Neoarchean tectonics: *insight from the deformation of the Archean basement of North China Craton*

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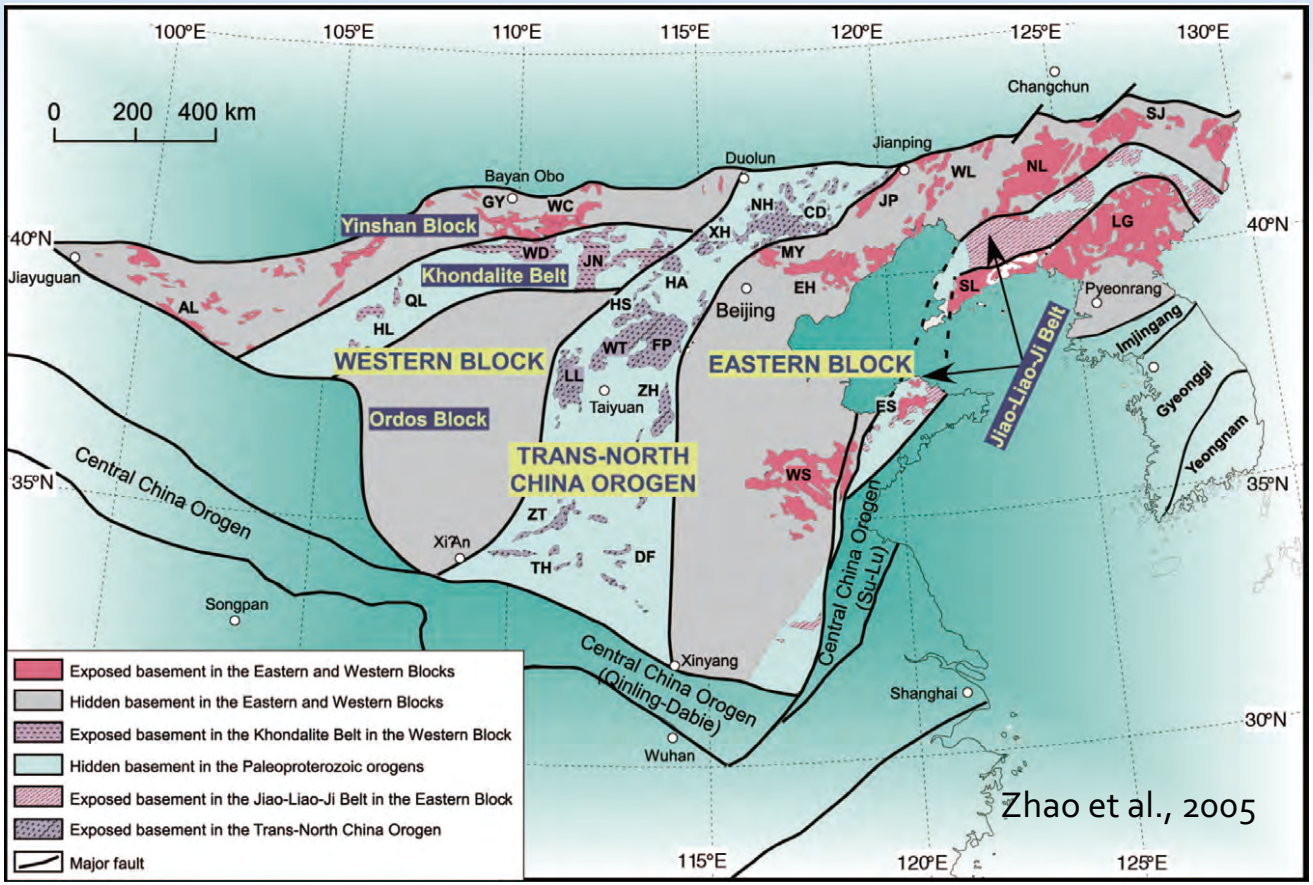
EGU in Vienna

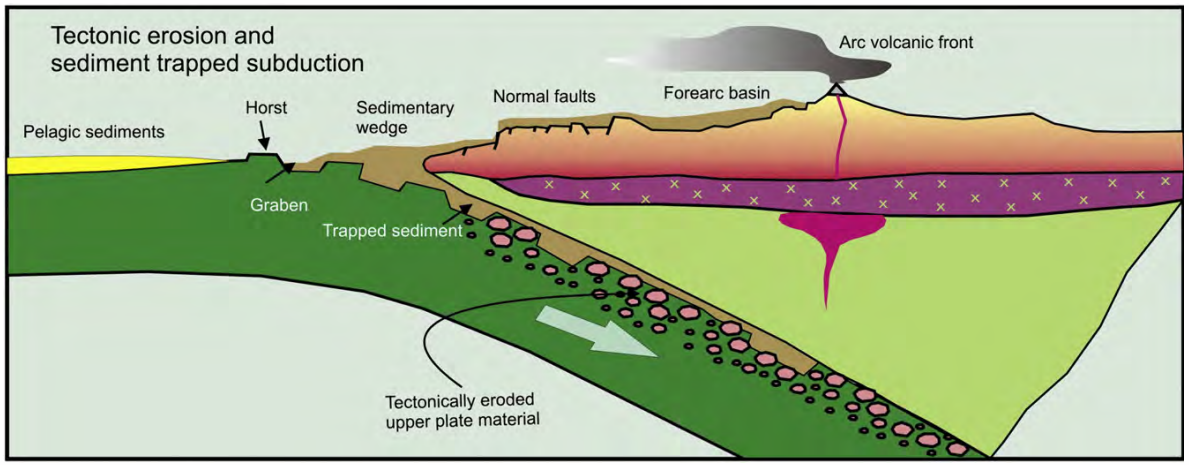


Jing Li, Yong-Jiang Liu, Wei Jin, Xian-Hua Li, Franz Neubauer, Wei-Min Li, Chen-Yue Liang, Quan-Bo Wen, Yuan-Yuan Zhang. 2017. Neoarchean tectonics: Insight from the Baijiafen ductile shear zone, eastern Anshan, Liaoning Province, NE China. Journal of Asian Earth Sciences, 139，165-182

Liu XY, Li WM, Liu YJ, Dai LM, Dong H, Li J and Zhao YL. 2019. Archean tectonic pattern and its numerical simulation in Anshan area，eastern Liaoning Province. Acta Petrologica Sinica, 35, 1071-1084

When did plate tectonics begin?

Although plate tectonics is the most important geological process of the modern Earth, its form and existence during the Archean era (4.0–2.5Ga ago) are disputed.

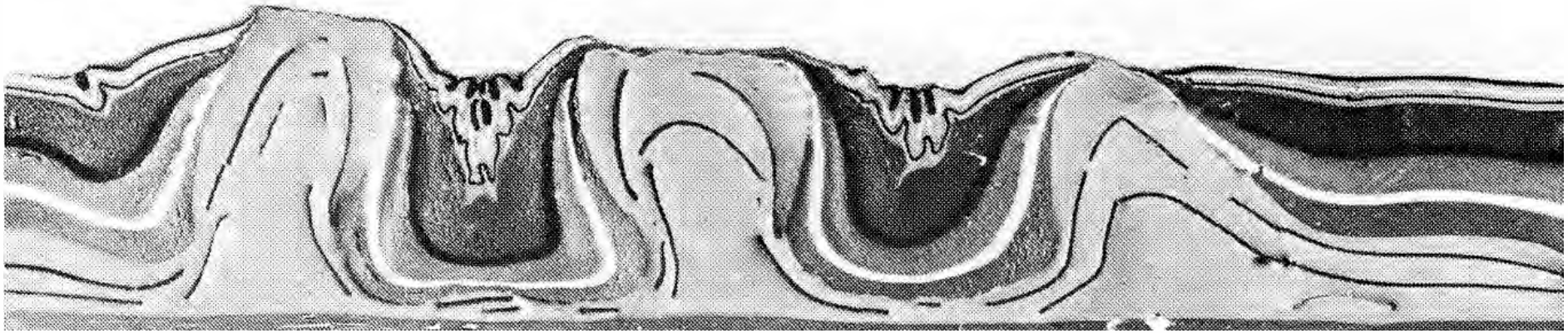


There are two classical tectonic models for Archean era

Vertical Tectonism vs Horizontal Tectonism

Vertical Tectonism

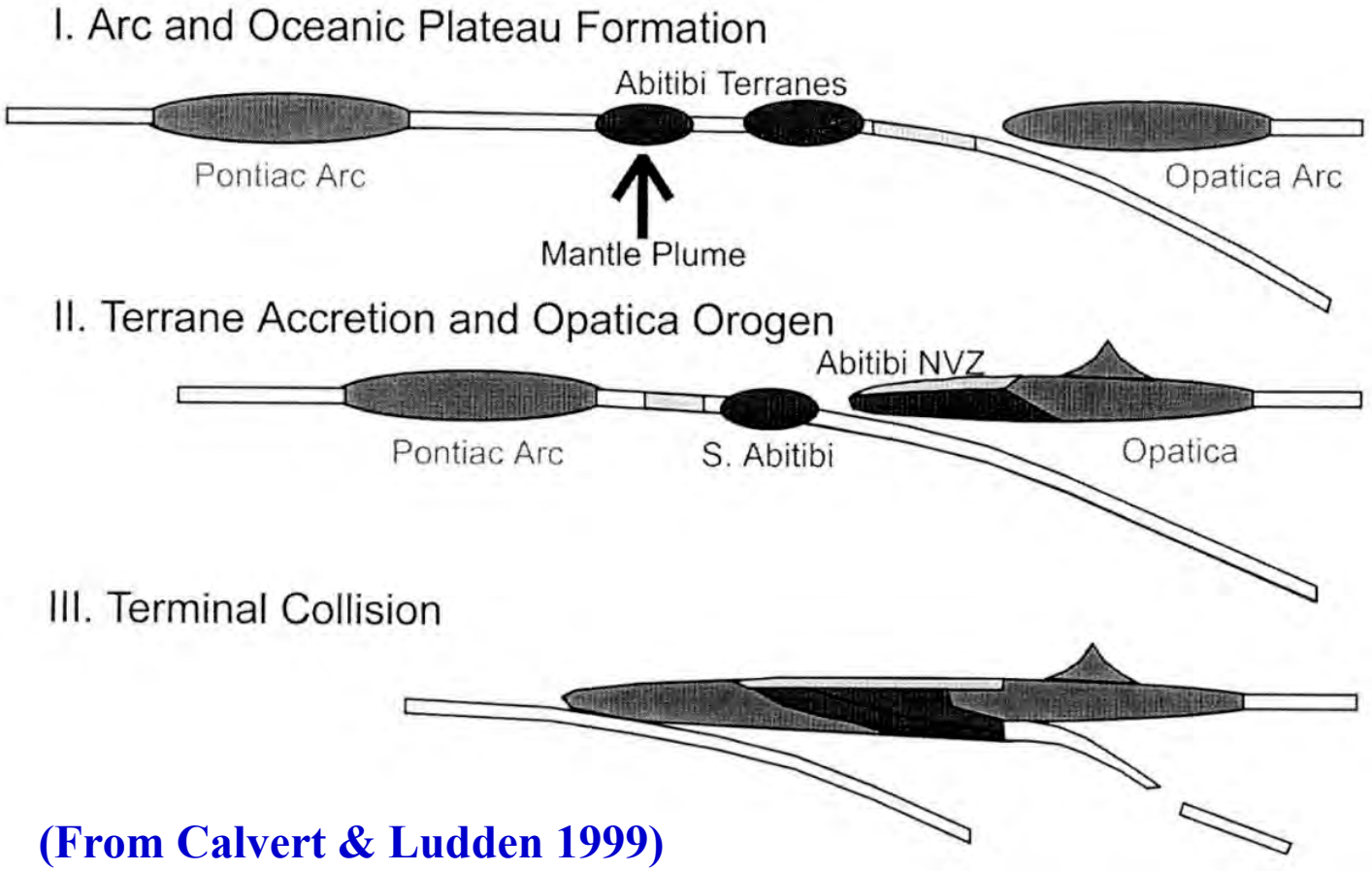
Including plume-driven magmatism, crustal melting, diapirism. In particular, density inversion leads to buoyant uplift (diapirism) of granitoids and associated synclinal down-folding (sagduction) of greenstones.



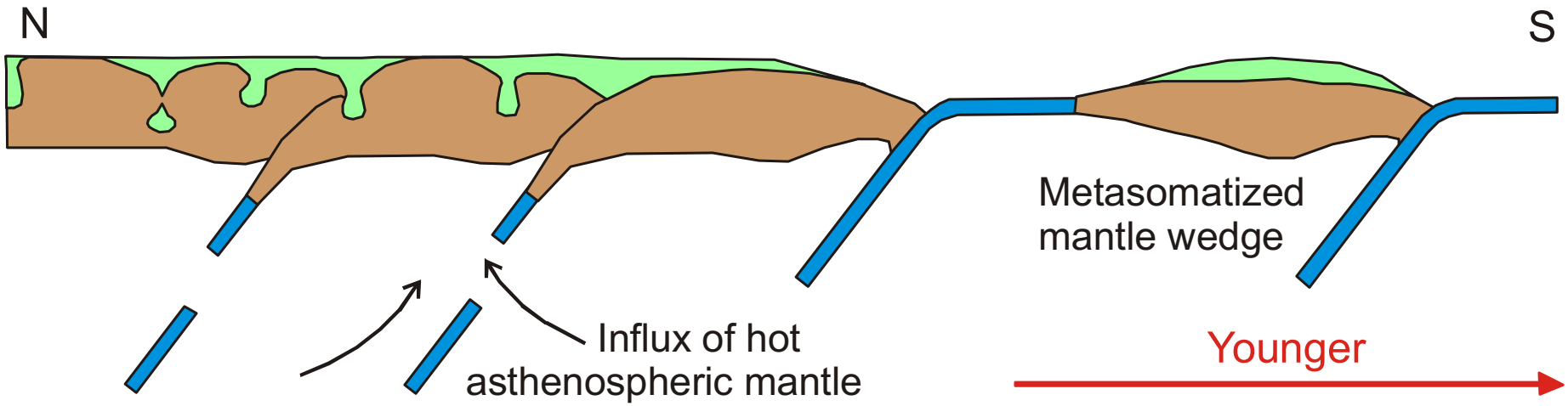
(From Ramberg 1981)

Horizontal Tectonism:

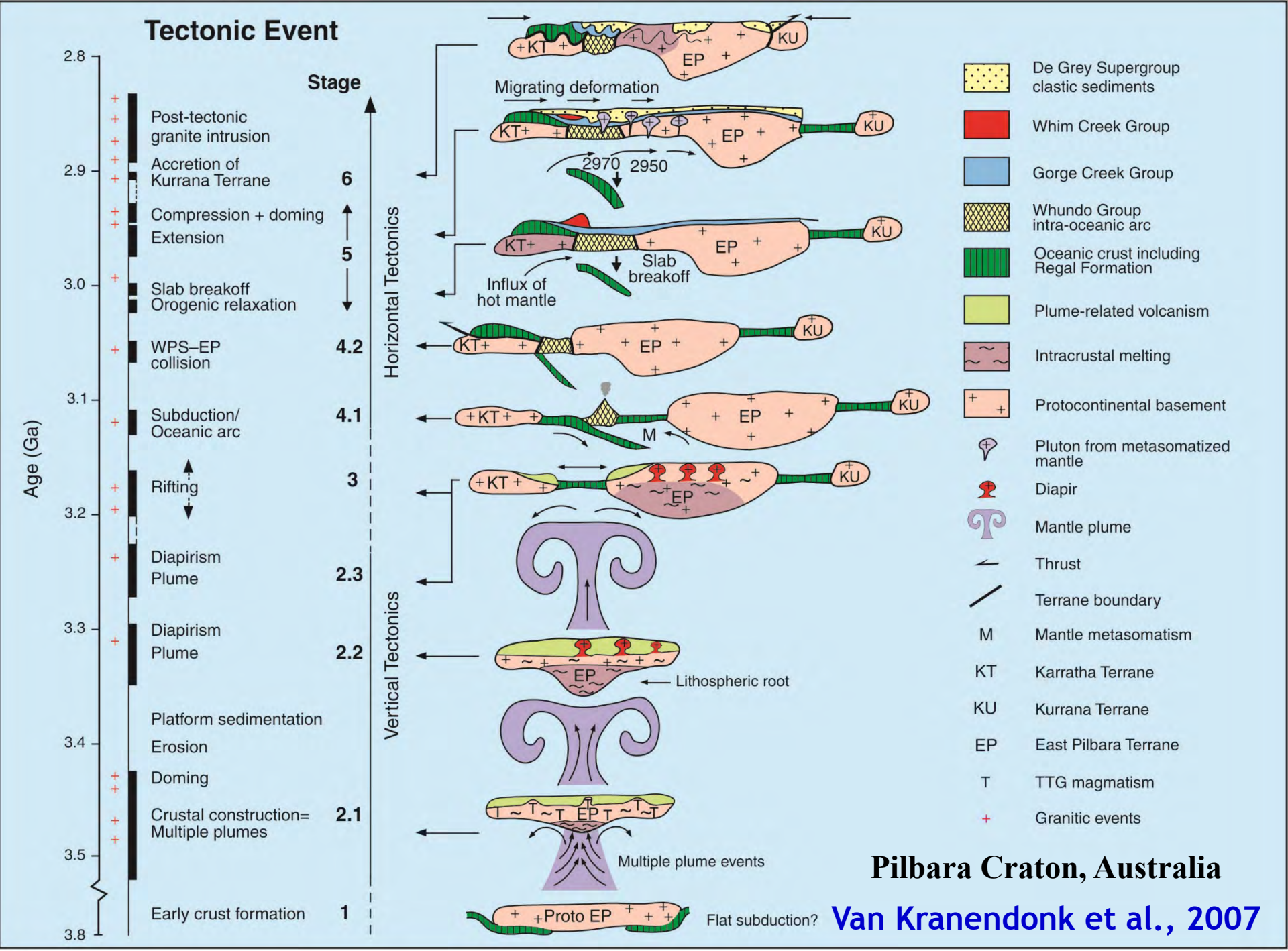
A plate tectonics-like process characterized by large-scale horizontal displacement (drift) of "plates" or "microplates" and interactions (e.g. collision) among them.



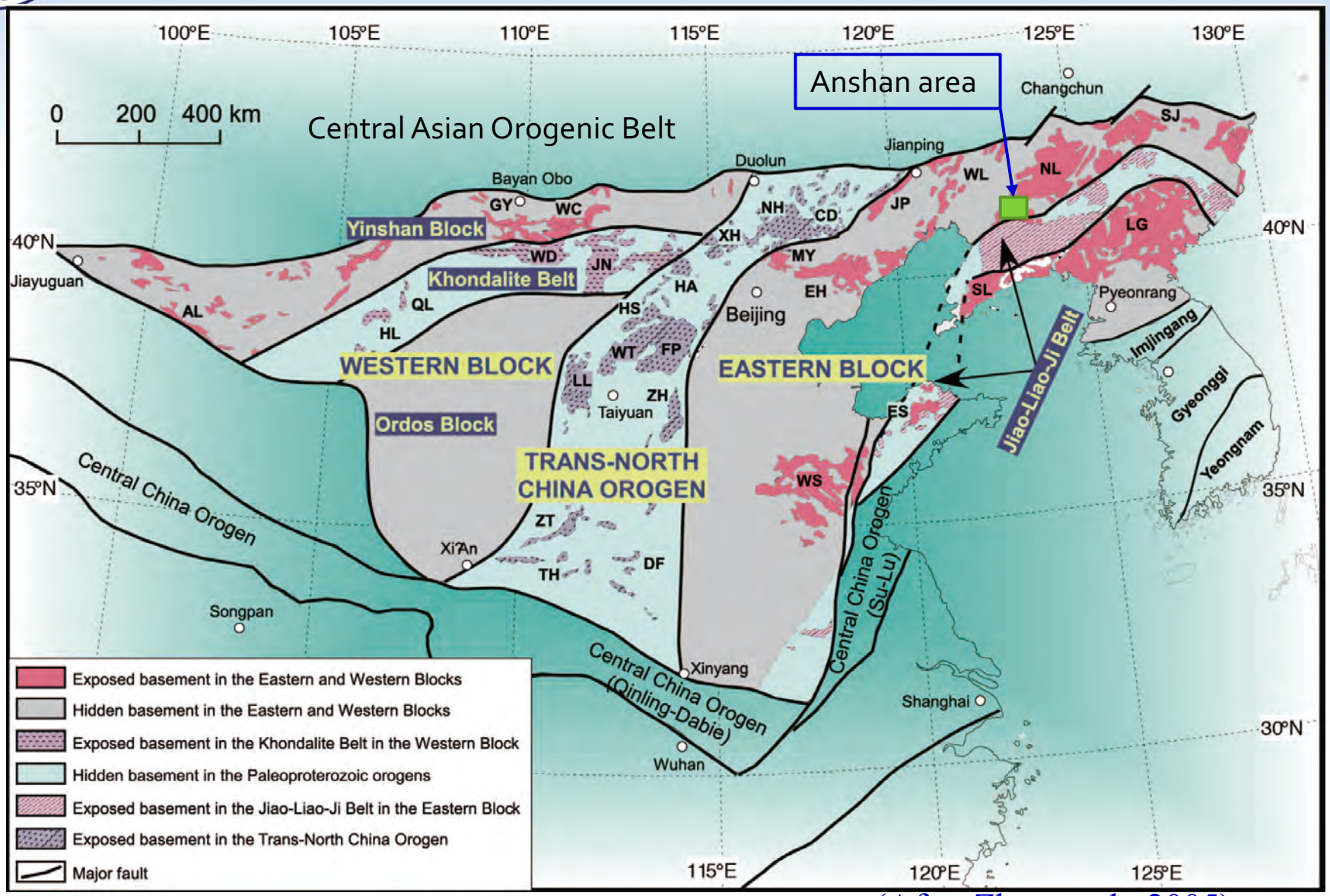
(From Calvert & Ludden 1999)



(From Lin and Beakhouse 2013)


Tectonic Event
Stage
Age (Ga)
2.8
2.9
3.0
3.1
3.2
3.3
3.4
3.5
3.8
Post-tectonic granite intrusion
Accretion of Kurrana Terrane
6
Compression + doming
Extension
5
Slab breakoff
Orogenic relaxation
WPS–EP collision
4.2
Subduction/ Oceanic arc
4.1
Rifting
3
Diapirism
Plume
2.3
Diapirism
Plume
2.2
Platform sedimentation
Erosion
Doming
Crustal construction= Multiple plumes
2.1
Early crust formation
1
Horizontal Tectonics
Vertical Tectonics
KT
EP
KU
Migrating deformation
2970
2950
Slab breakoff
Influx of hot mantle
M
Lithospheric root
Multiple plume events
Proto EP
Flat subduction?
De Grey Supergroup clastic sediments
Whim Creek Group
Gorge Creek Group
Whundo Group intra-oceanic arc
Oceanic crust including Regal Formation
Plume-related volcanism
Intracrustal melting
Protocontinental basement
Pluton from metasomatized mantle
Diapir
Mantle plume
Thrust
Terrane boundary
M Mantle metasomatism
KT Karratha Terrane
KU Kurrana Terrane
EP East Pilbara Terrane
T TTG magmatism
Granitic events
Pilbara Craton, Australia
Van Kranendonk et al., 2007

Neoarchean Tectonics in Anshan area



(After Zhao et al., 2005)

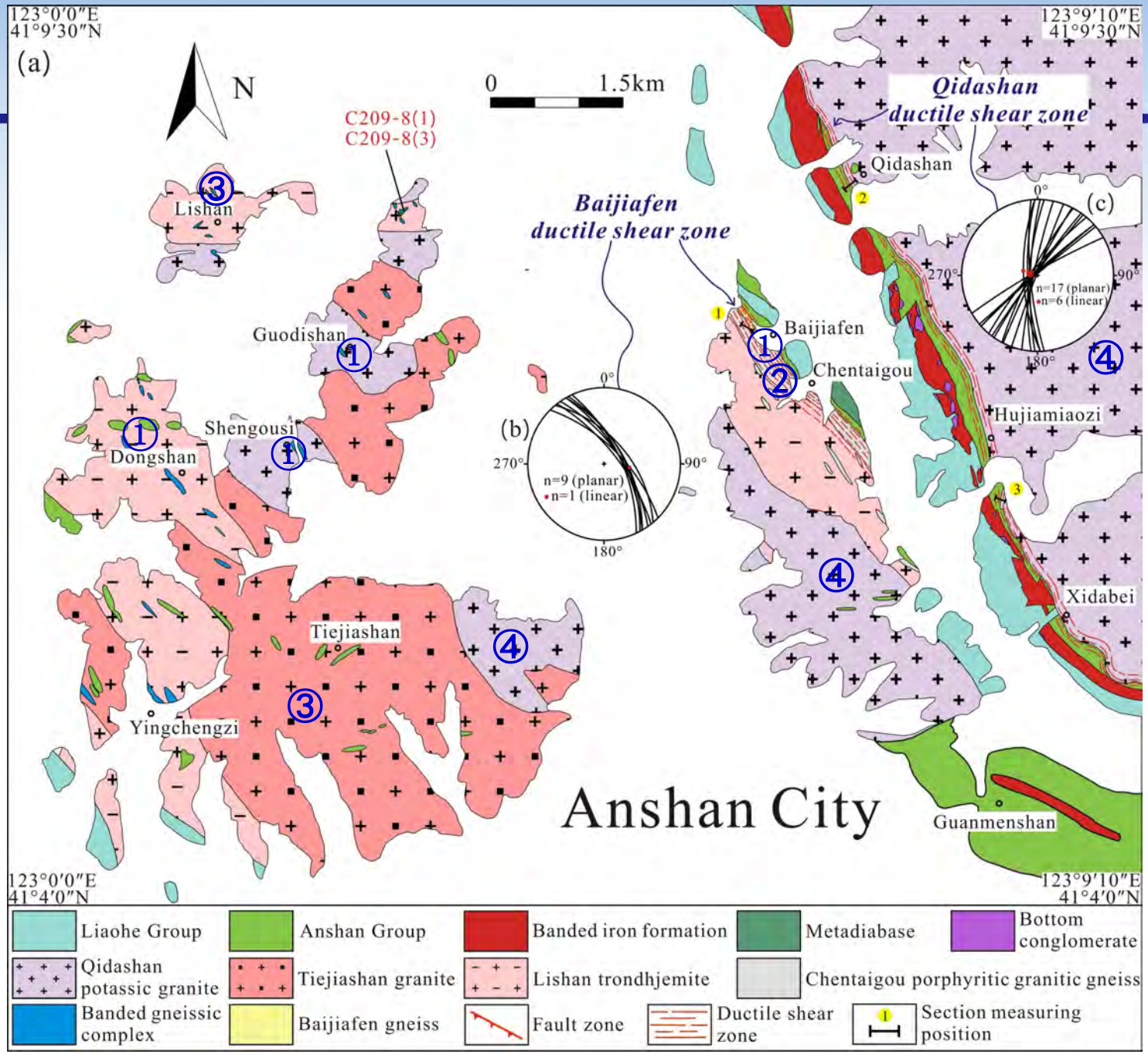
Lithological Units:

①3.80~3.65Ga: Baijiafen, Dongshan and Shengousi granitic gneisses.

②3.35~3.30Ga: Chentaigou granite, granitic gneiss.

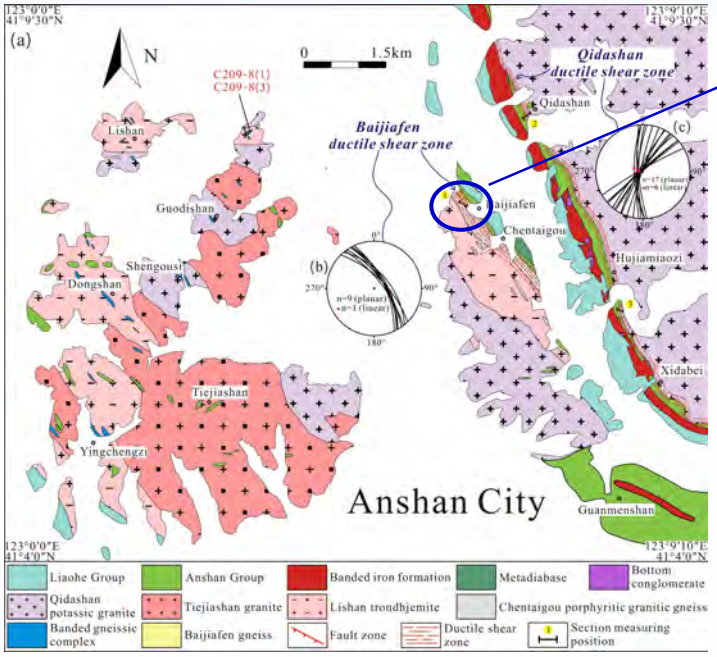
③3.14~2.96Ga: Lishan trondhjemite, Tiejiashan granite

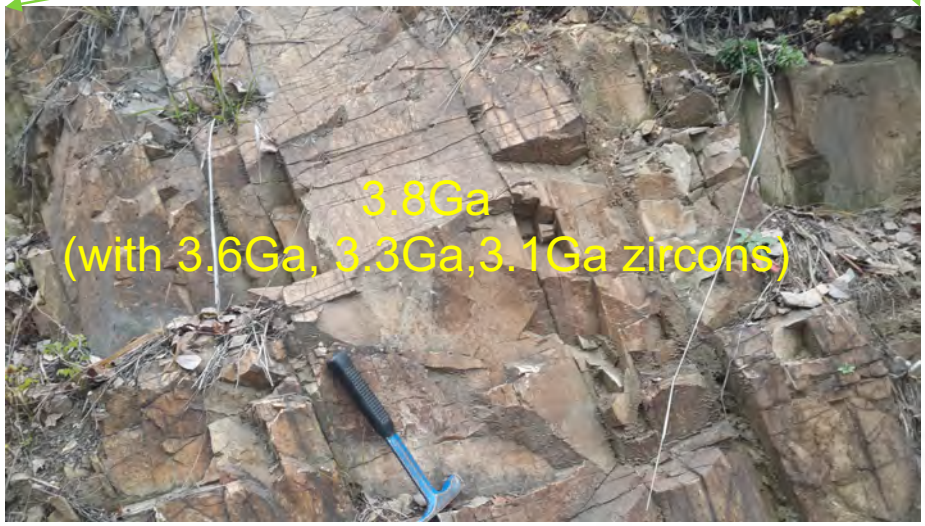
④~2.5Ga: Qidashan granite



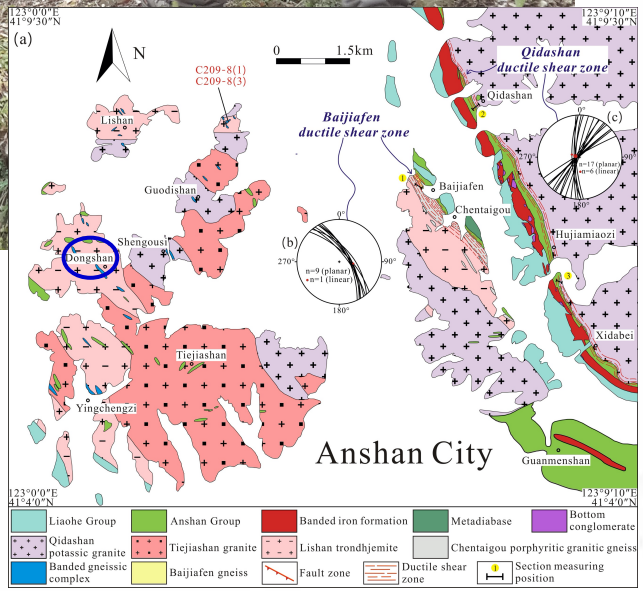
Oldest rock in China

Baijiafen

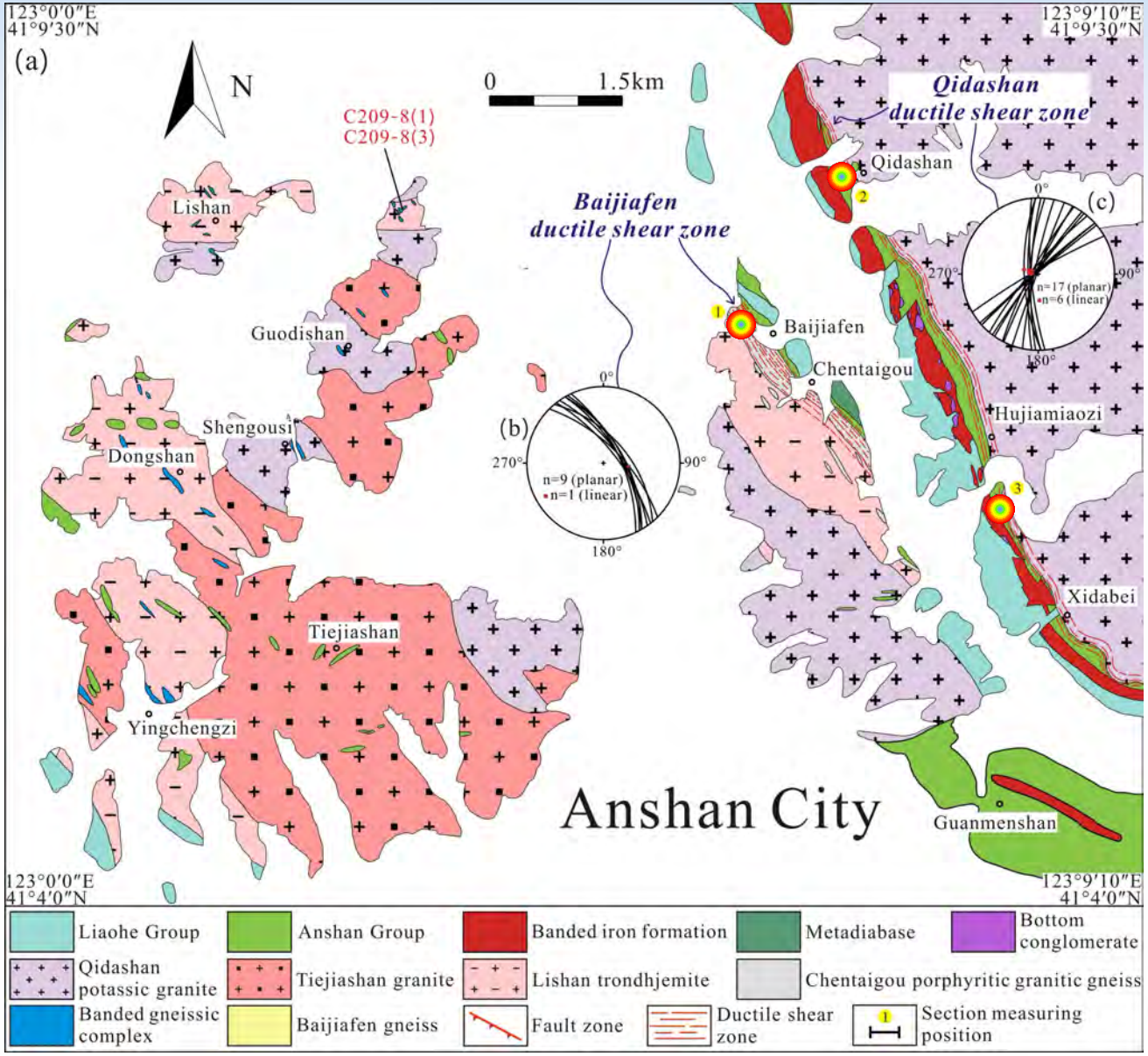




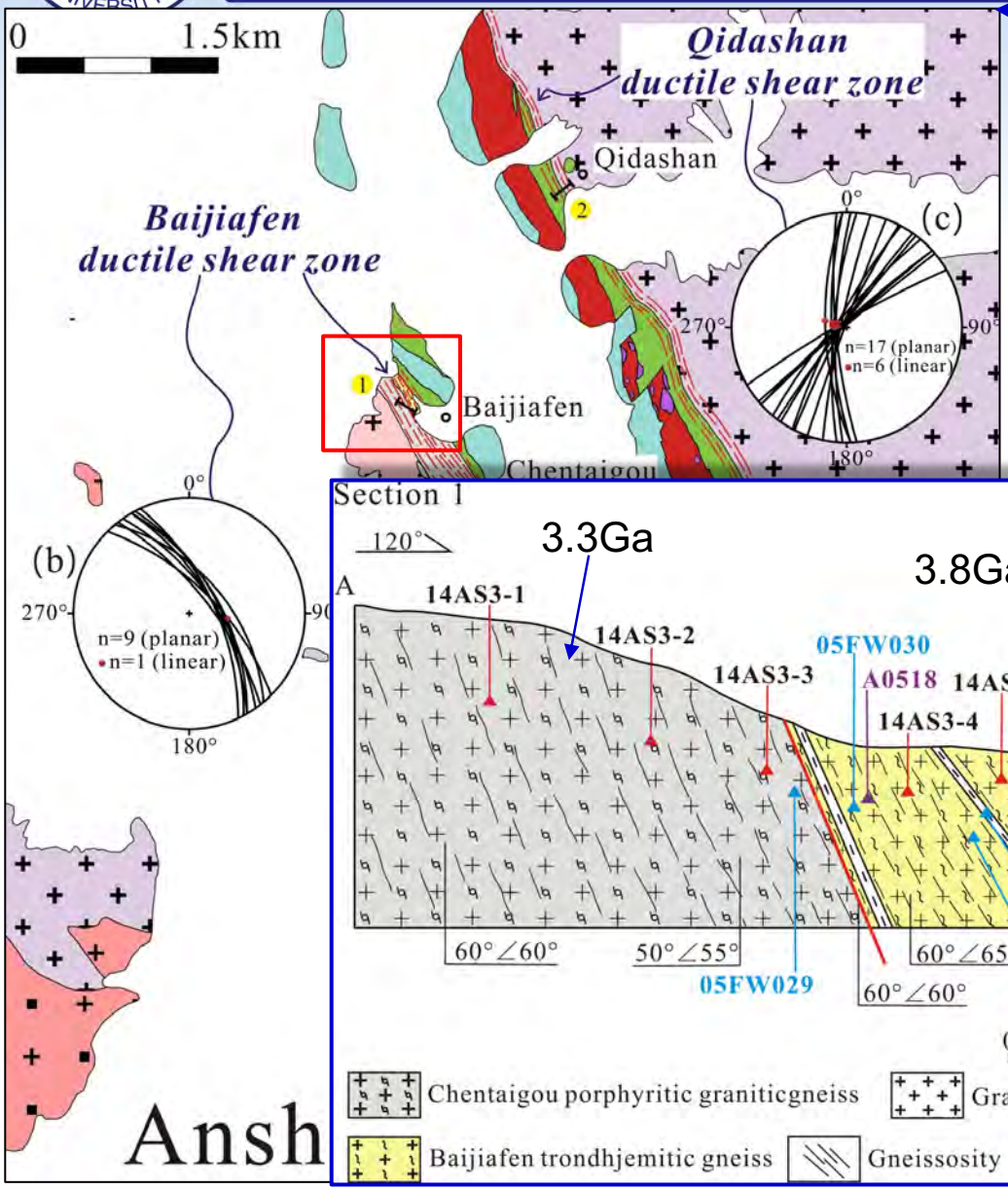
Oldest rock in China

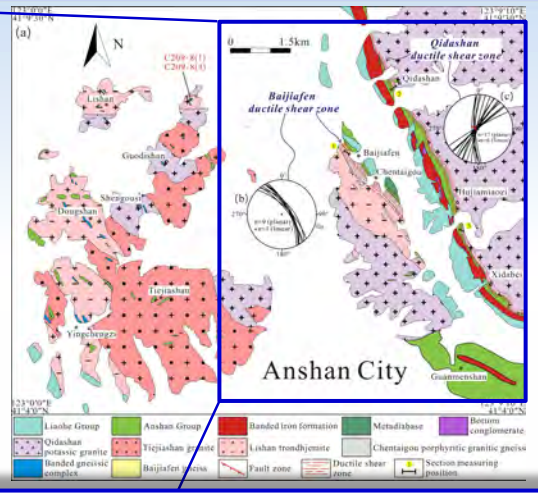


What's the relationship between BIF and TTG?



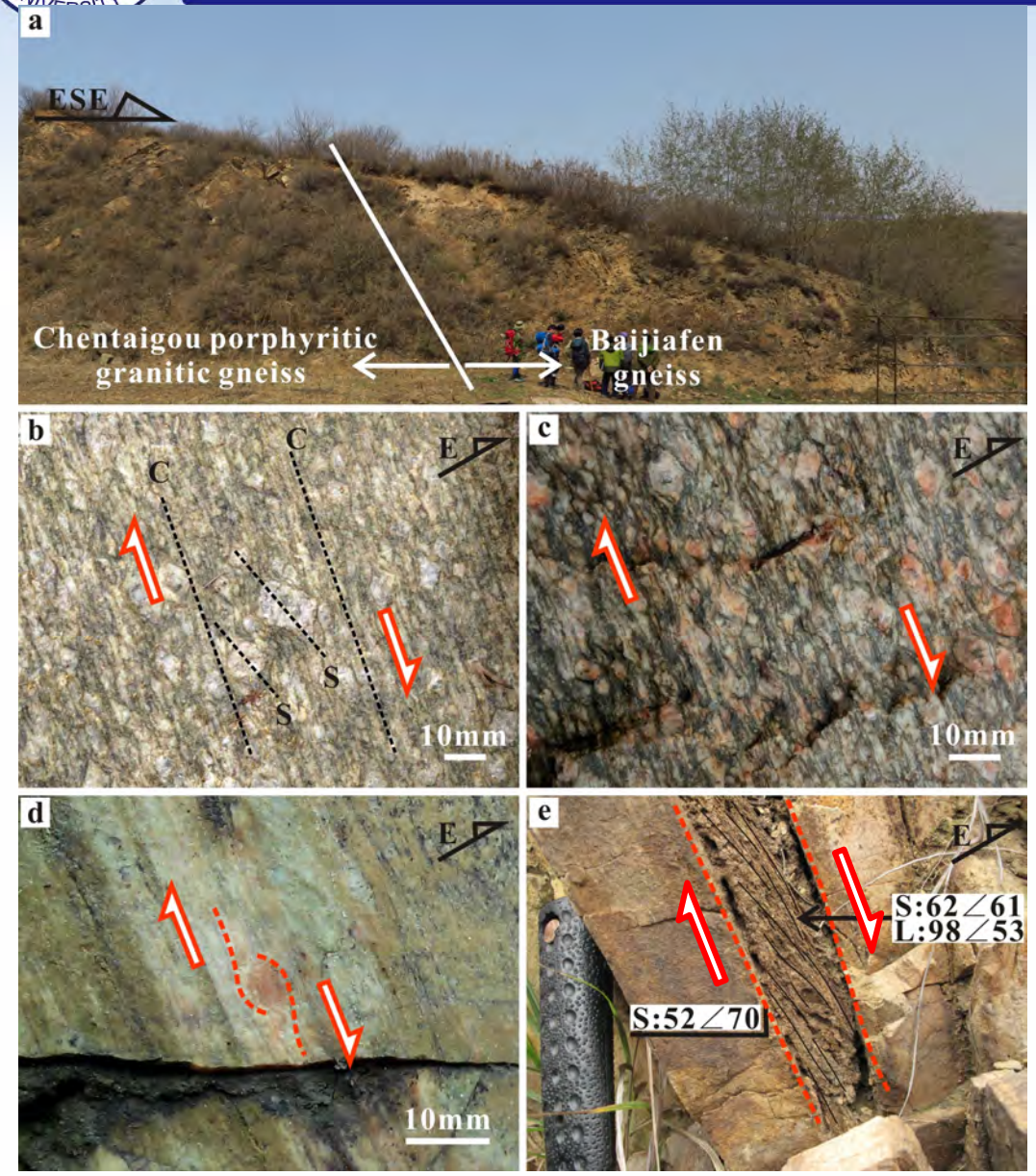
Baijiafen ductile shear zone in the west of BIF belt





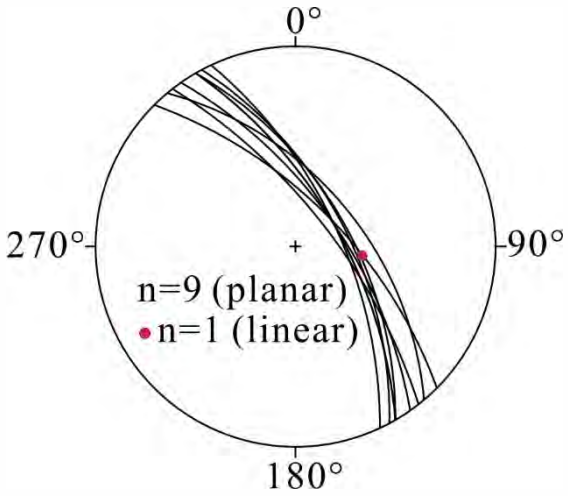
Baijiafen section

Field Observation



Foliation：50° ~70° ∠ 55° ~65°

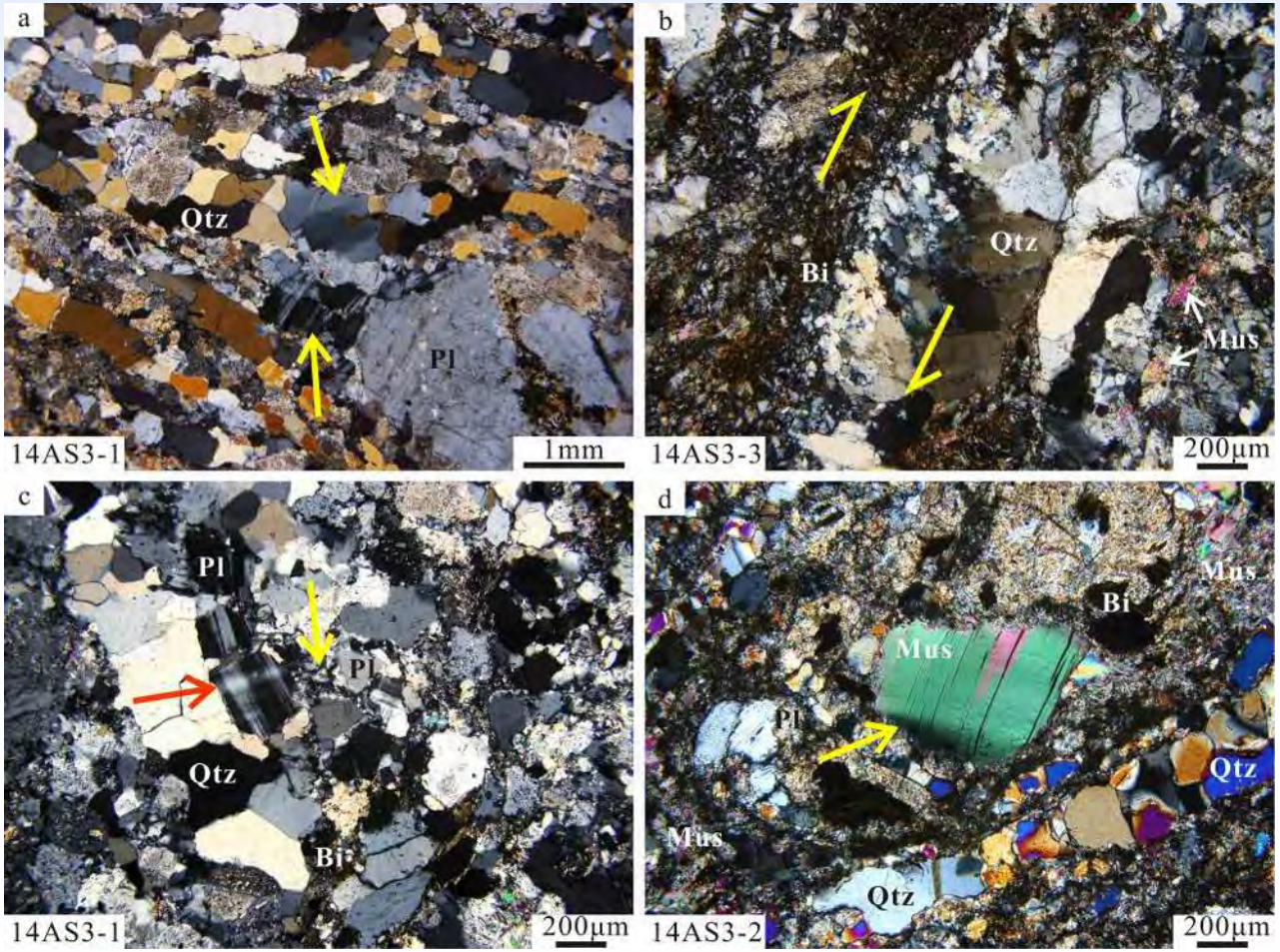
Lineation：86-95° ∠ 53°



Top-to **ENE down shearing**

Micro-structure

Chentaigou granitic gneiss



- **Quartz**

  Multi-grain ribbon

  L/W：1.2~2.5

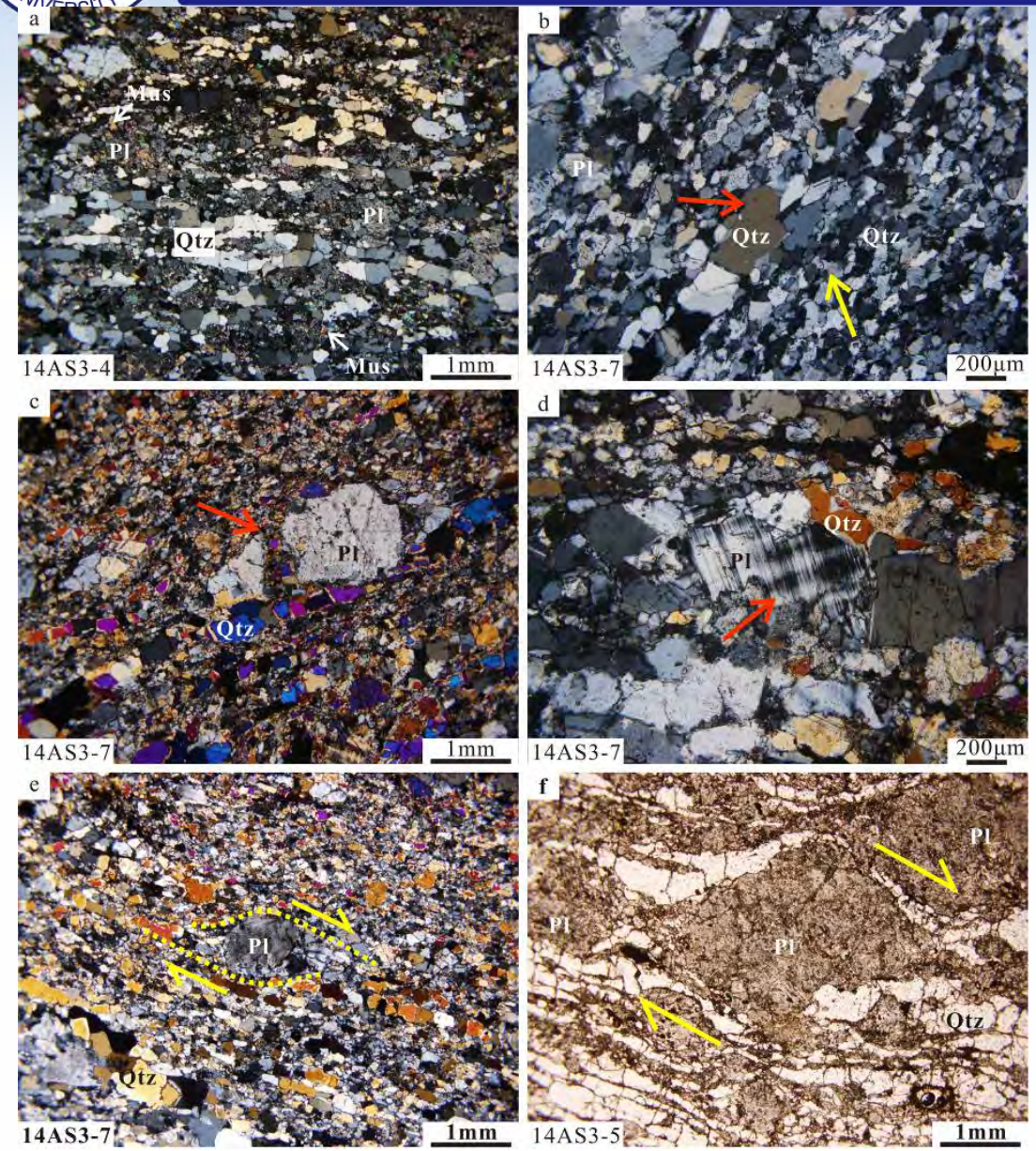
  BLG+SGR
- **Feldspar**

  Elongation,

  Mechanical twin,
- **Deformed muscovite**

Middle-lower T

Baijiafen trondhjemitic gneiss



- **Quartz ribbon**

  L/W：1.5~4.0

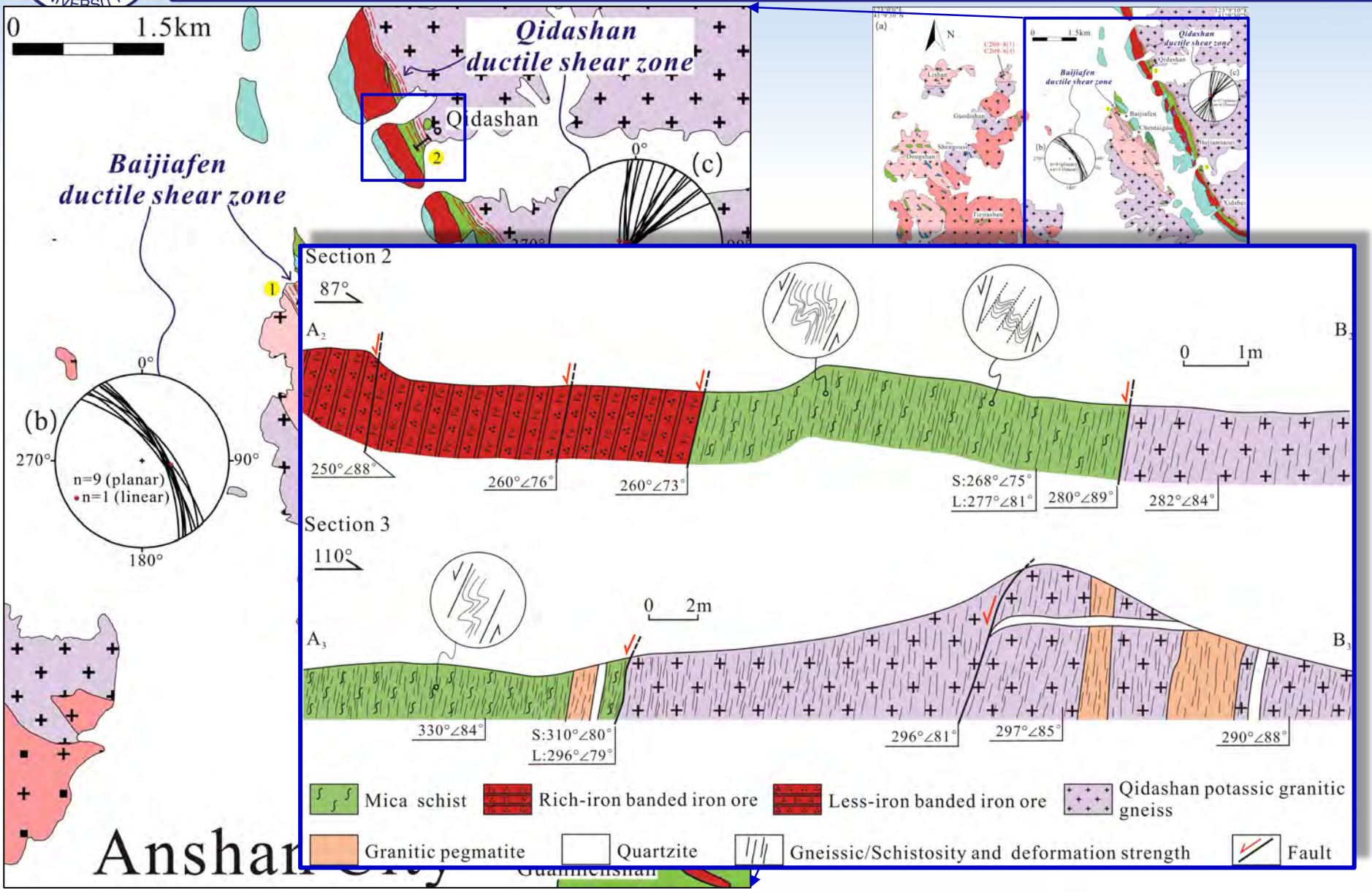
  BLG+SGR

- **Feldspar**
  Elongation，mechanical twin

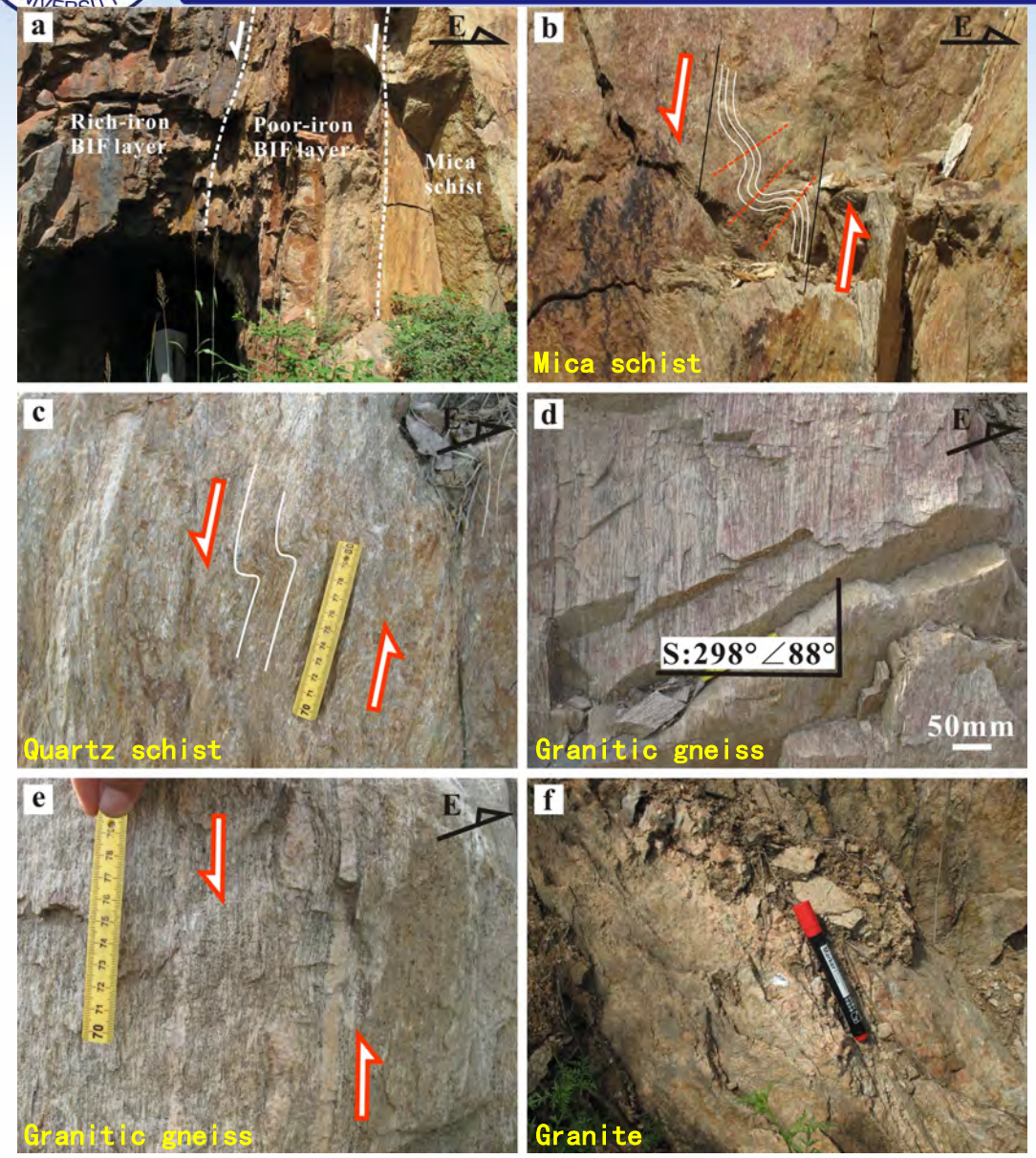
- **Dextral shearing （NEE)**

Middle-lower T

Qidashan ductile shear zone in the east of BIF belt

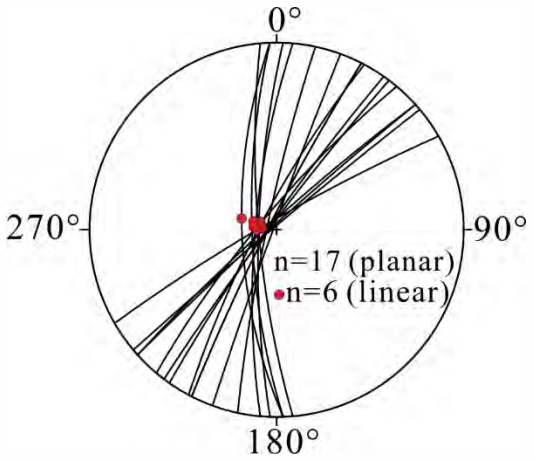


Field Observation



Foliation：265° ~330° ∠69° ~88°

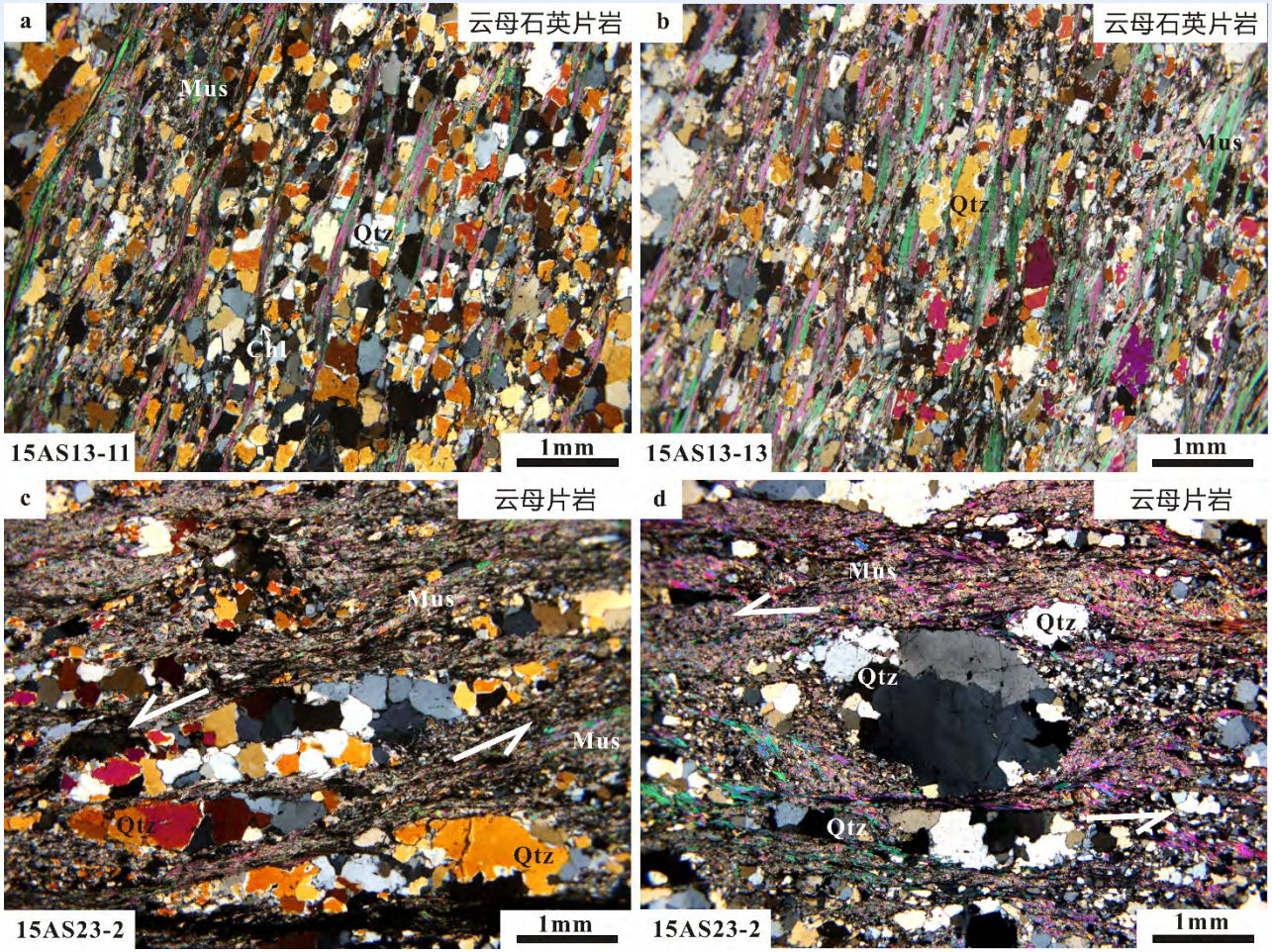
Lineation：270° ~296° ∠64° ~81°



Top-to **WNW down shearing**

Micro-structure

Mica schist

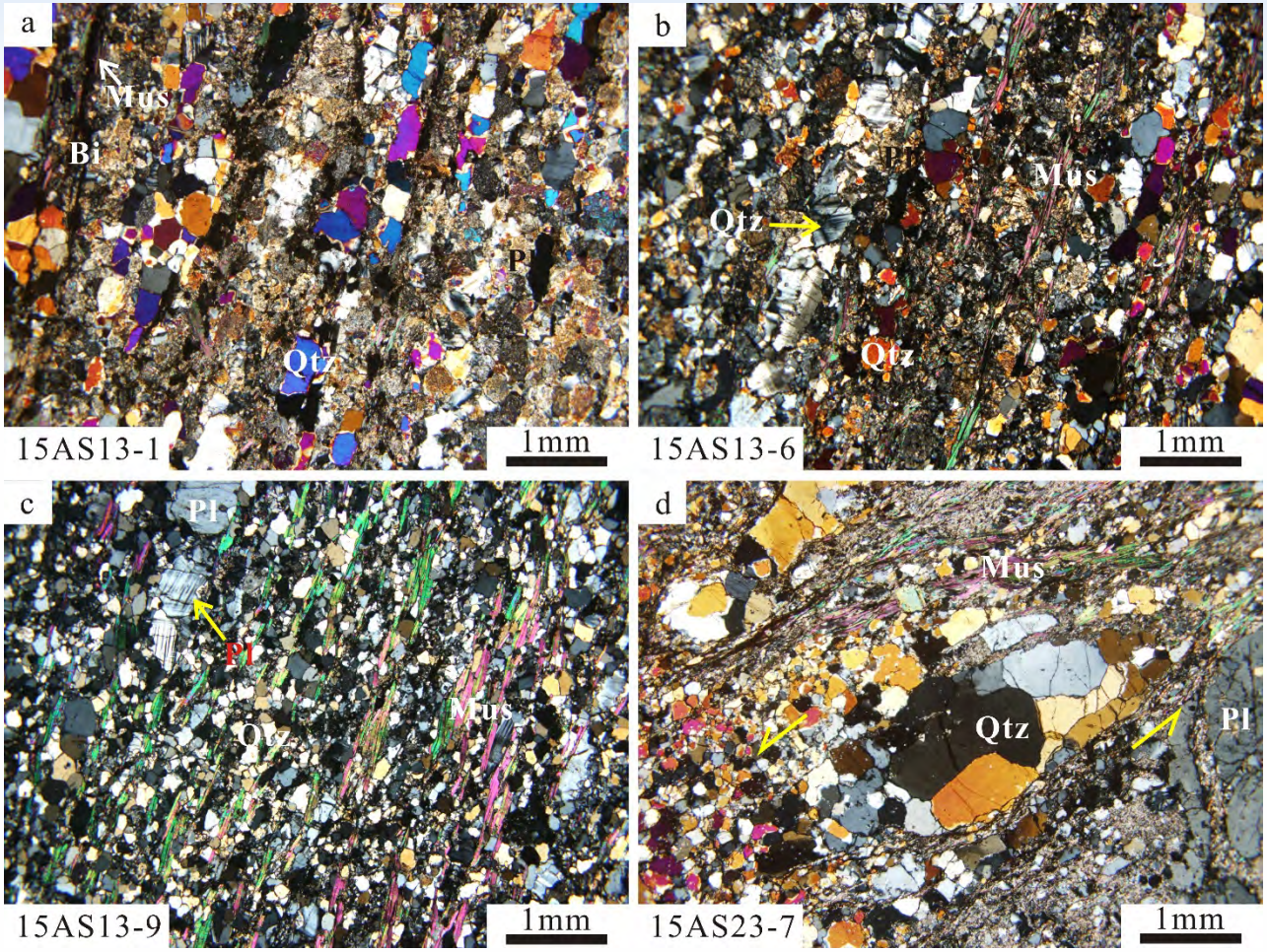


Quartz grain

- **Elongated**
- **Ribbon**
- **BLG+SGR.**

Middle-lower T

Granitic gneiss



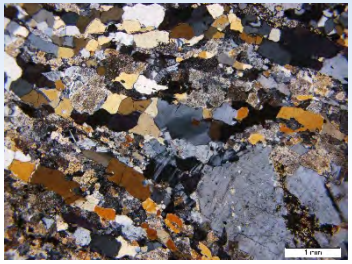
- **Elongated quartz Ribbon, BLG+SGR.**
- **Elongated feldspar, grain fining, mechanic twin.**
- **Sinistral shearing （NWW).**

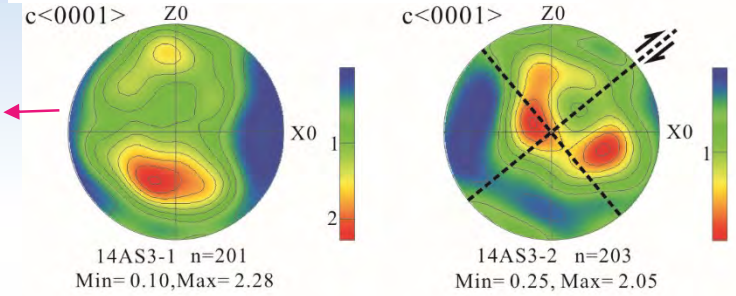
Stronger deformation with increasing muscovite closing to the BIF belt

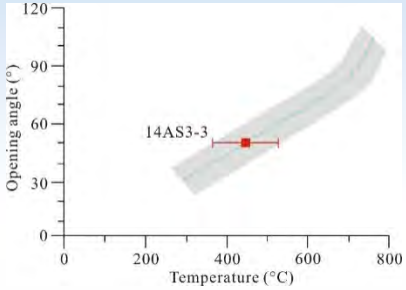
Quartz grain EBSD analyses

Baijiafen ductitle shear zone

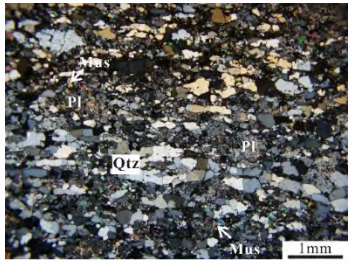
Chentaigou granite

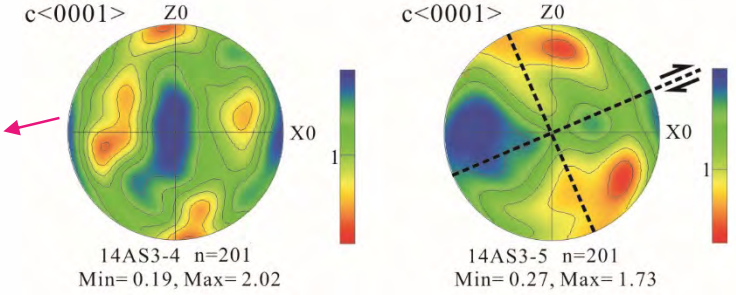






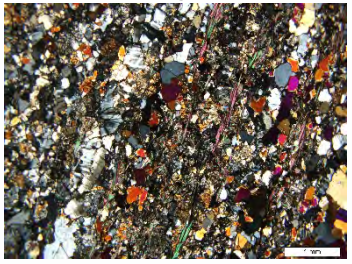
Baijiafen trondhjemite

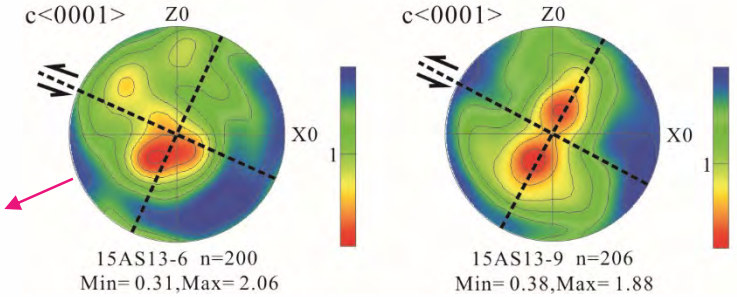




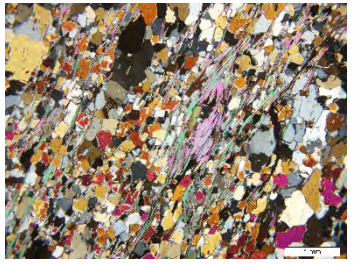
Qidashan ductitle shear zone

Qidashan granite





Mica-quartz schist



- C axis of quartz: rhomb <a> slip and basal <a> slip
- Deformation temperature（400~500℃）

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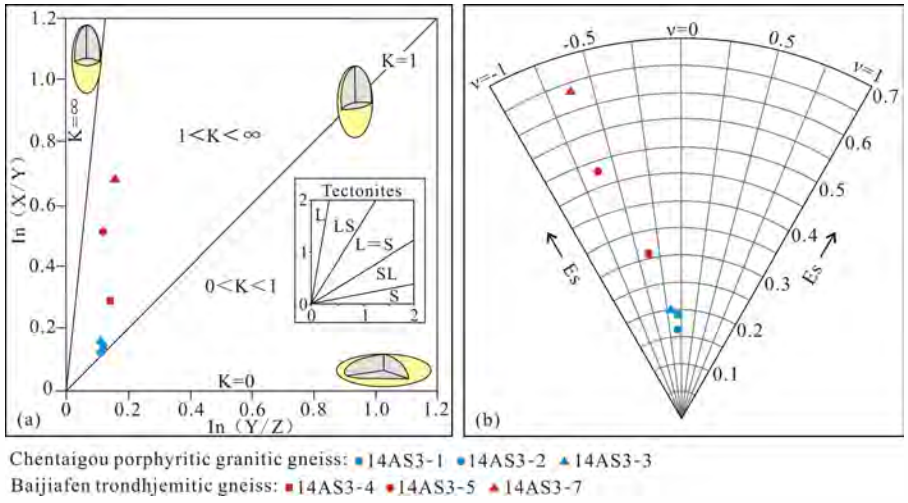
Finite strain measurement and kinematic velocity

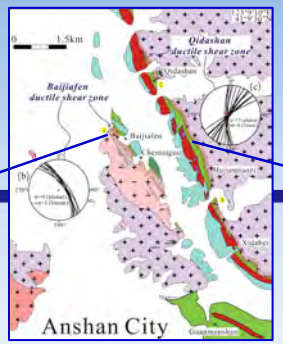
Measurement：Quartz grain

Parameter	Baijiafen ductile shear zone		Qidashan ductile shear zone	
	Chentaigou Gr.	Baijiafen Gr.	Mica-schist	Qidashan Gr.
Flinn（k）	1.15-1.45	2.17-4.32	2.94-5.62	1.26-1.62
Strain（Es）	0.16-0.20	0.31-0.64	0.53-0.66	0.15-0.48
Tectonite	L=S	LS	LS	L=S
Strain pattern	Plane-elongate	Elongate	Elongate	Plane-elongate
Kinematic velocity W_k	0.707-0.883	0.731-0.848	0.848-0.951	0.906-0.961



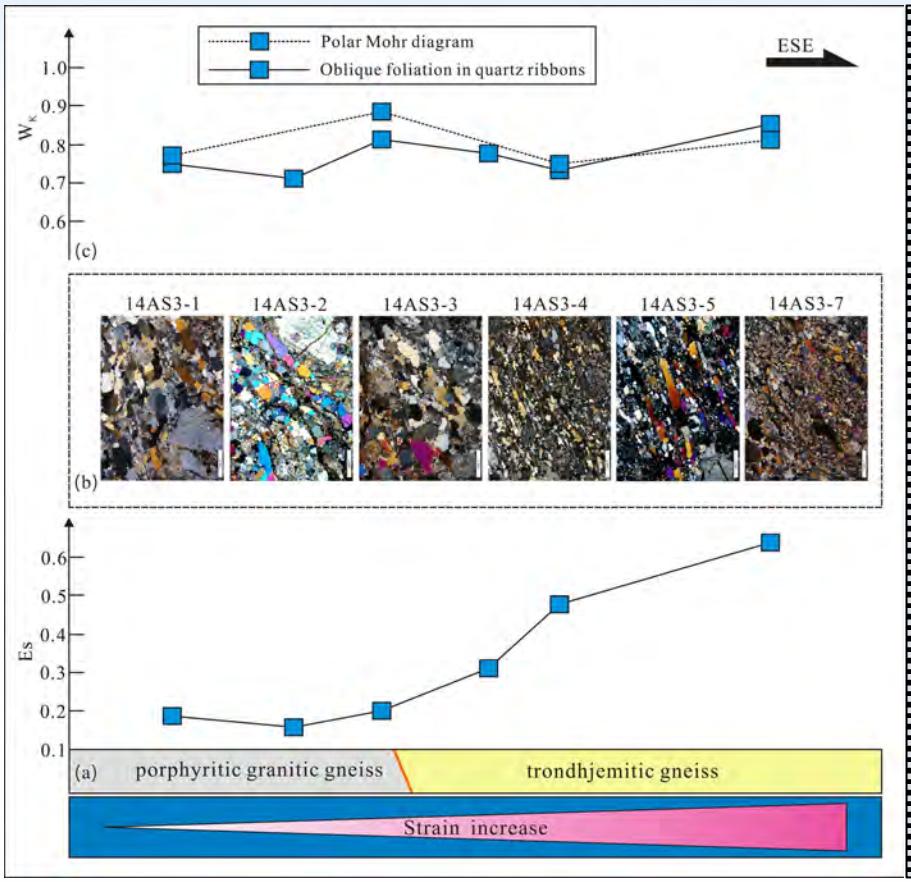
Logarithmic Flinn diagram（a） and Hossack diagram（b）

- $W_k > 0.75$
- Simple shear-dominated general shearing

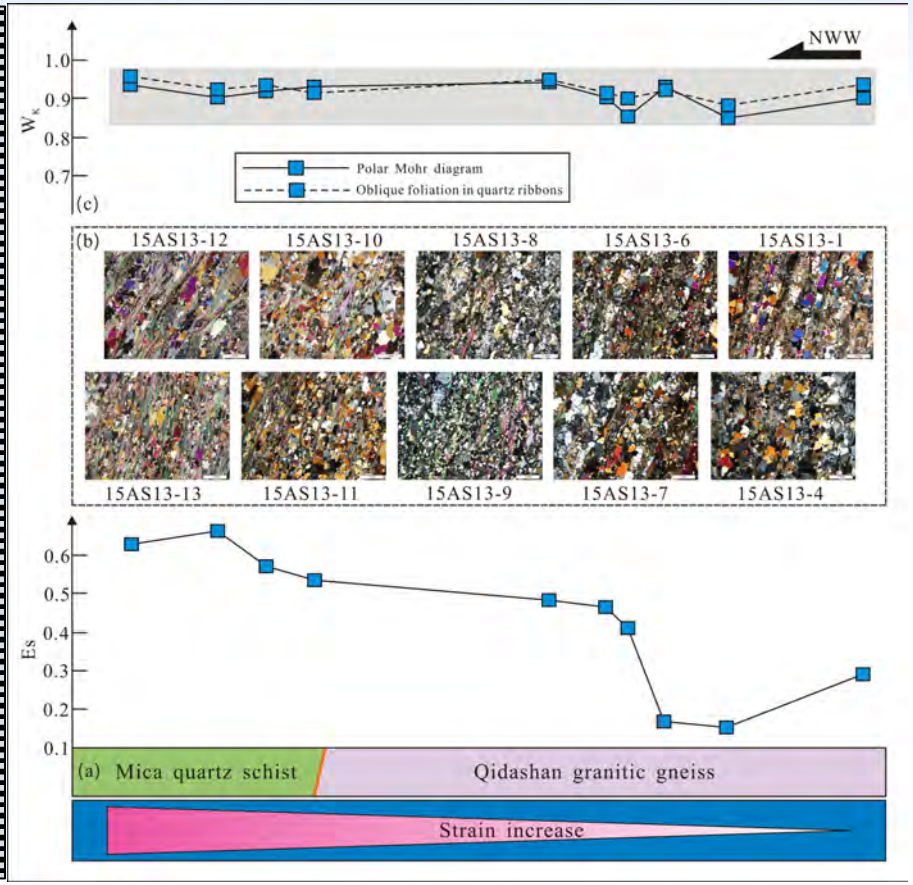


Baijiafen Shear Zone

Qidashan Shear Zone



BIF Belt



Closing to BIF: Strain intensity increasing, mineral grain size decreasing

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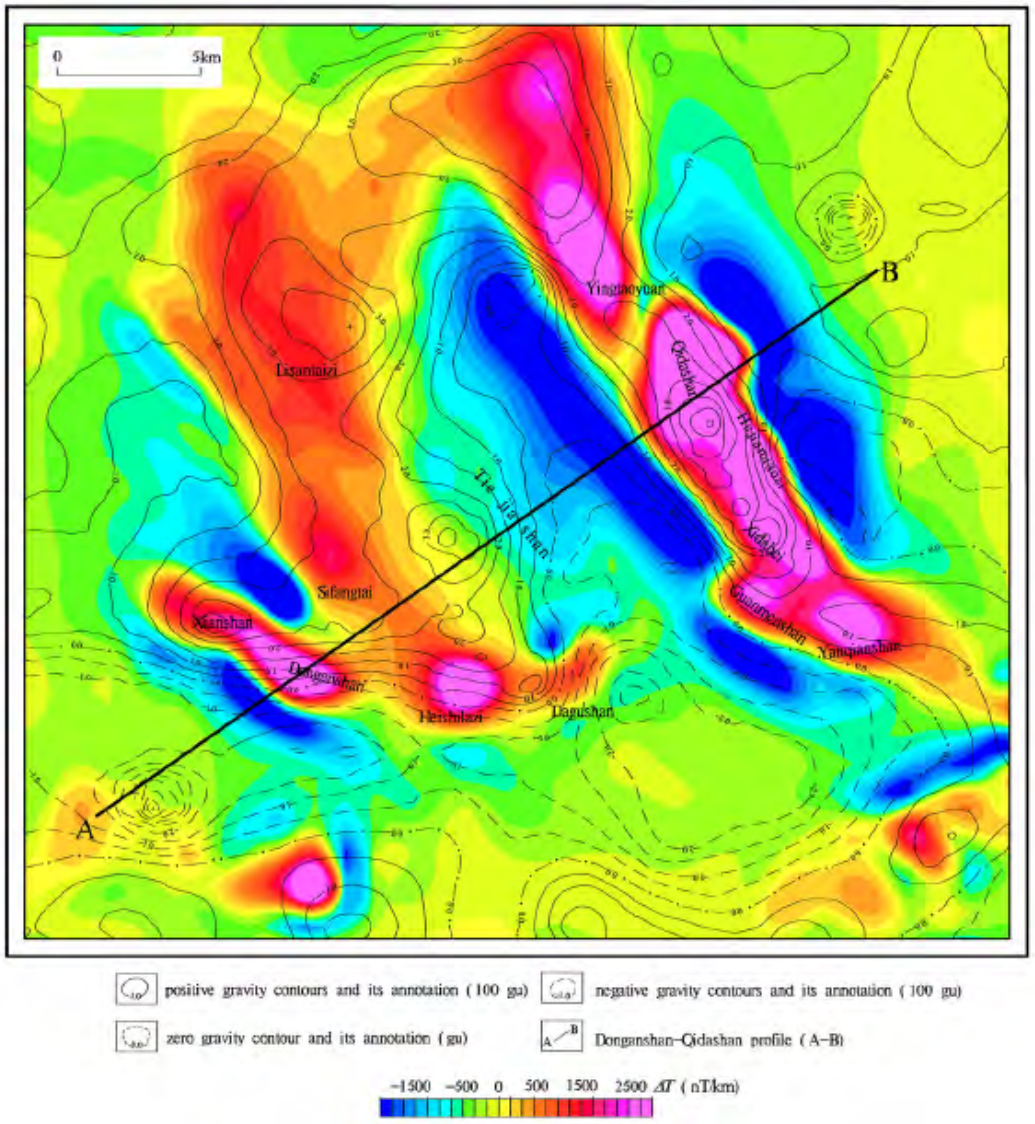
小结:

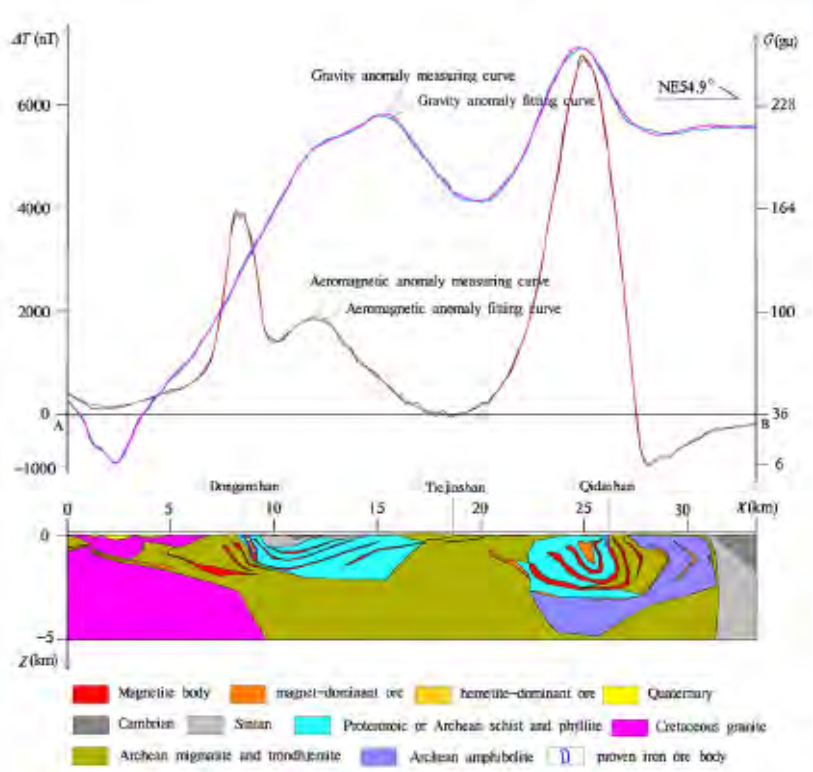
The two steep-slide ductile shear zones were formed by the subsidence of the BIF layer.

Shear zone	Baijiafen shear zone	Qidashan shear zone
Location	West of the BIF belt	East of the BIF belt
Lithology	Granitic and trondhjemitic gneisses	Granitic gneiss, mica-schist, quartz schist
Macro-Str.	Band, steep foliation and lineation	Band, steep foliation and lineation
Micro-Str.	Quartz: BLG+SGR	Quartz: BLG+SGR
Strian	Plane-elongate	Plane-elongate
Shear	General shearing	General shearing
T	400~500℃	400~500℃
Shear sense	ENE directed steep-slide	WNW directed steep-slide
Strain intensity	Stronger deformation with increasing muscovite closing to the BIF belt	

Geophysical data interpretation



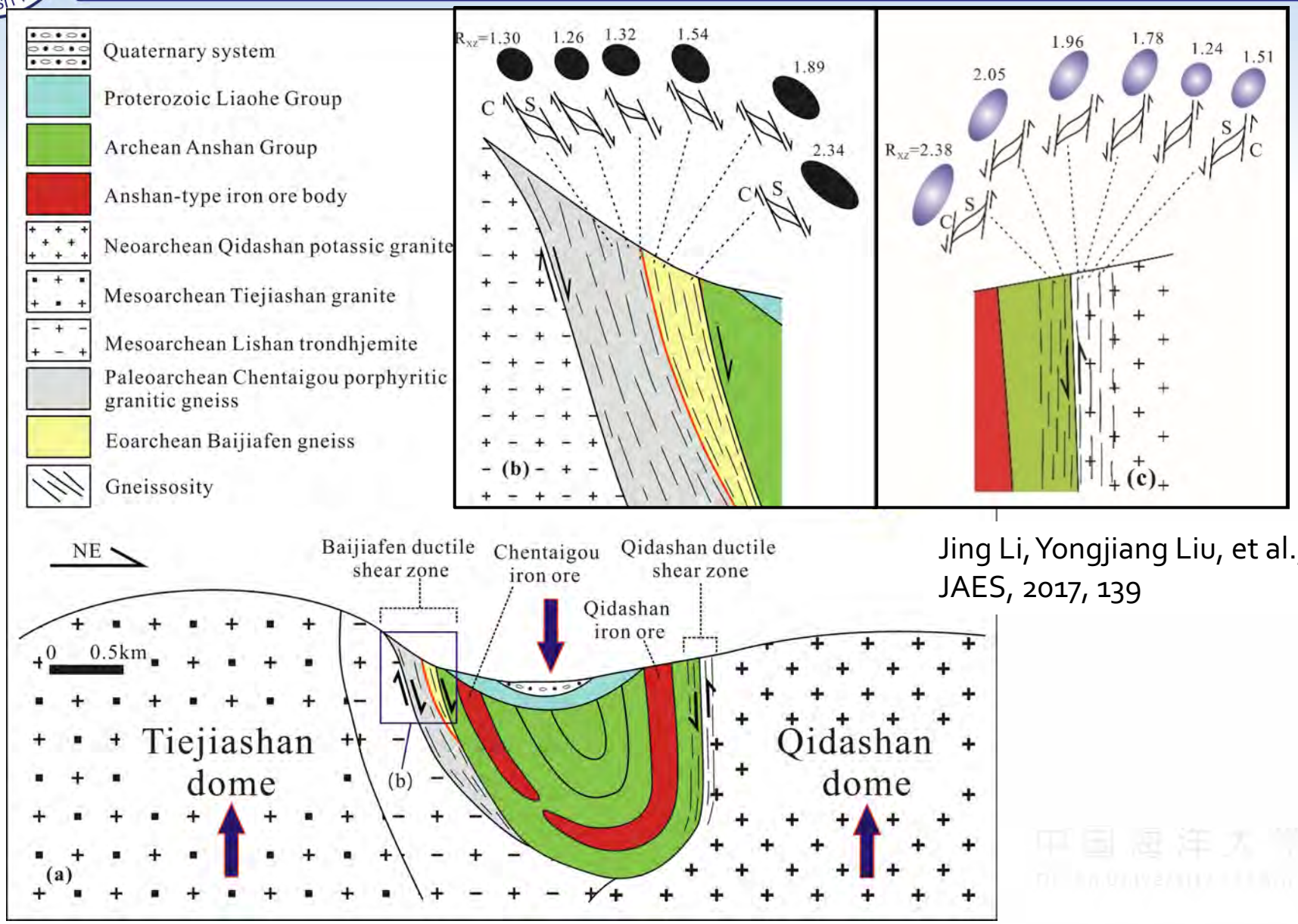
Gravity abnormally of Anshan area



Geological interpretation（A-B）

(Fan et al., 2014)

Steep-slide ductile shearing



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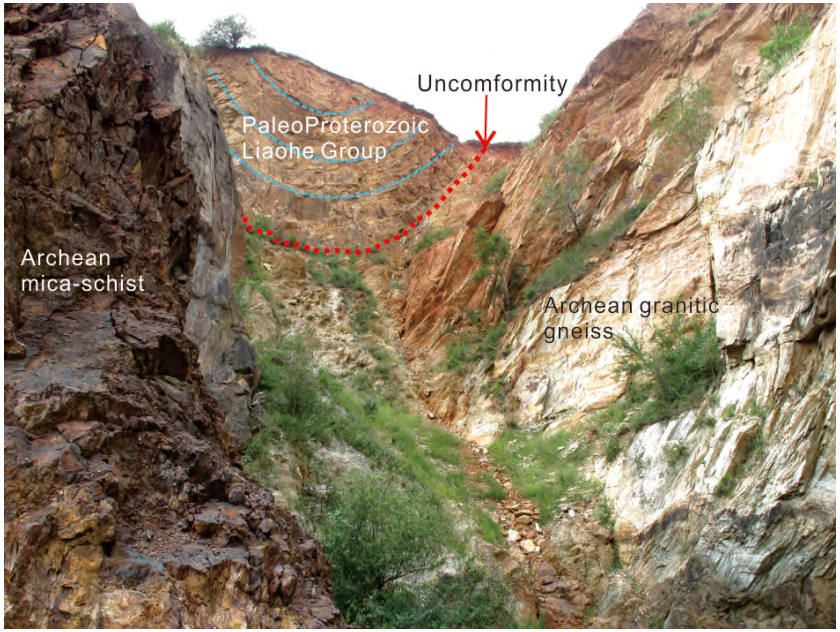
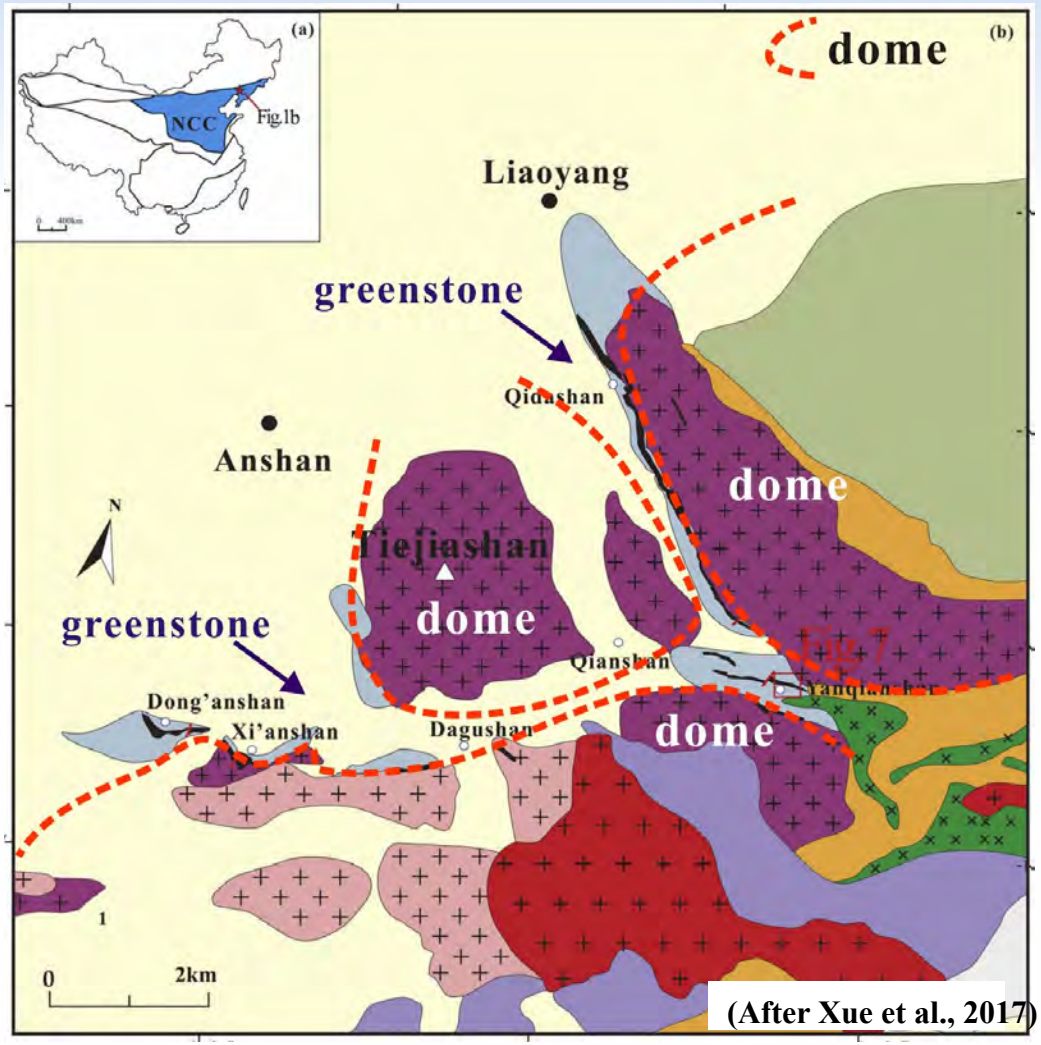
Dome and keel structure, timing

The time of the structures is constrained by an unconformity between Archean basement and Paleo-Proterozoic cover (~2.5Ga).



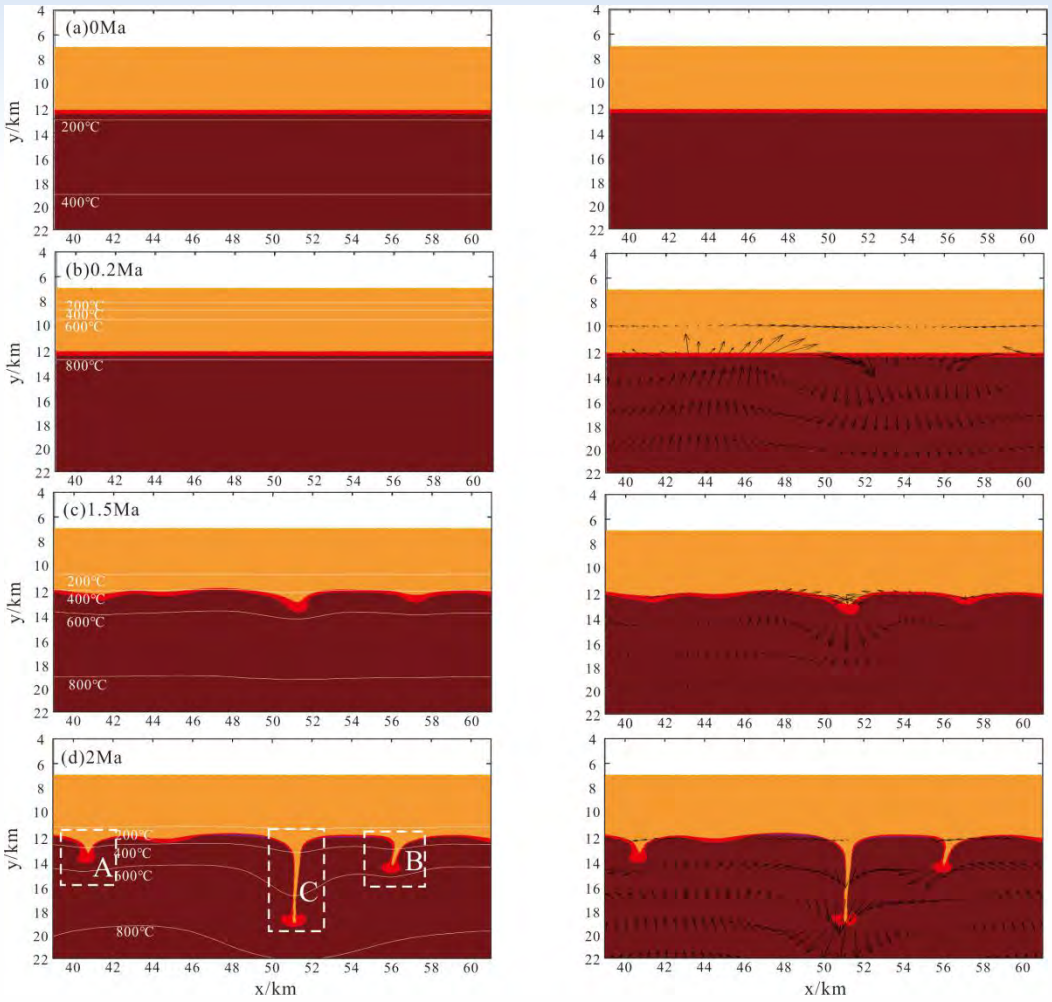


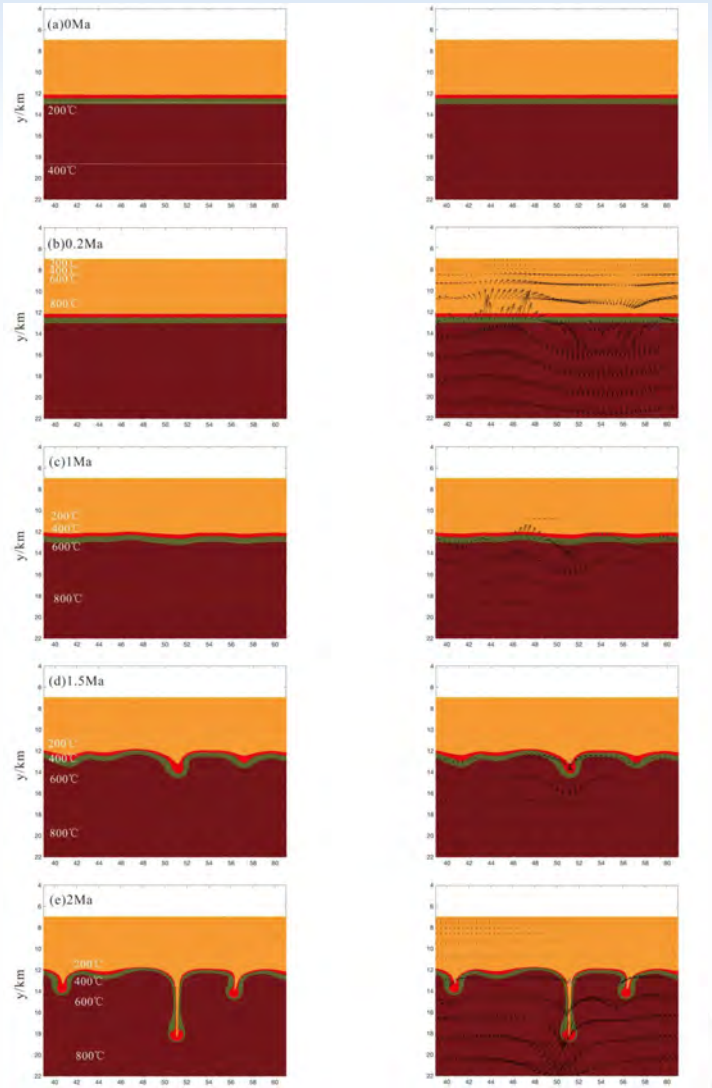
(After Xue et al., 2017)

Digital modelling for the sagduction

BIF / TTG directly contact

BIF / greenschist / TTG contact





Key parameters: density difference and T

Xinyue Liu, YJ Liu, et al., Acta Petrologica Sinica, 2019,35(4)

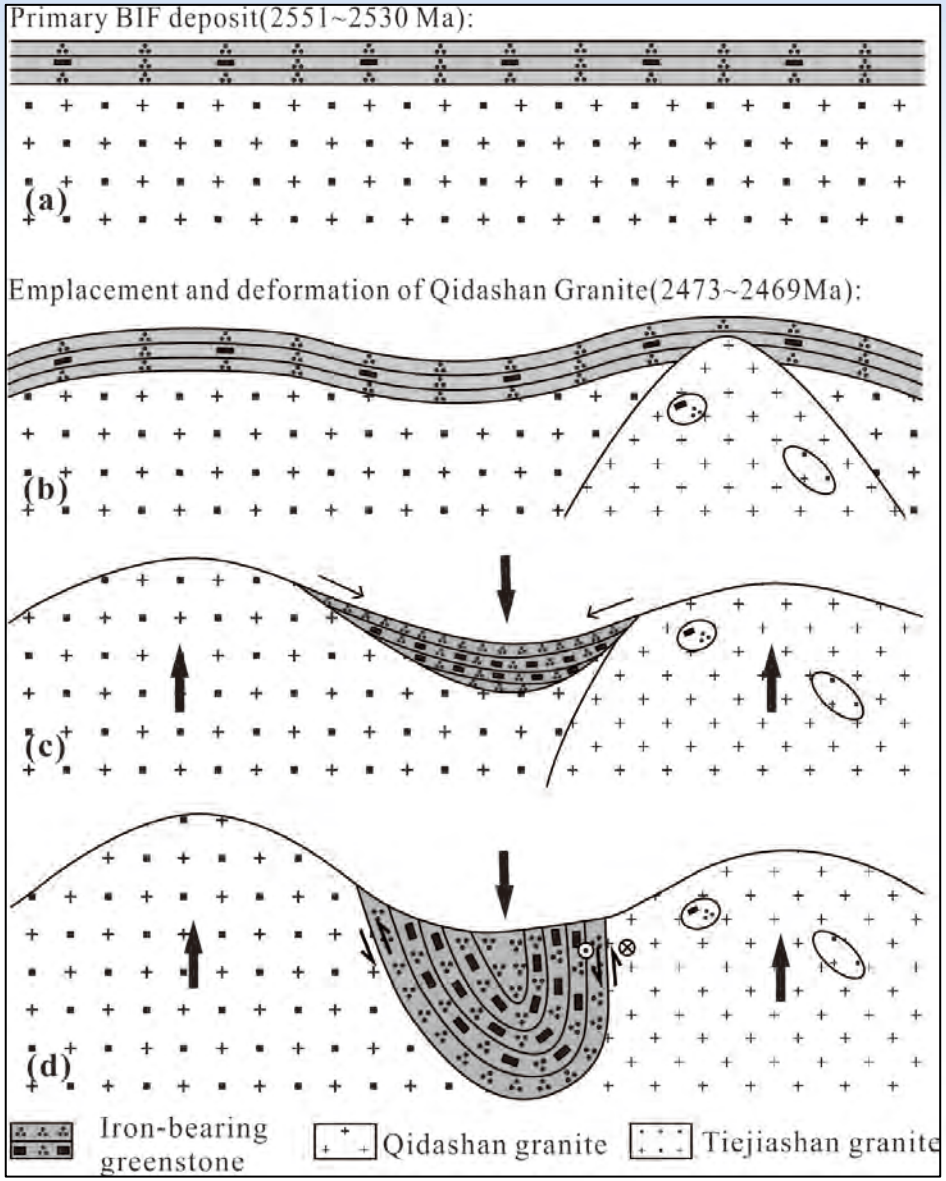
Tectonic model- Gravitational overturn (Sagduction)

High density difference

BIF F.

Granite

Sagduction of BIF F.



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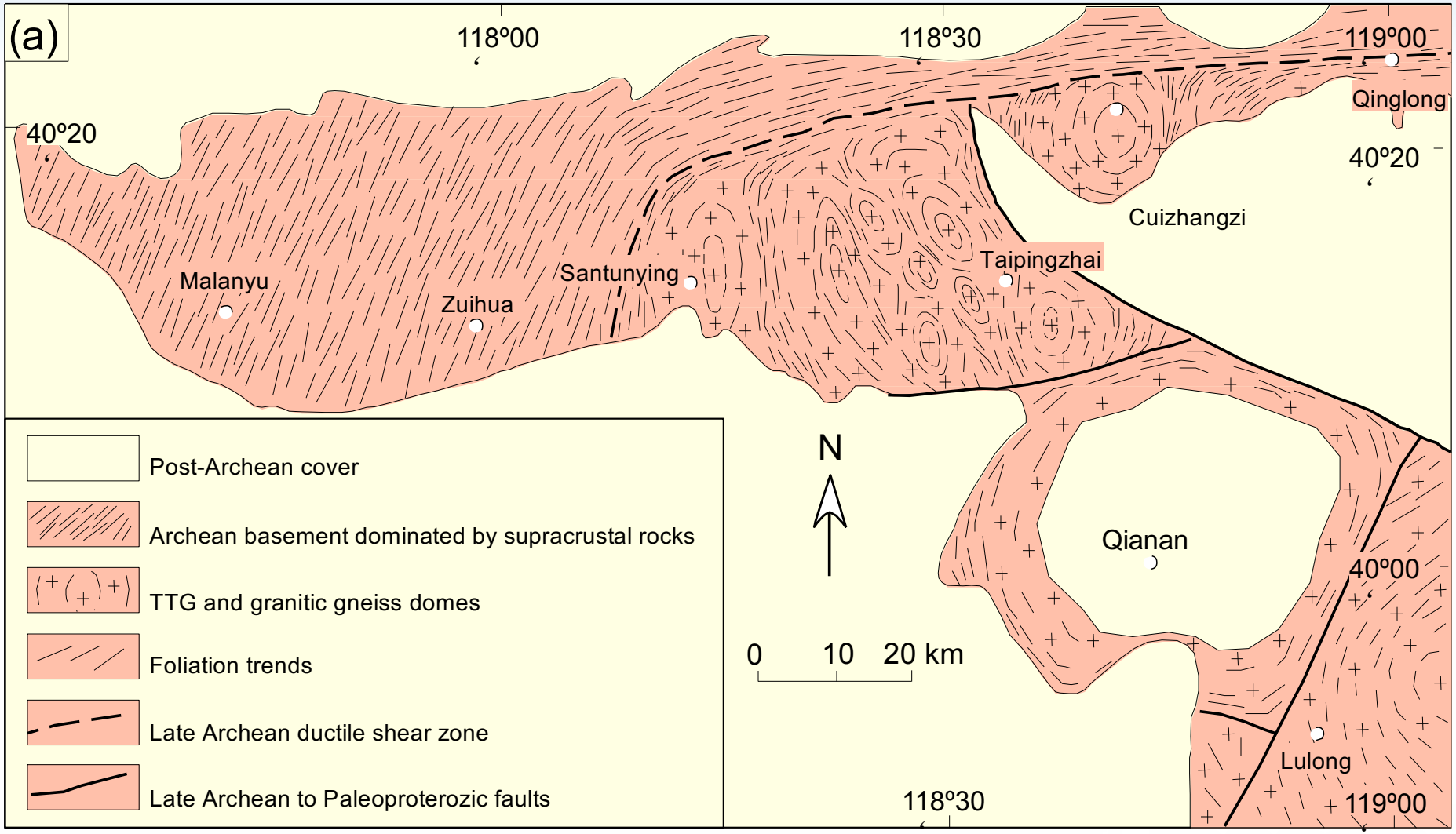
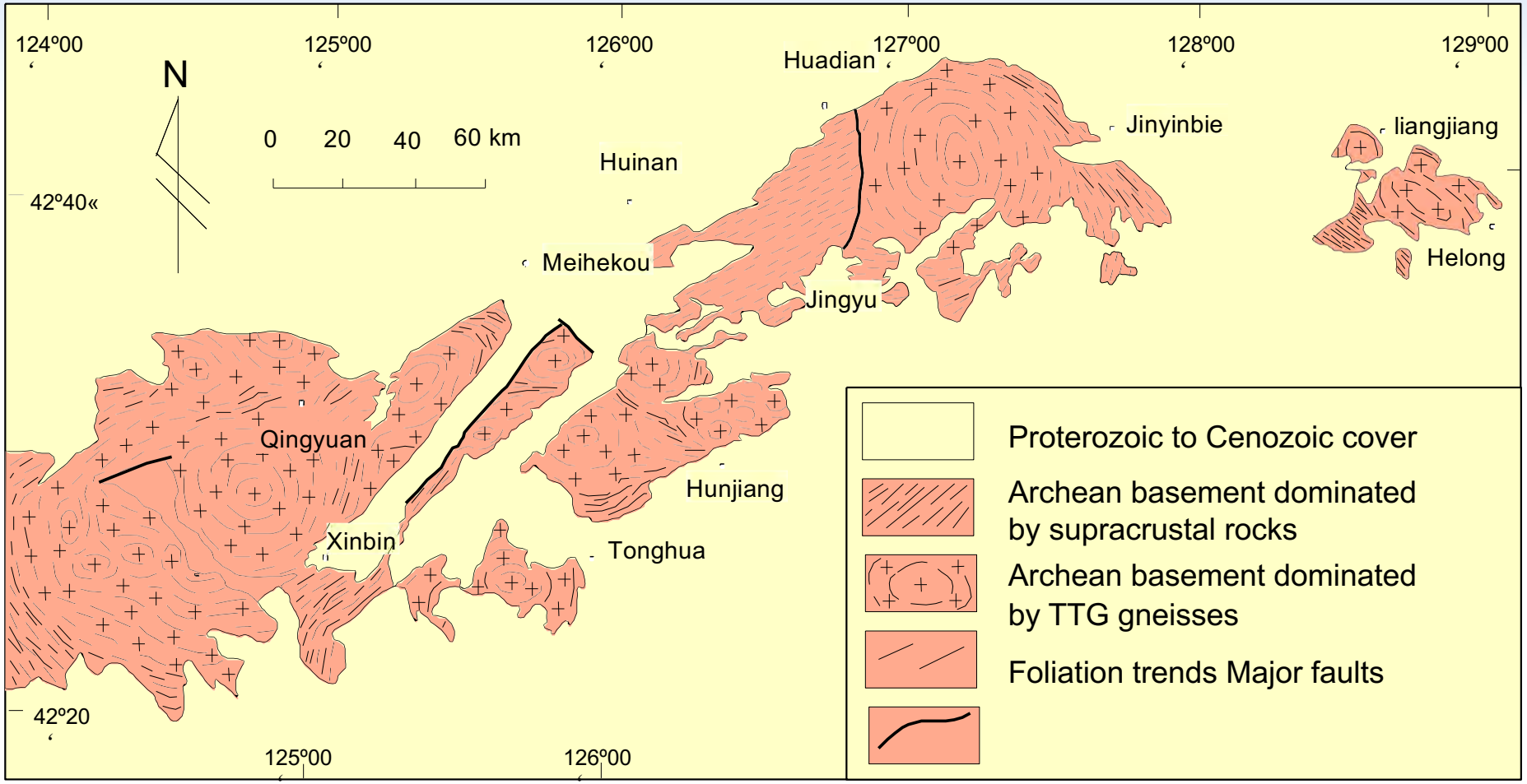
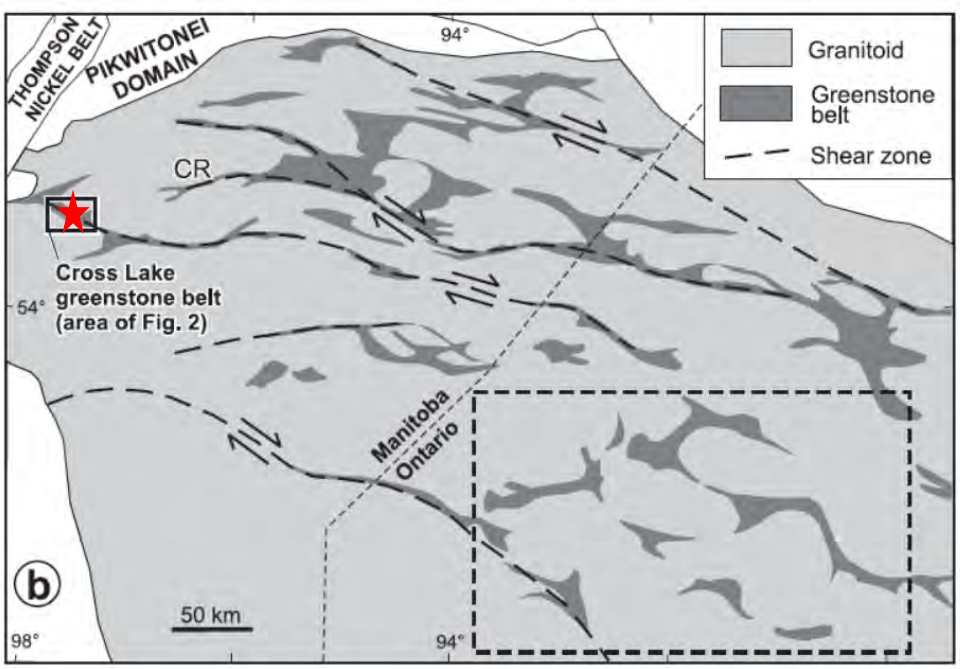
Domes in Eastern Hebei
(After He et al., 1991)



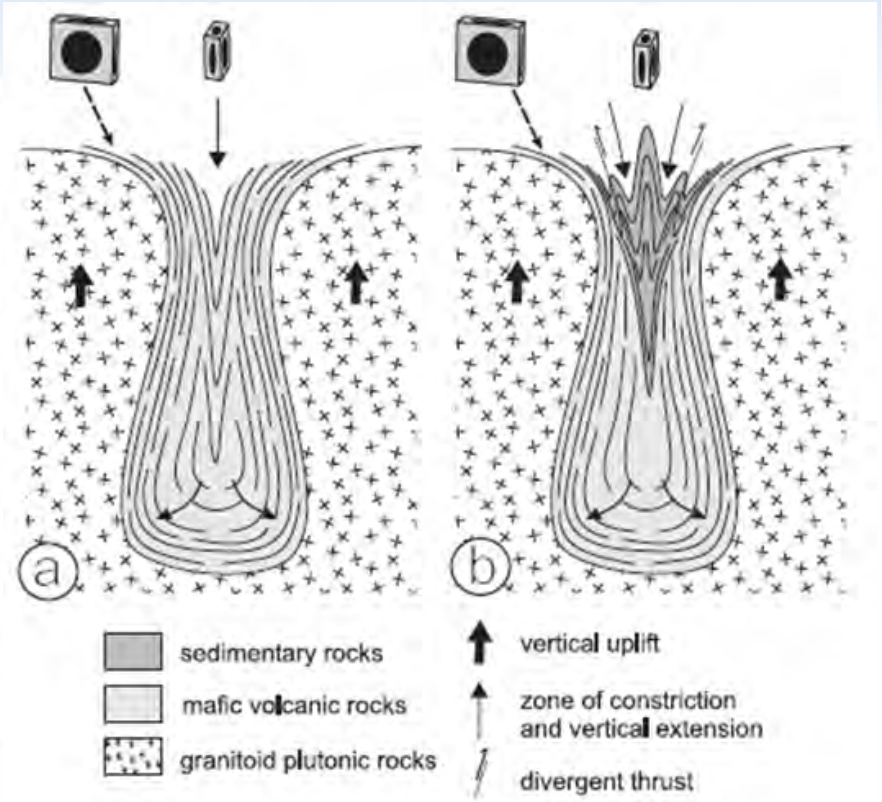
Domes in Northern Liaoning and Southern Jilin (After Suu et al., 1993)



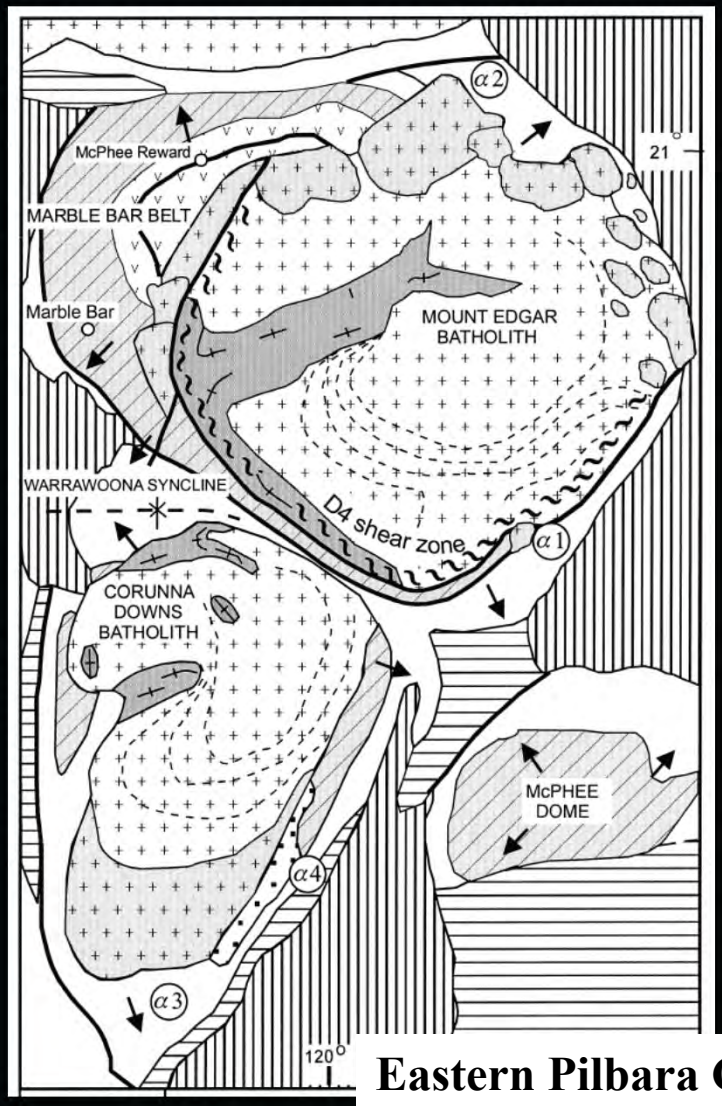
Cross Lake greenstone belt (Superior Craton)

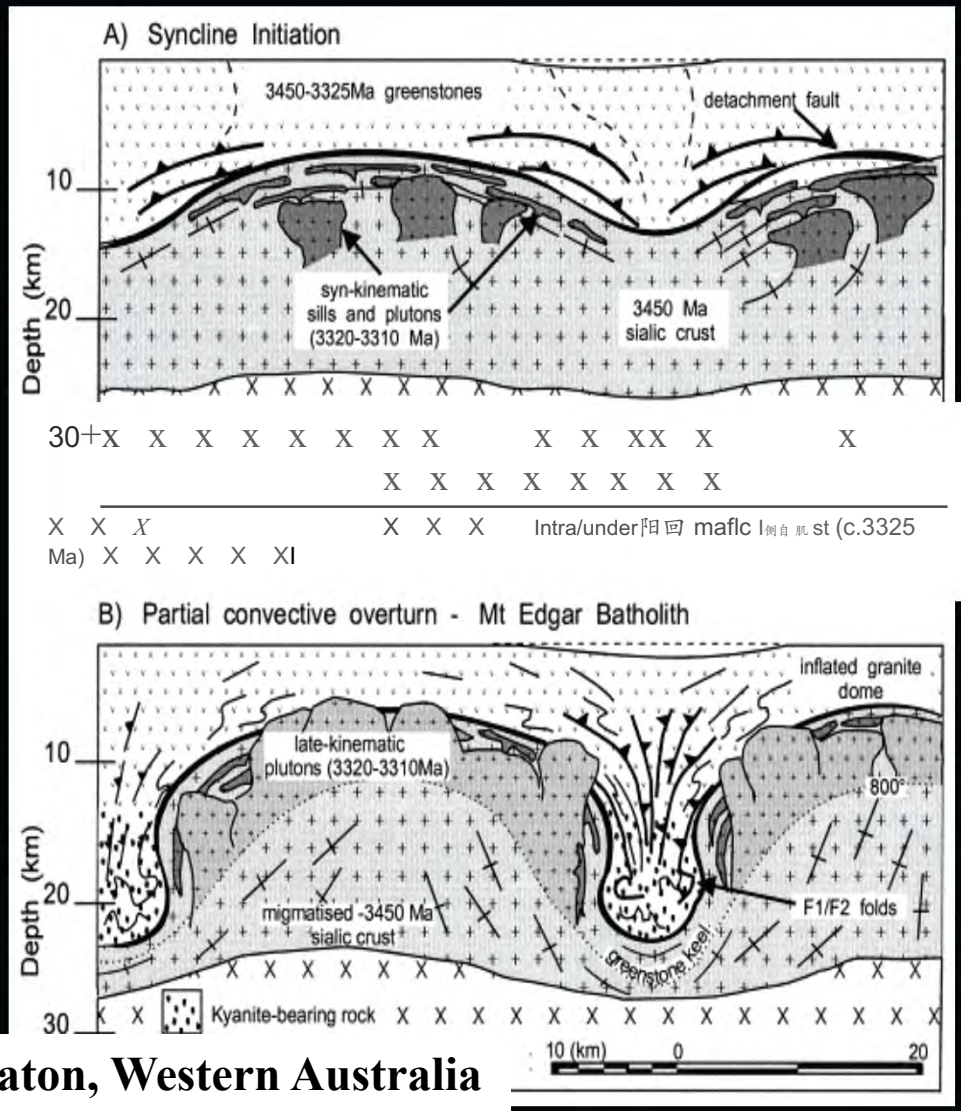


(From Parmenter et al., 2006)

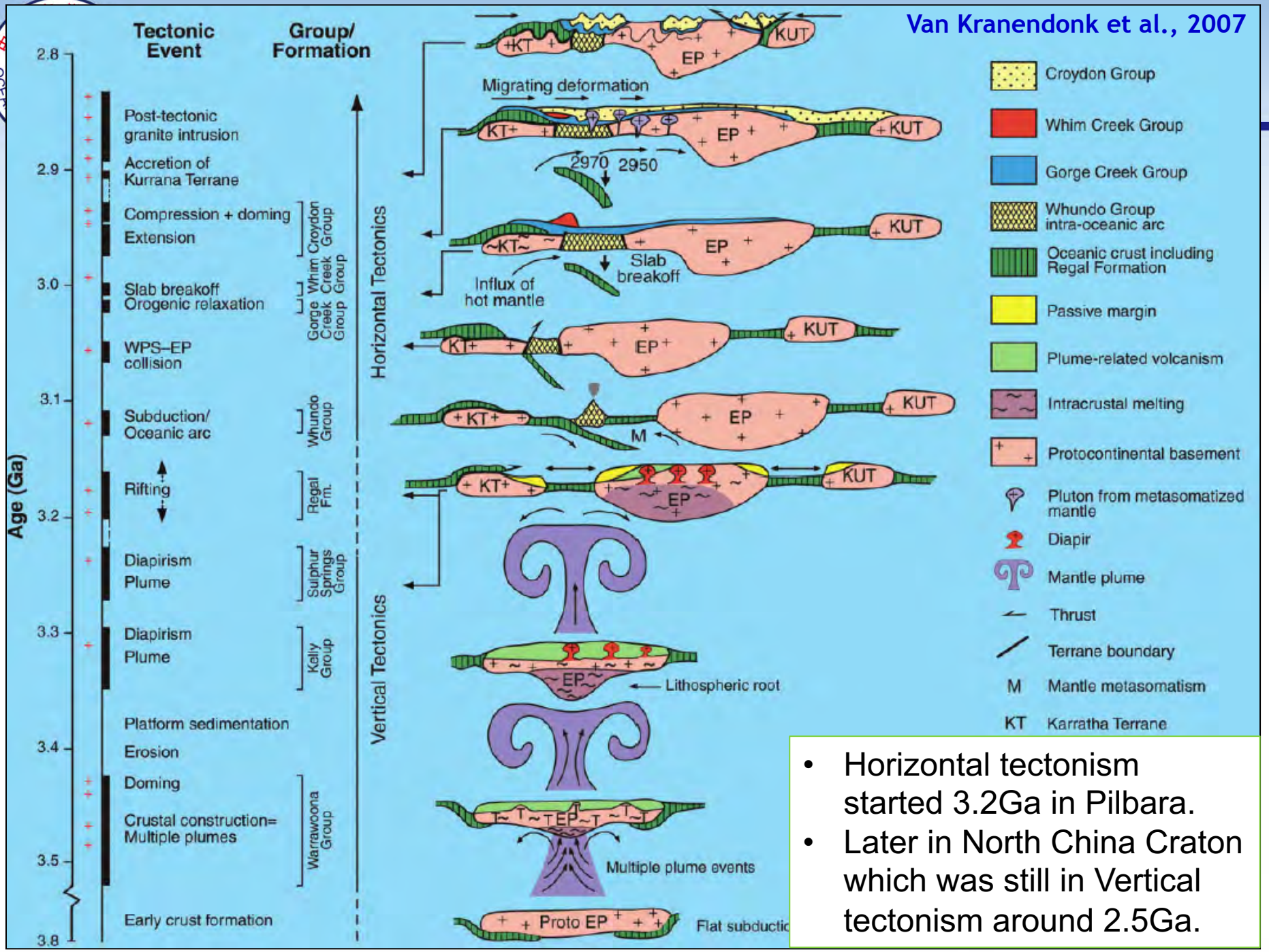


Diapirism involving gravitational overturn of dense greenstone crust (Collins & van Kranendonk, 1999)





Eastern Pilbara Craton, Western Australia



- Horizontal tectonism started 3.2Ga in Pilbara.
- Later in North China Craton which was still in Vertical tectonism around 2.5Ga.

Thanks for your attention

The beautiful night in Qingdao, China