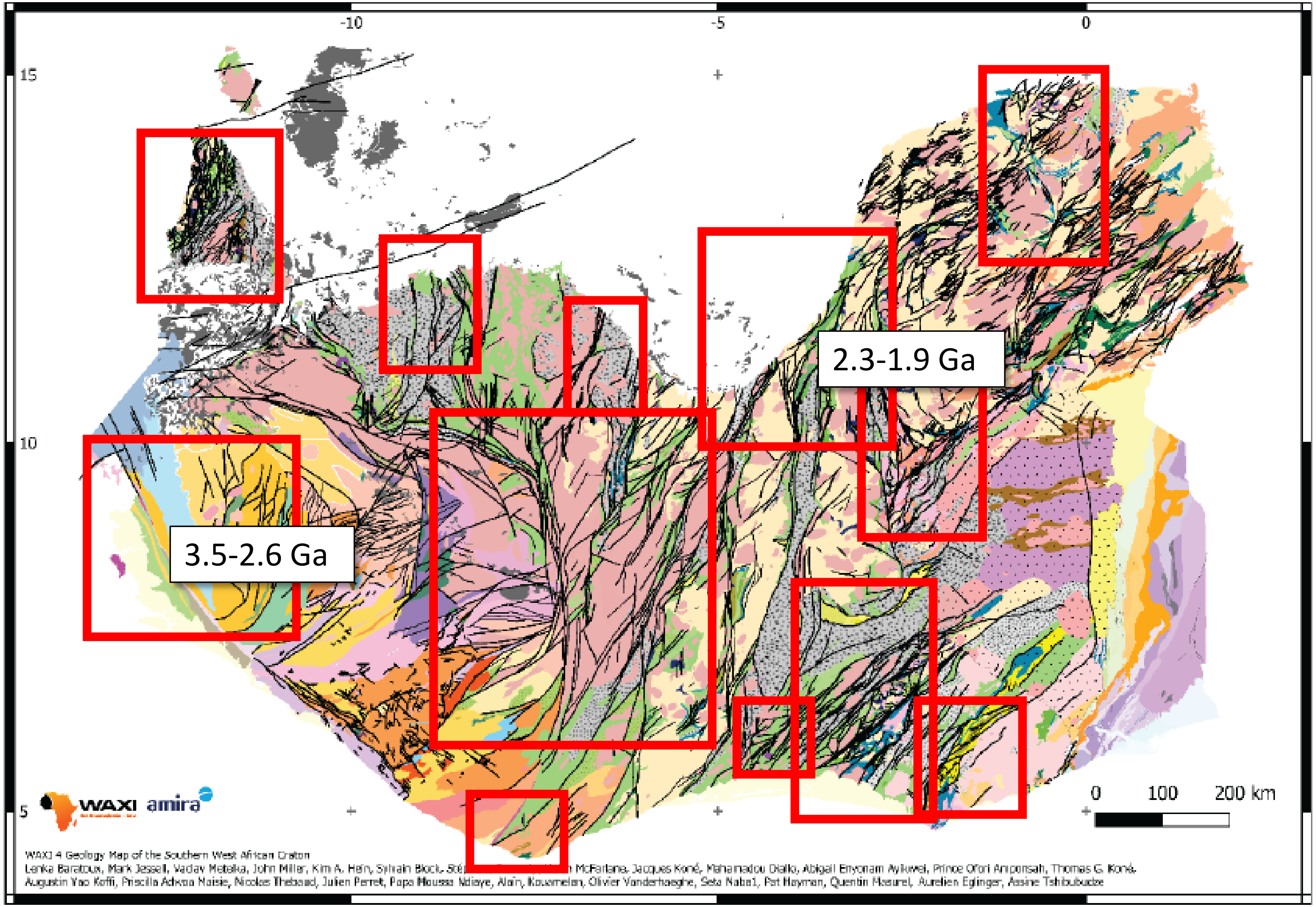
D3, D4, D5 – switch from predominant pure shear collisional regime to transcurrent regime, cooling and collapse of the orogen

D2 – extension or transtension and exhumation of the high grade rocks

D1 – major crustal shortening, tectonically driven rock burial and medium to high grade metamorphism
Clockwise P-T paths, cold apparent geothermal gradients (10-15°C/km)

Oceanic plateaus and volcanic arcs, initial subduction zones

The southern West African Craton



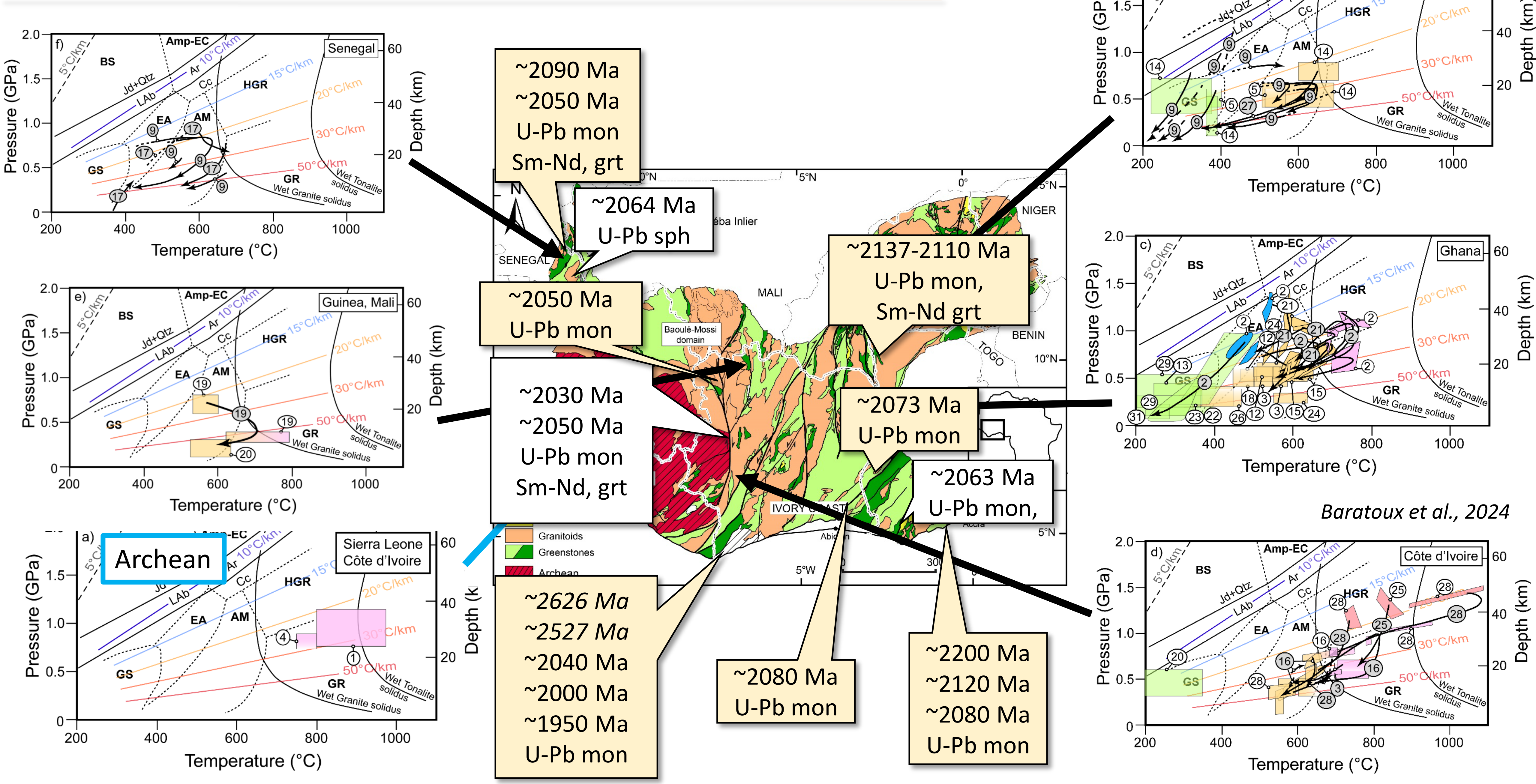
WAXI research (2006-2026)

WAXI
West African Exploration Initiative

sWAC metamorphic conditions and timing

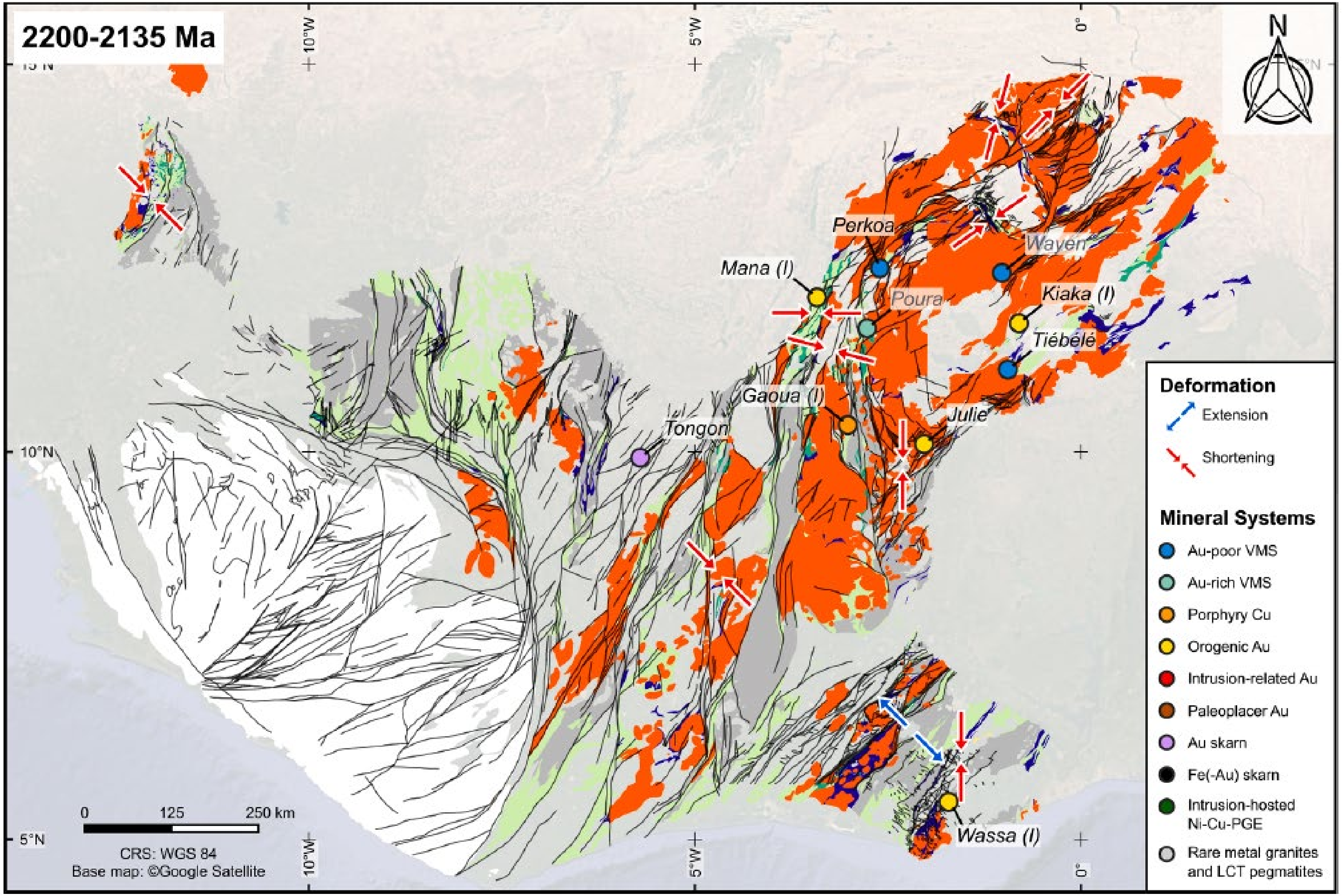
WAXI data

bibliography



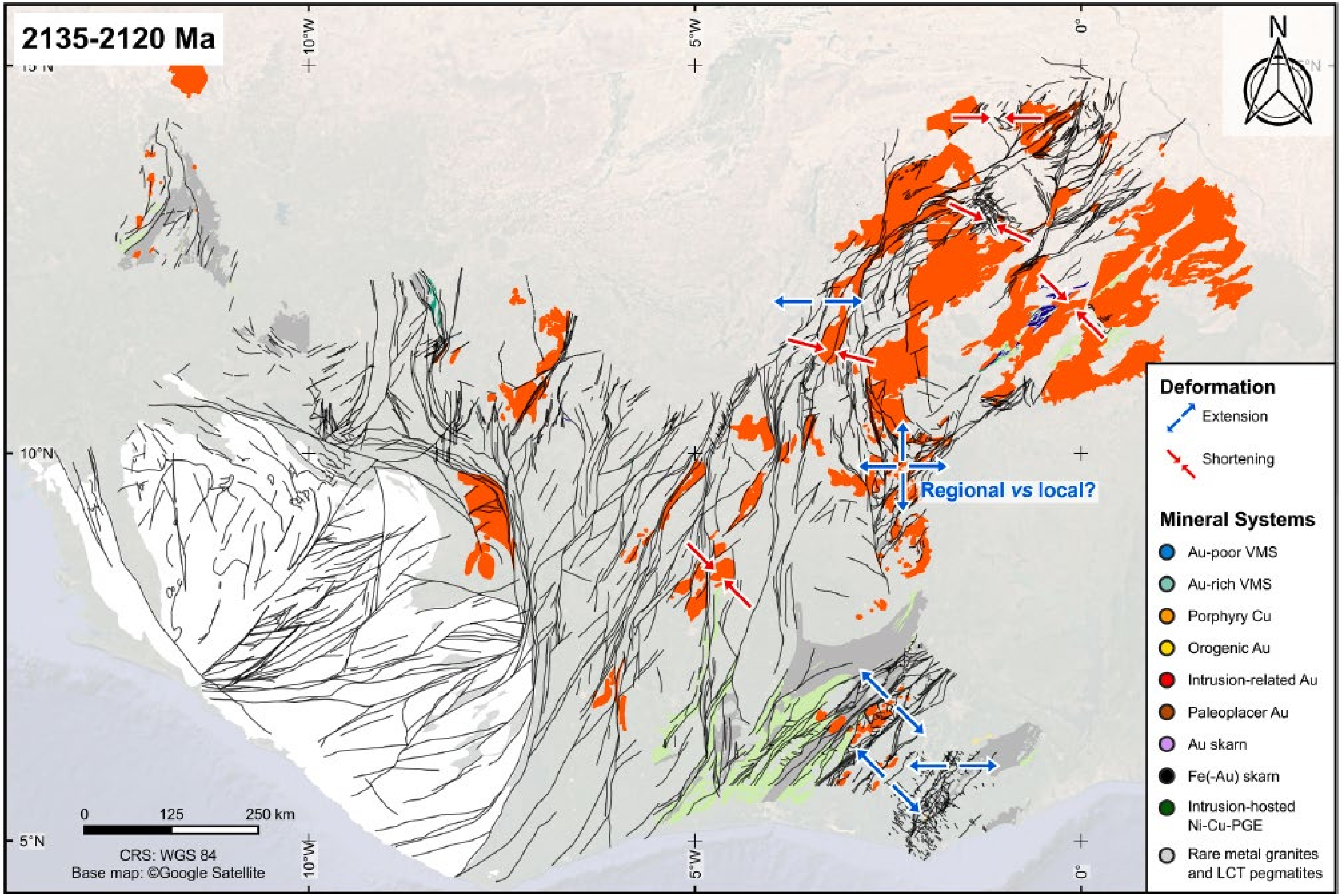
Baratoux et al., 2024

Tectonic scenario



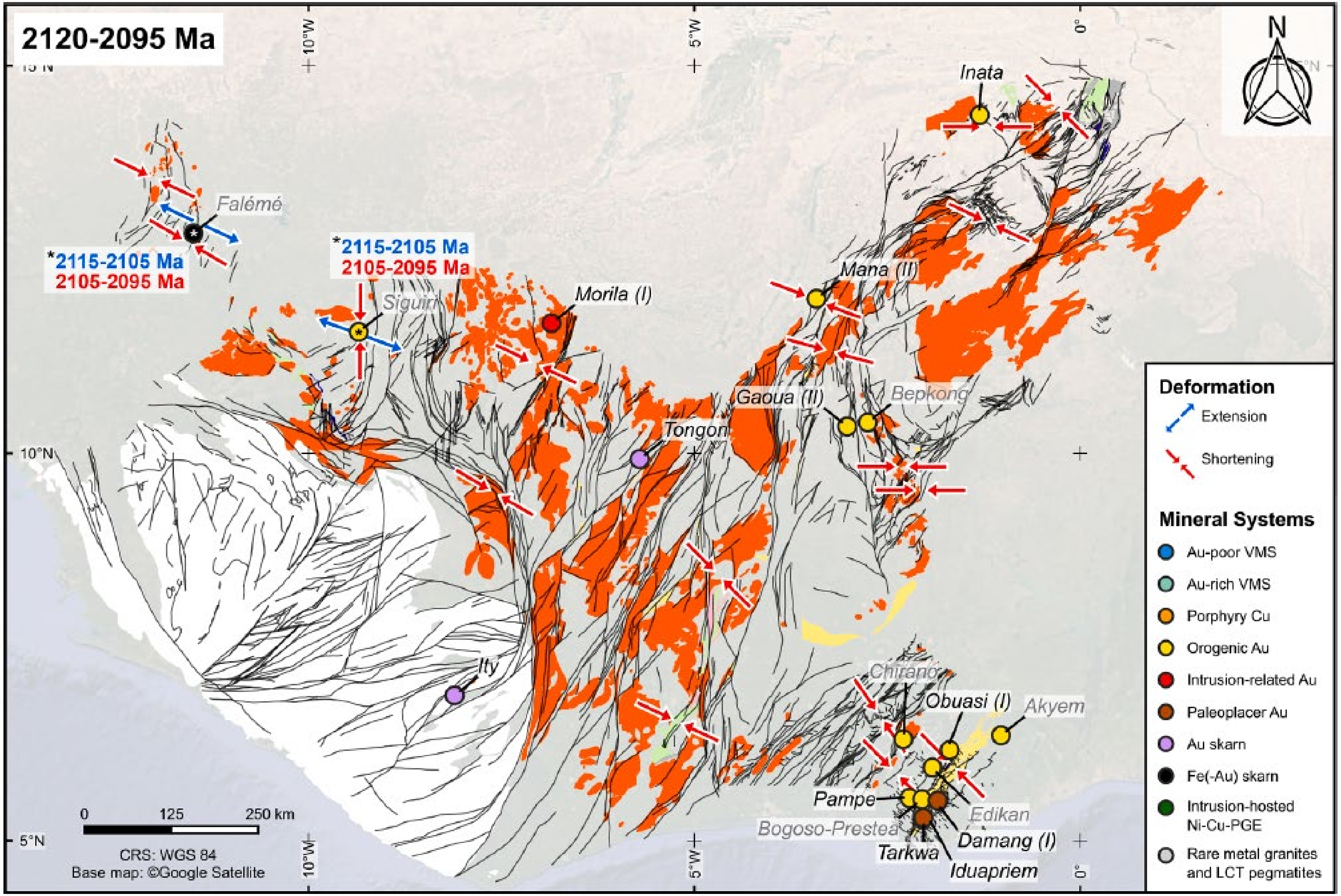
Perret et al., 2025

Tectonic scenario



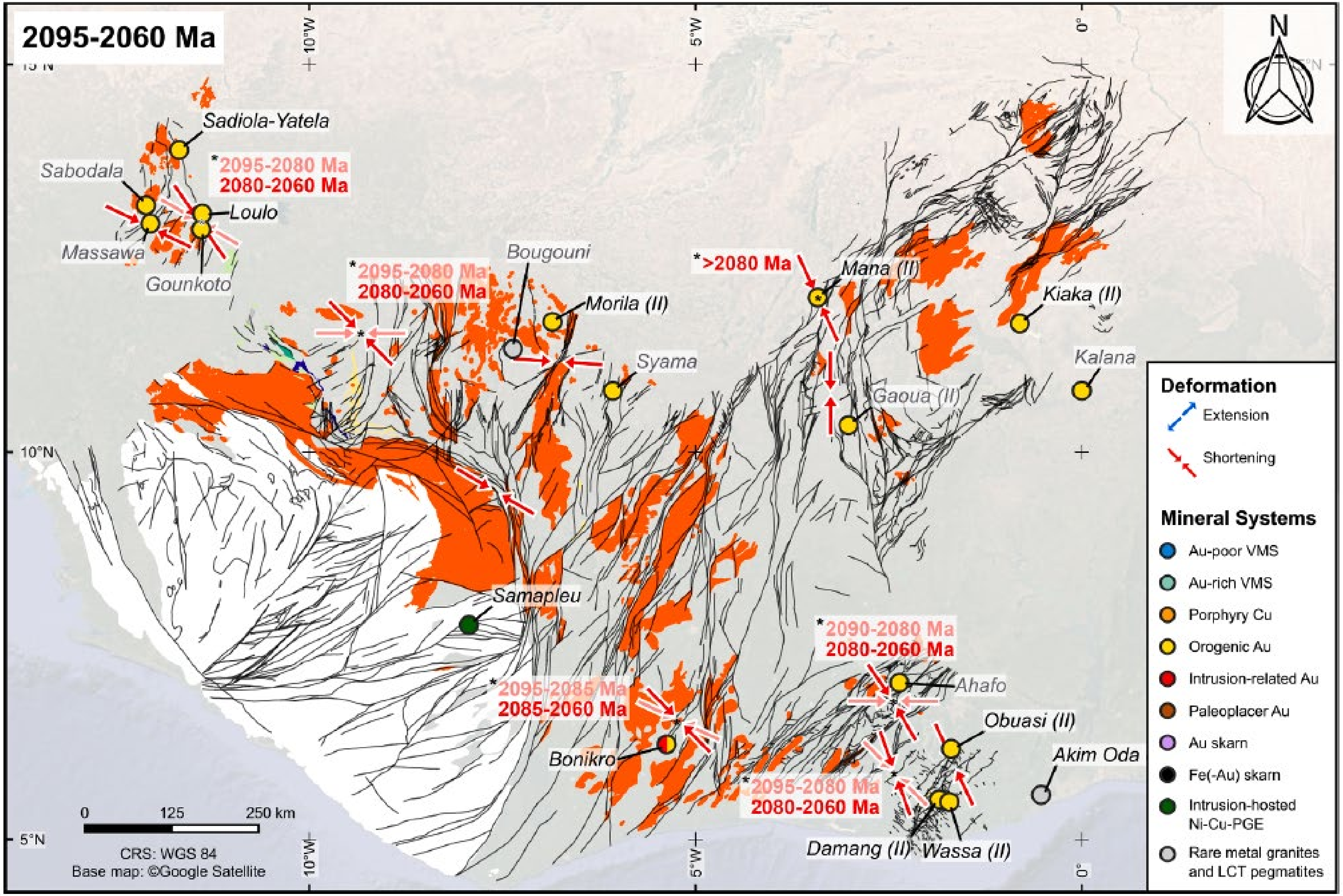
Perret et al., 2025

Tectonic scenario



Perret et al., 2025

Tectonic scenario



Perret et al., 2025

Data synthesis across the sWAC

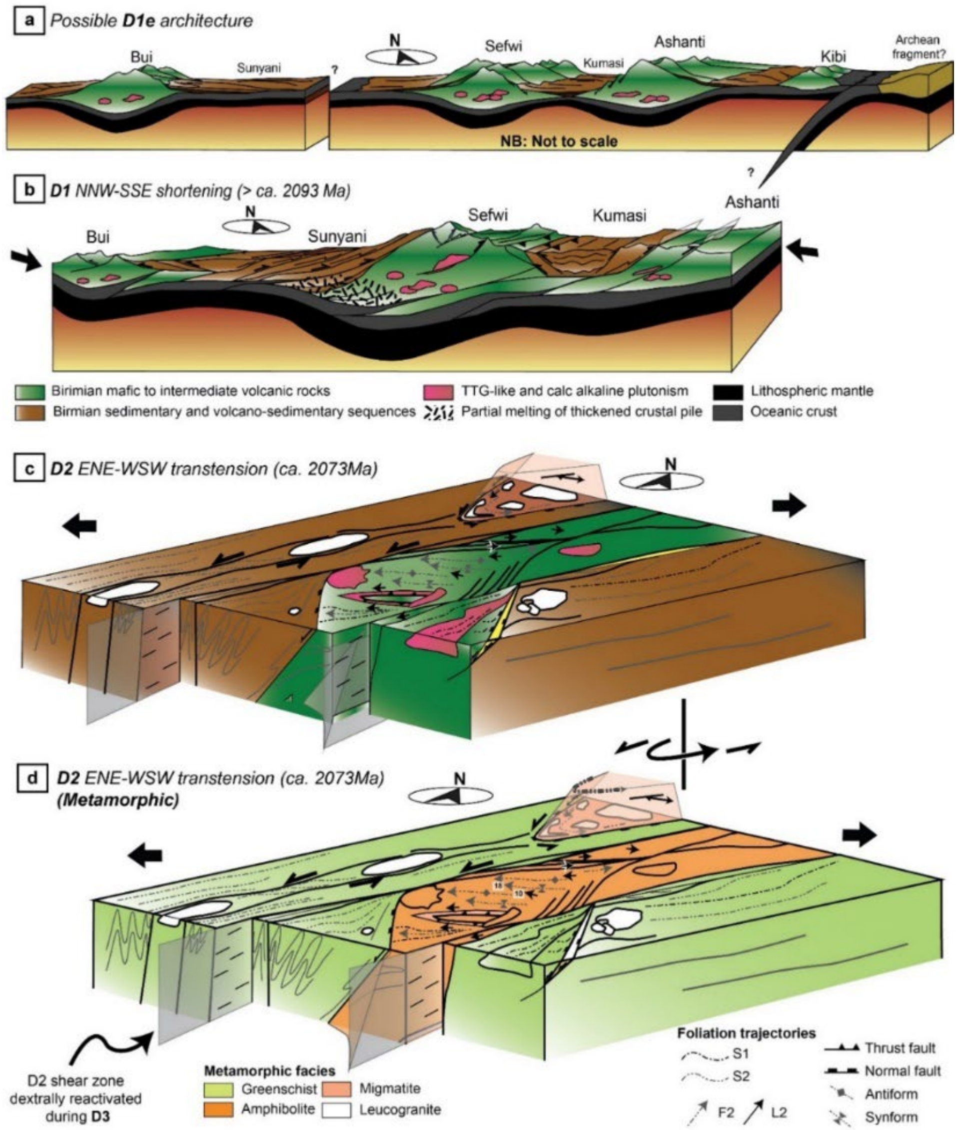
Conclusions

- The **geodynamic setting in Paleoproterozoic domains** is transitional between the **(hot) "archaic" style in** Archean domains of the WAC and **modern plate tectonics** style

- The data are consistent with an evolution from **primitive tholeiitic volcanism** (probably plume-triggered extension of the pre-existing Archean continents), formation of **volcanic arcs, accretion of these arcs** (subduction needed!), **collisional thickening** of the newly formed crust and **thermal relaxation, heating** and **collapse of the orogeny**

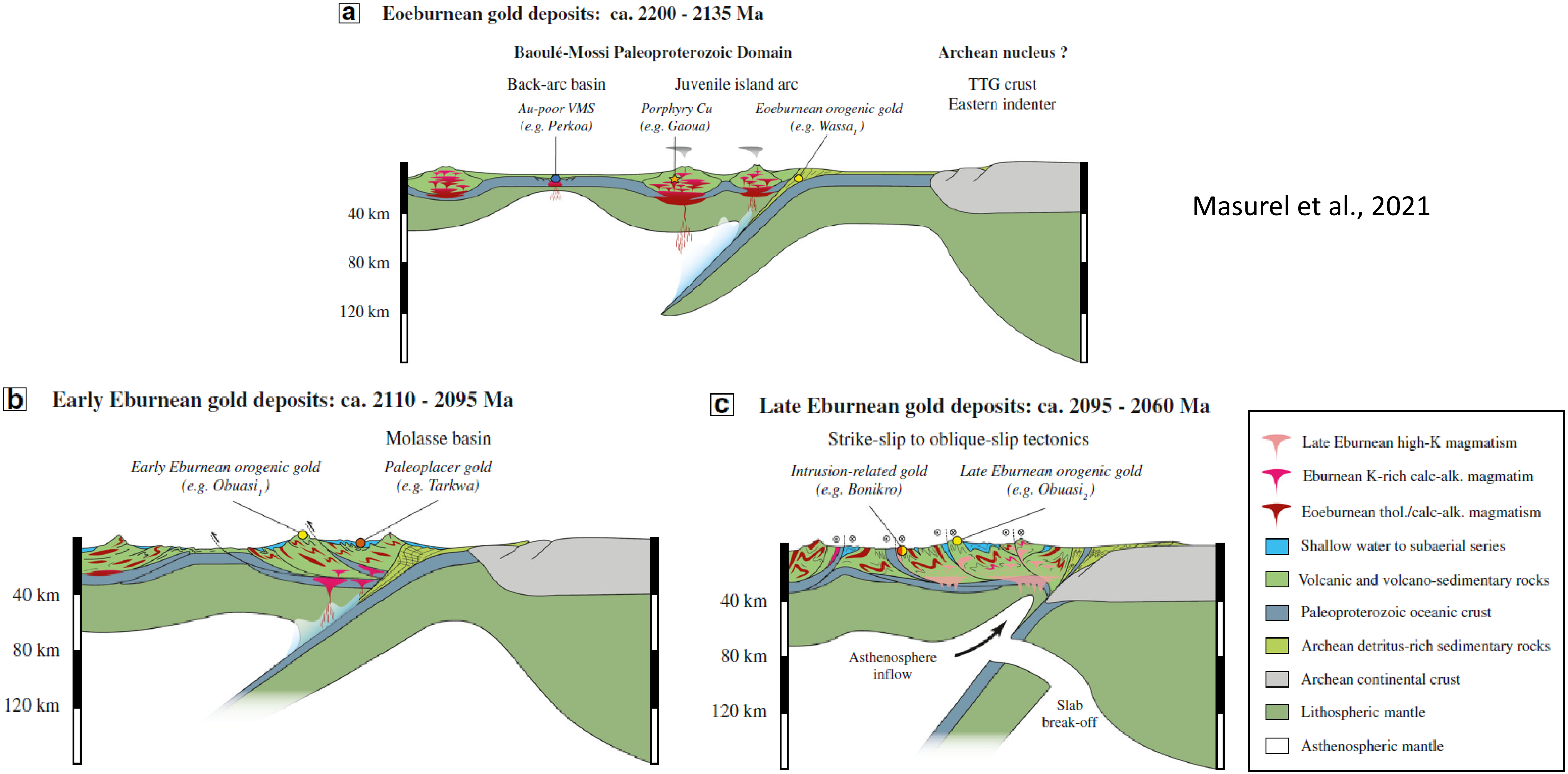
- **Same processes** but **diachroneous** across the West African Craton

- Most of the **gold deposits** are of **orogenic type**, often **polyphase**. They are related to structures of variable scale, developed under consecutive deformation events. **Porphyry Cu, VMS deposits** in **volcanic arc setting**.



McFarlane et al., 2019

Conclusions



Masurel et al., 2021

WAXI
West African Exploration Initiative

https://waxi4.org/

Thank you for your attention!