Precambrian eclogite and its implication for plate tectonics

Докембрийский эклогит и его геодинамическое значение

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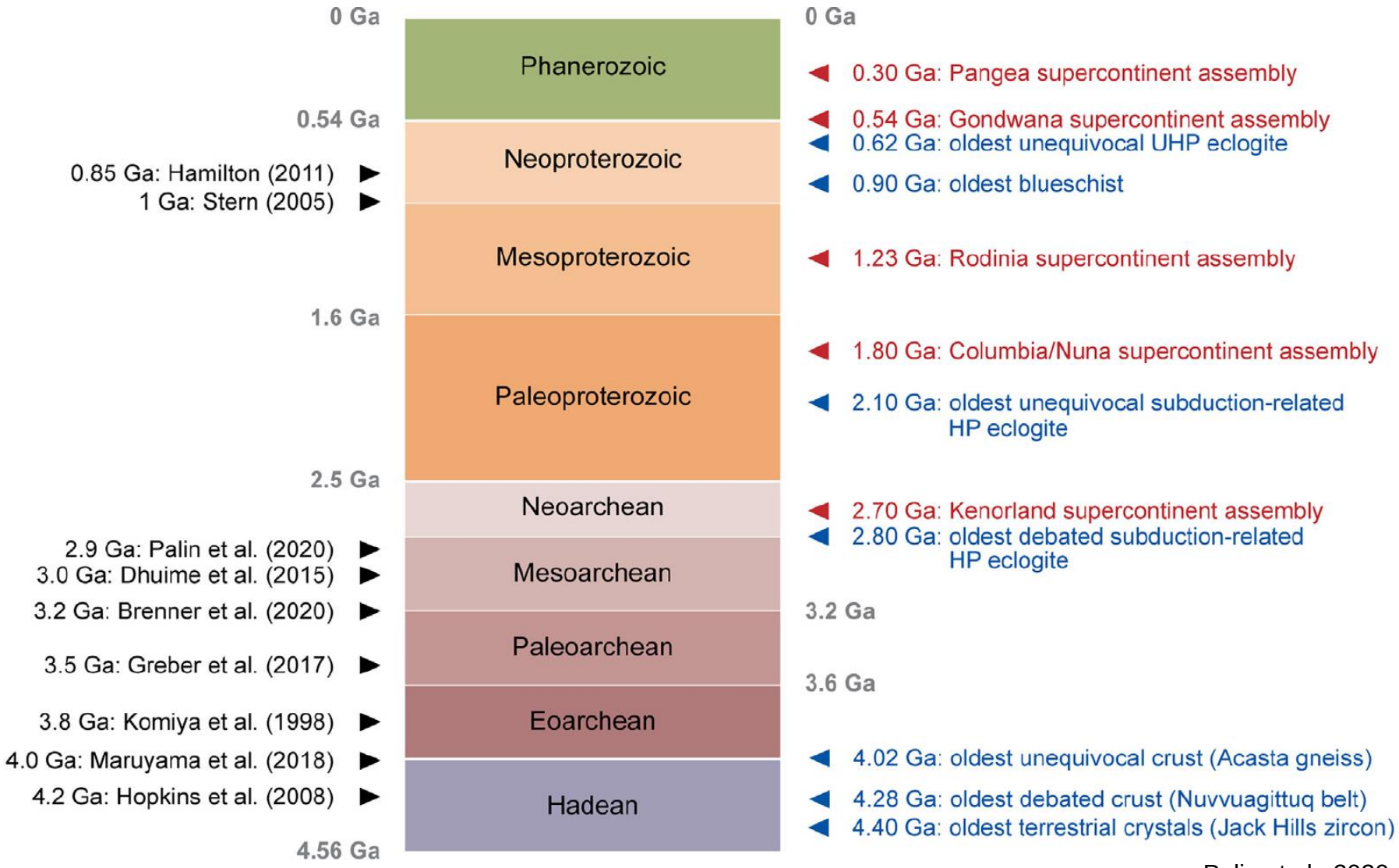
Geological Background

Геологическое Положение

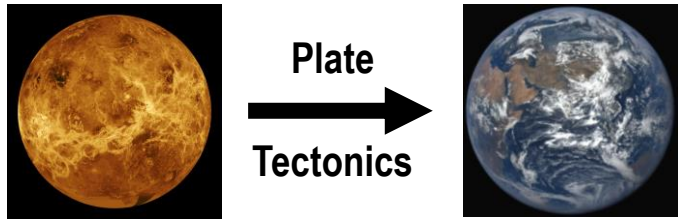
When Plate Tectonics started



Palin et al., 2020

Evidences:

- ✓ Tectonic (structural)
- ✓ Geochemical (isotopic)
- ✓ Geophysical
- ✓ Numerical modeling
- ✓ ……
- ✓ Petrological (metamorphic)



What is Plate Tectonics

- Divergent Plate
- Convergent Plate
- Transform Fault

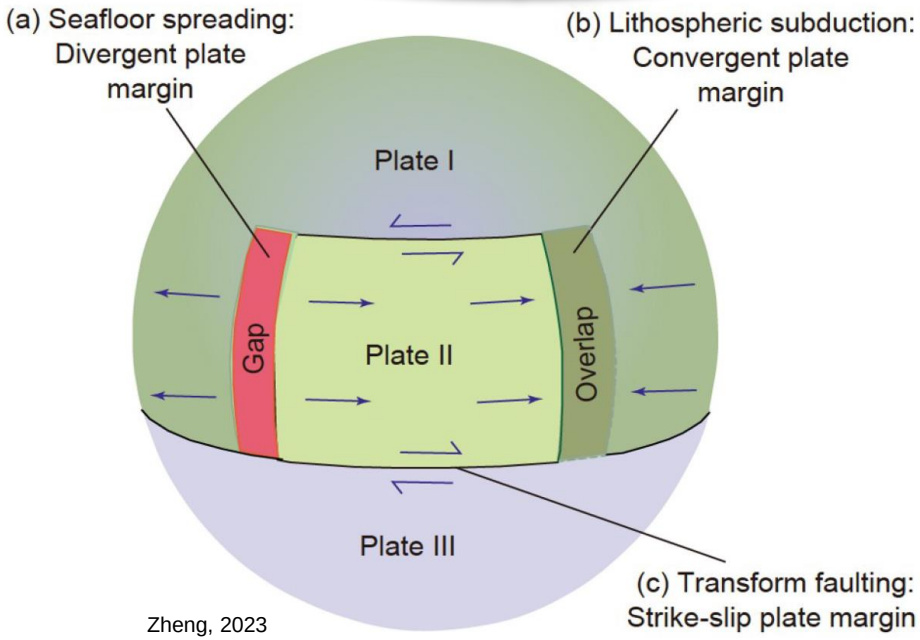
Subduction / Collision

(ultra-)high-pressure metamorphism

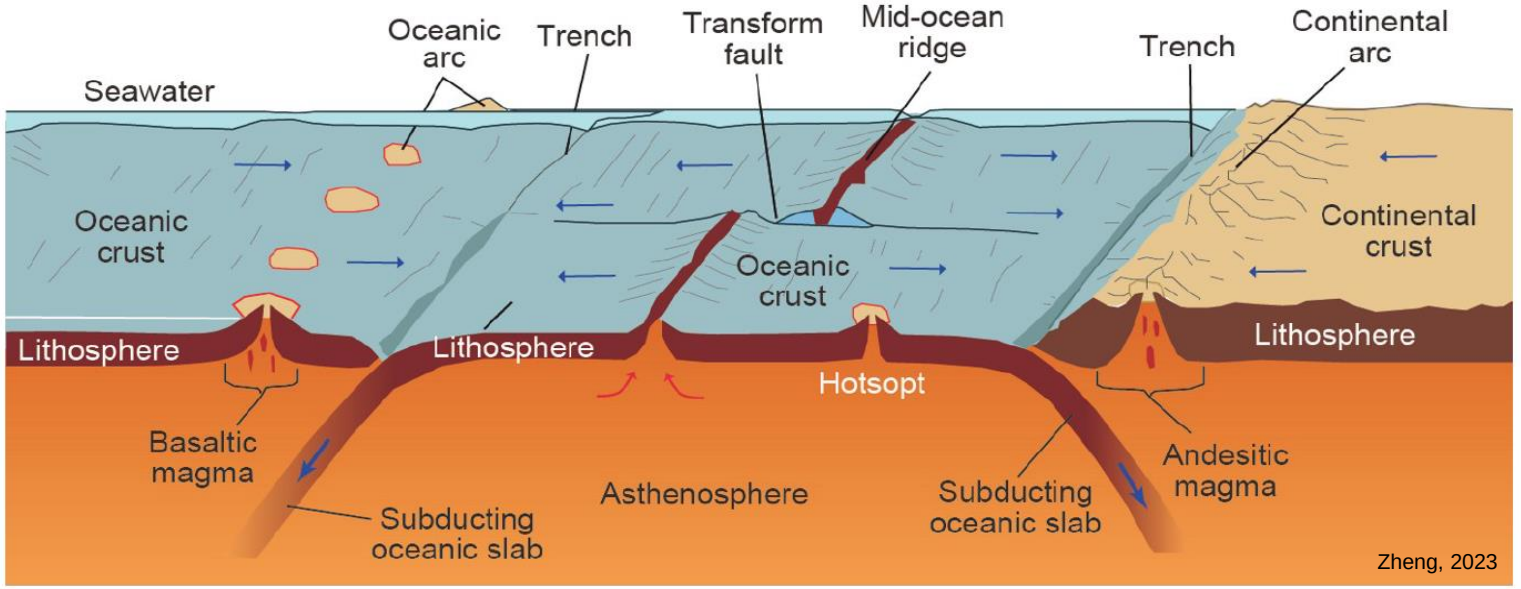
Eclogite & Blueschist (facies)

robust evidence of plate subduction-collision

P-T → depth

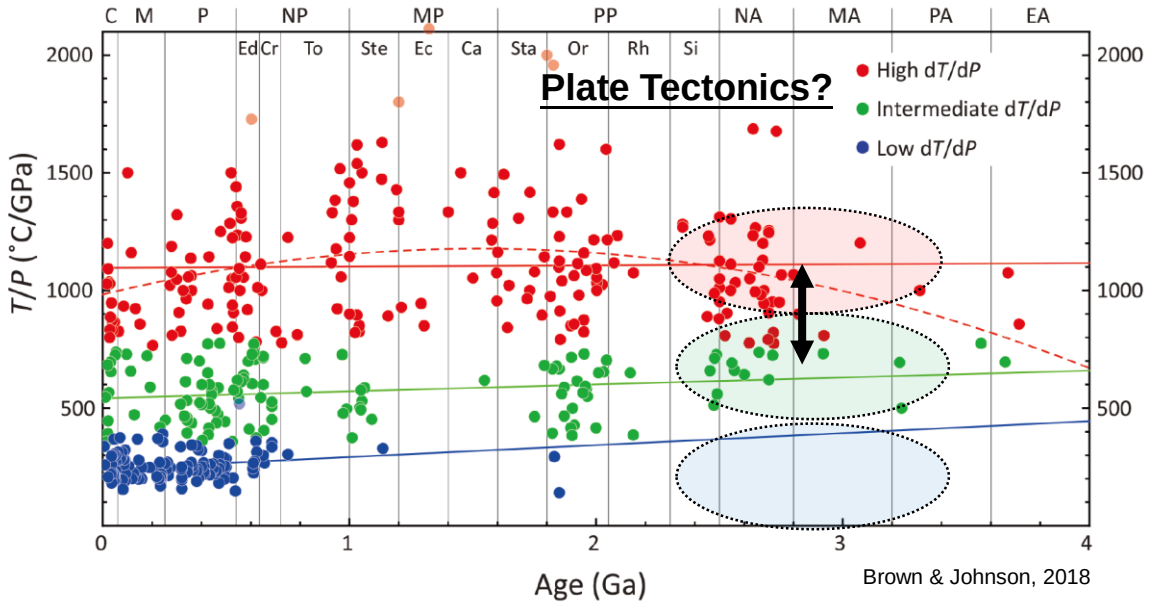


Zheng, 2023

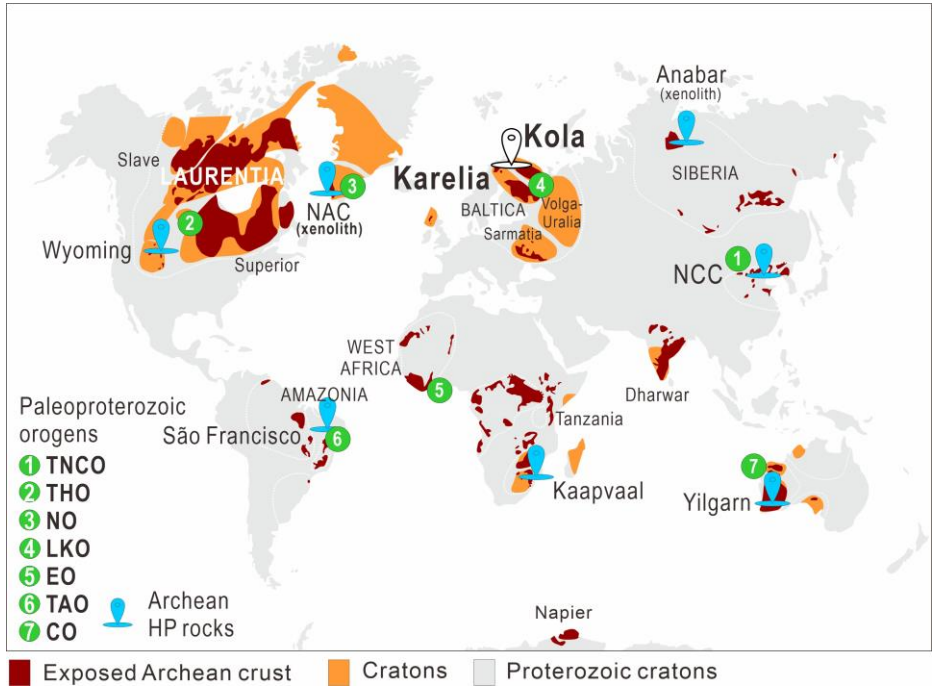


Zheng, 2023

Metamorphic T/P of worldwide localities



Brown & Johnson, 2018



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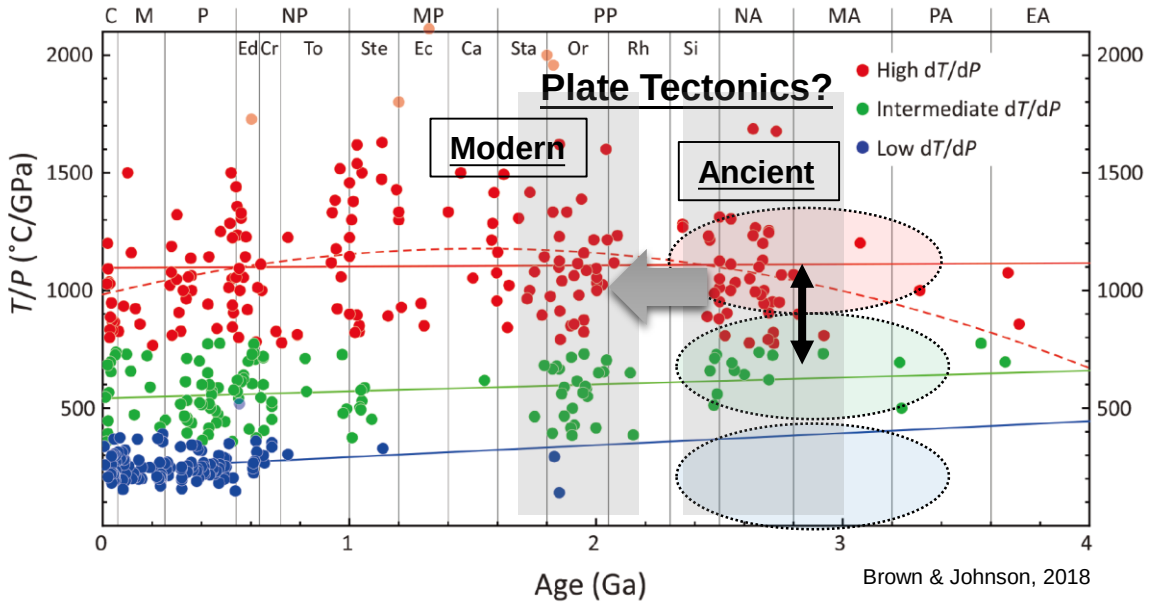


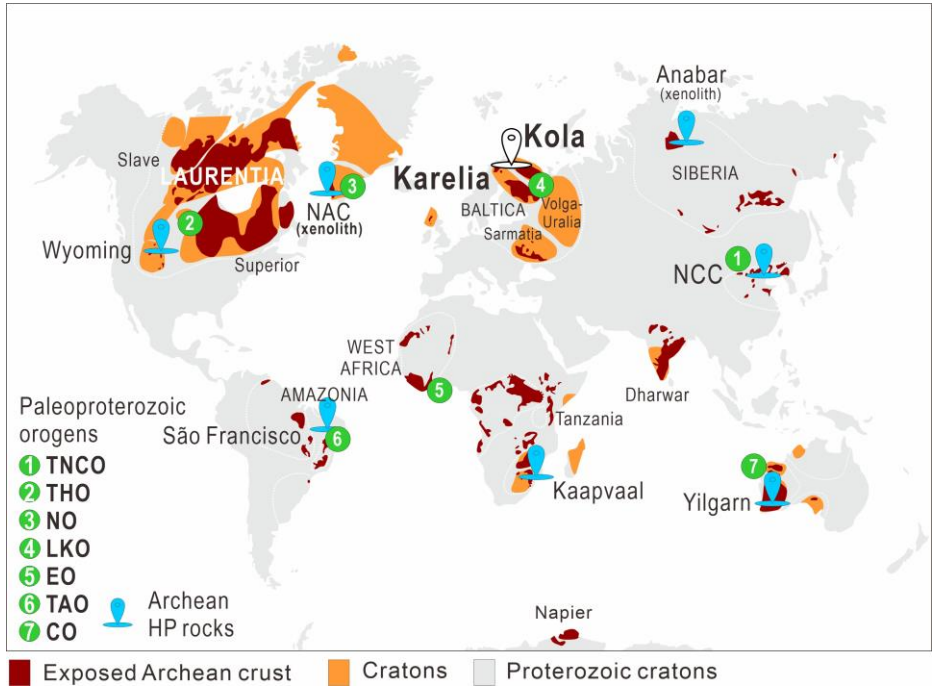
Brown & Johnson, 2018

Rare HP rocks > 2.5 Ga (no cold lithology)

- 2.7 Ga, 3.2 Ga Amphibolite (Barberton, Yilgarn)
- 2.7 Ga HP granulite (Wyoming, Sao Francisco)
- 2.5 Ga pyroxenite (NCC)
- **2.82 Ga Eclogite ? (Belomorian)**

Rare eclogite > 2.0 Ga (cold lithology)

- 2.0 Ga blueschist ? (W.Africa)
- 2.0 Ga eclogite (W.Africa)
- **1.9 Ga eclogite (Belomorian)**
- 1.9 Ga xenolith eclogite (NCC)
- 1.8 Ga UHP metabasite (W.Greenland)
- 1.8 Ga apoelcoigte (N.America)



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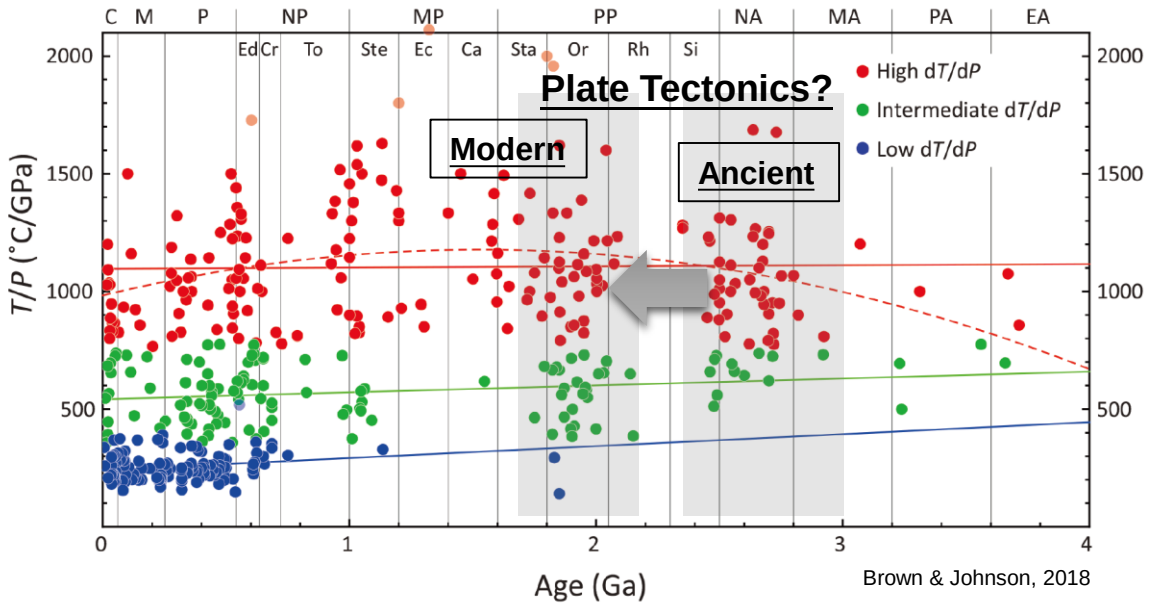

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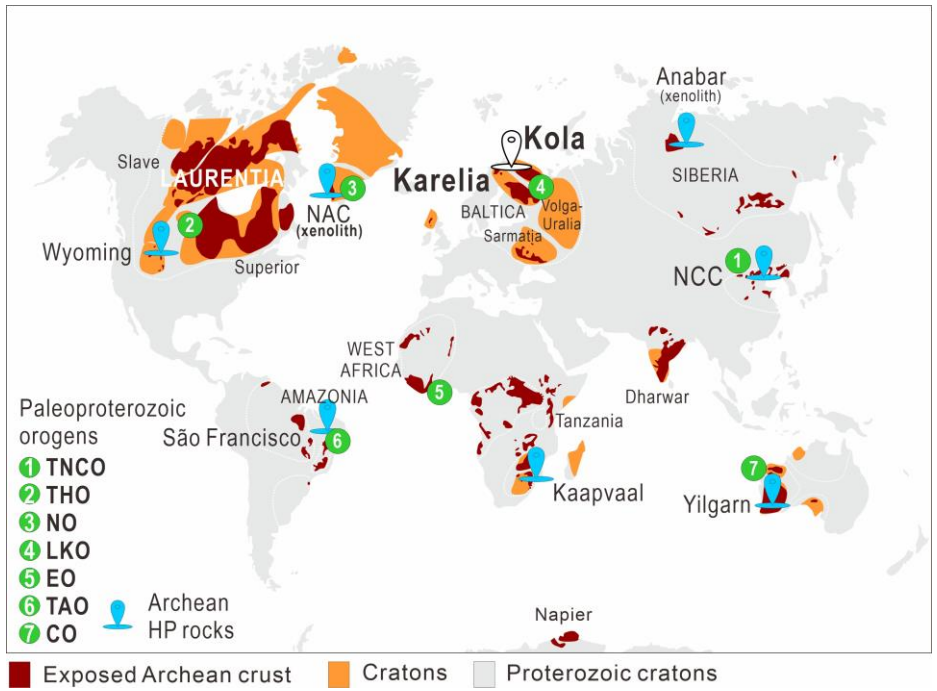
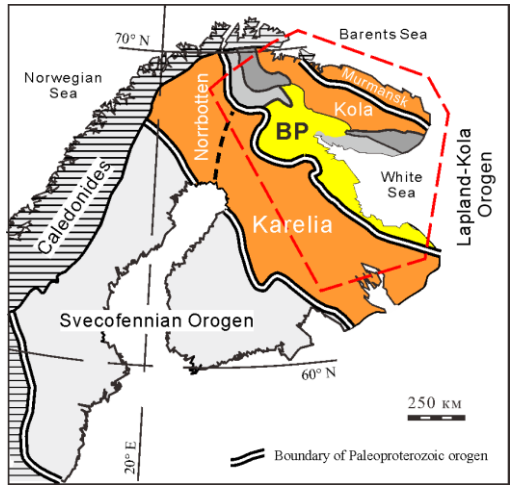
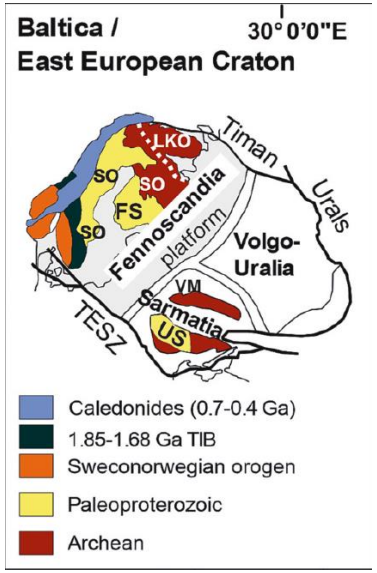


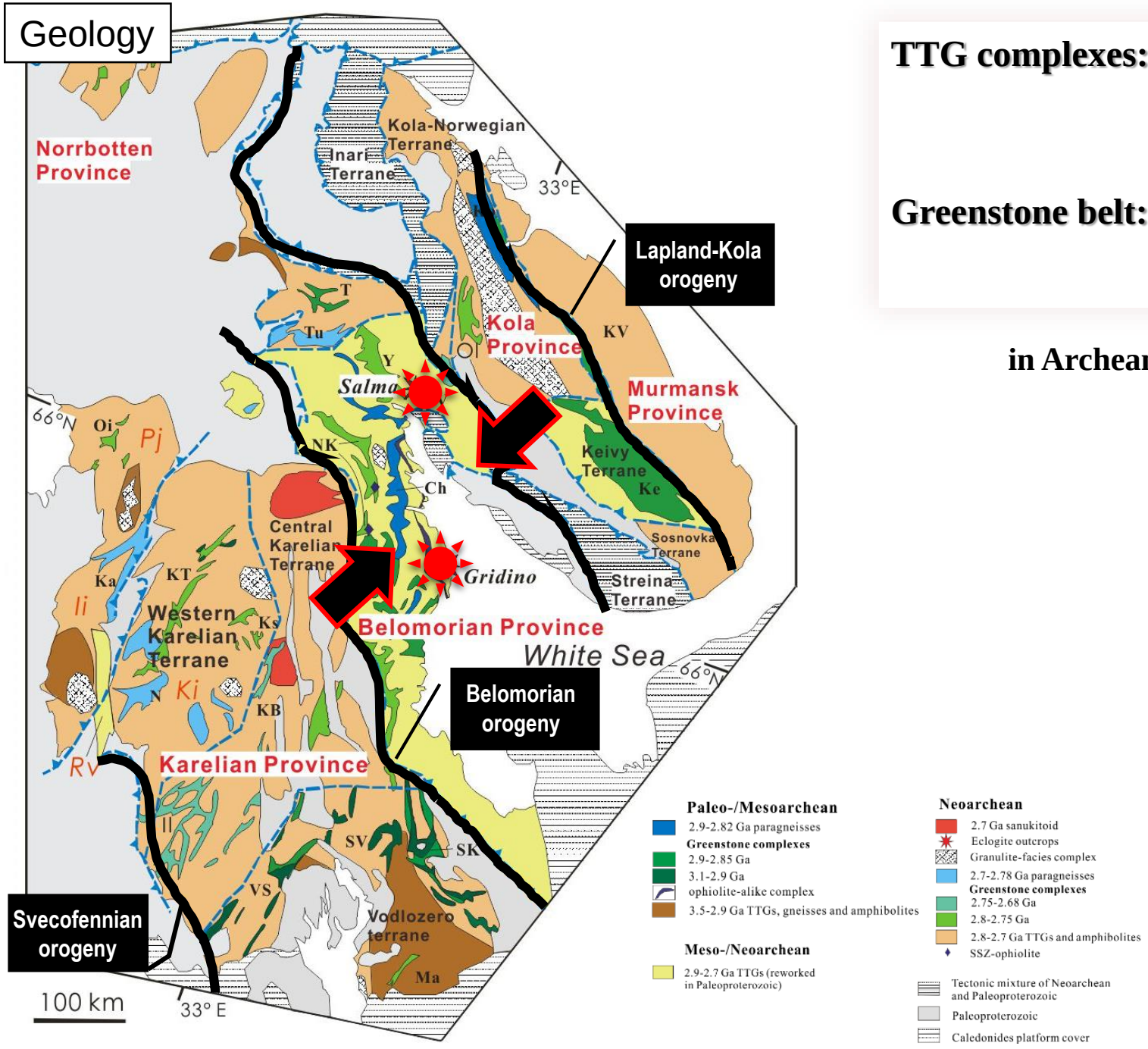
Archean vs. Paleoproterozoic Eclogite/Subduction

Belomorian Province (**BP**) b/w Kola and Karelian cratons





Geology



TTG complexes: Paragneisses + Granitoids (sanukitoids etc.)

3.5-2.9 Ga // 2.9-2.7 Ga, 2.8-2.7 Ga // 2.7 Ga // 1.8 Ga

Greenstone belt: Amphibolite + Ophiolite-alike (?) + Eclogite

3.1-2.9 Ga, 2.9-2.85 Ga, 2.8-2.75 Ga, 2.75-2.68 Ga

in Archean: High-grade Metamorphism + Migmatization

(> 9-12 kbar, > 650-950 °C)

- **Eclogite *sensu stricto***

  omphacite + garnet ± amphibole, epidote, kyanite

- **Eclogizited dyke**

  metagabbro-gabbronorite, Ol-gabbronorite, pyroxenite (Opx), zoisitite, enderbite, etc.

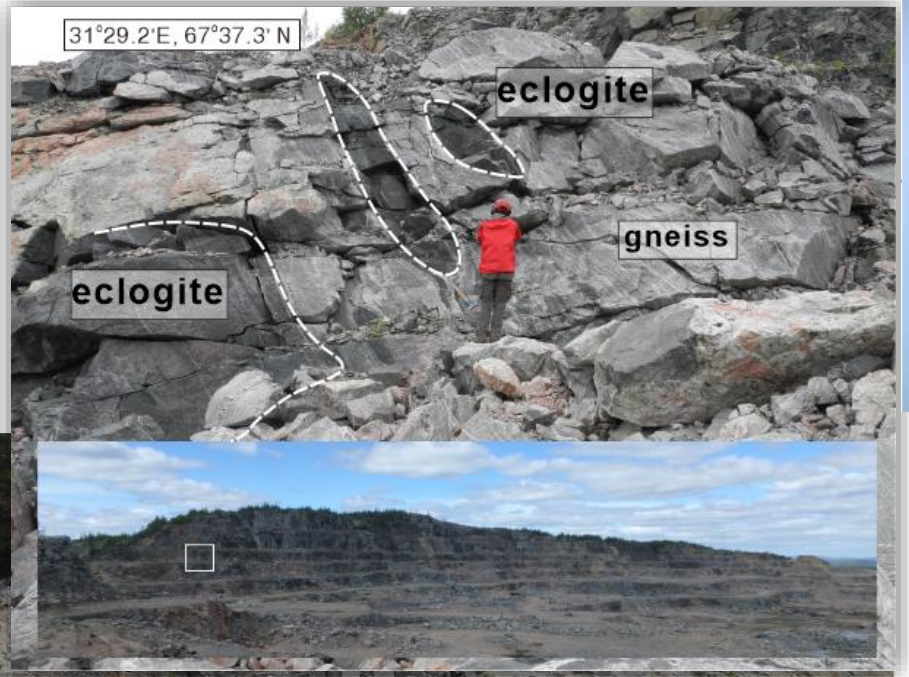
Chupa-Gridino

coarse-grain eclogite

Kuru-Vaara

Salma-type

Uzkaya/Shirokaya



fine-grain eclogite

Retrogressed eclogite (amphibolite)

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Scientific Problems

Научные Проблемы

Metamorphic peak PT conditions

1

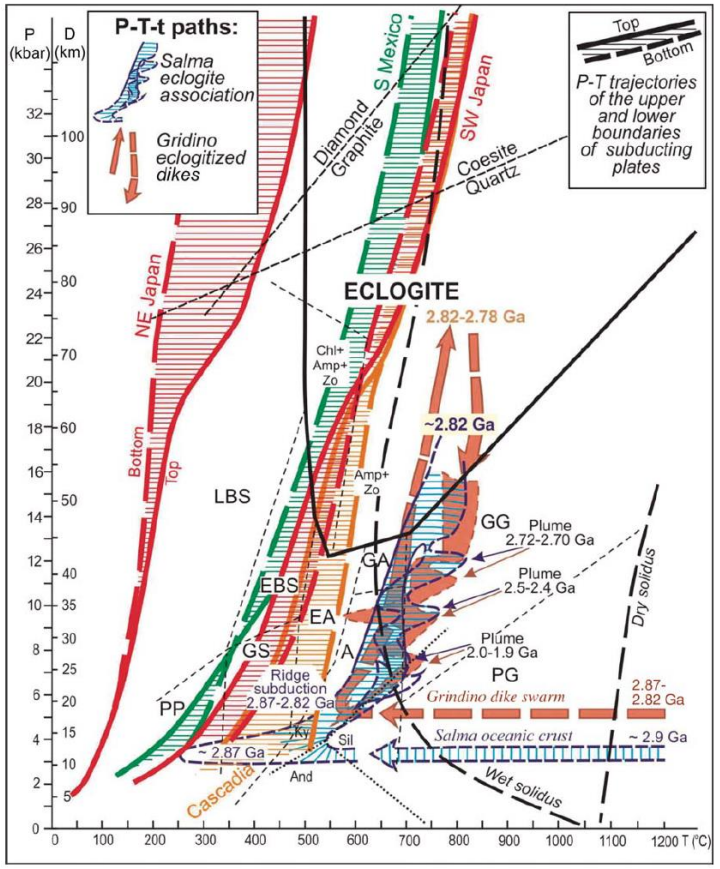
Prograde → Peak → Retrogression (peak Temperature)

poorly constrained

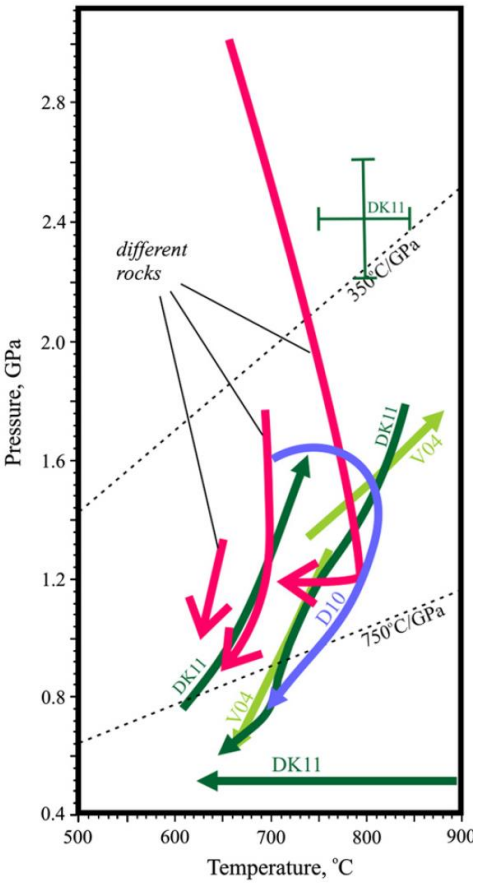
UHP?

UHT?

Mints et al., GSA SP, 2015



Perchuk & Morgunova, Gondwana Res., 2014



Metamorphic peak PT conditions

1

Prograde → Peak → Retrogression (peak Temperature)

poorly constrained

UHP?

UHT?

(1)Prograde

Salma:

1.4-1.5 GPa

~ 620-650 °C

(2) Peak eclogite facies

Gridino:

1.8 GPa, ~ 710 °C

(3.0 GPa, 660 °C ?)

Salma:

2.2-2.3 GPa, 650-670 °C

(3) Post-peak evolution

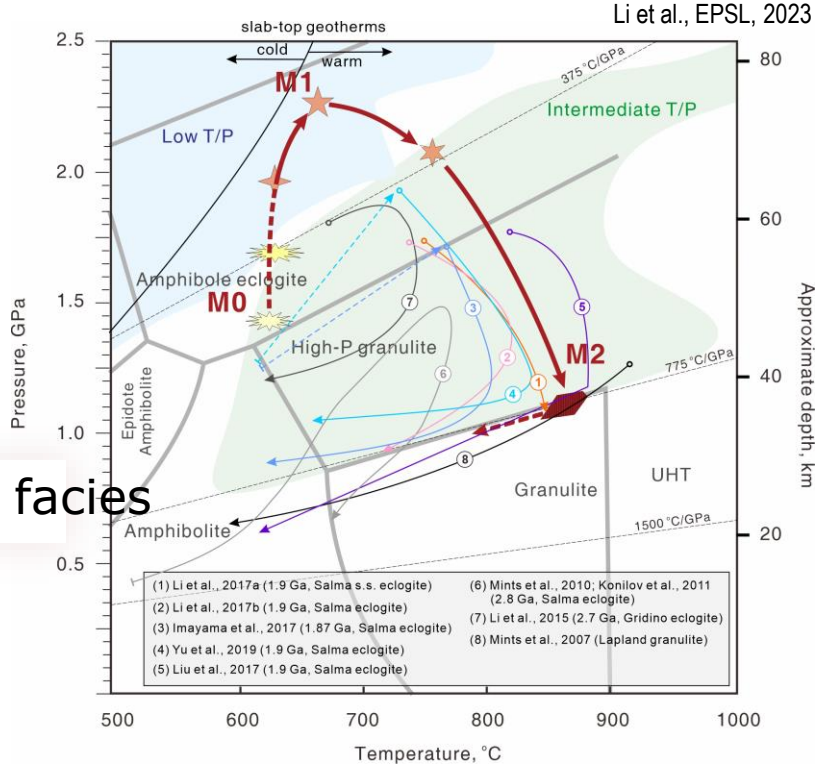
Gridino

~ 1.5 GPa, ~ 750 °C

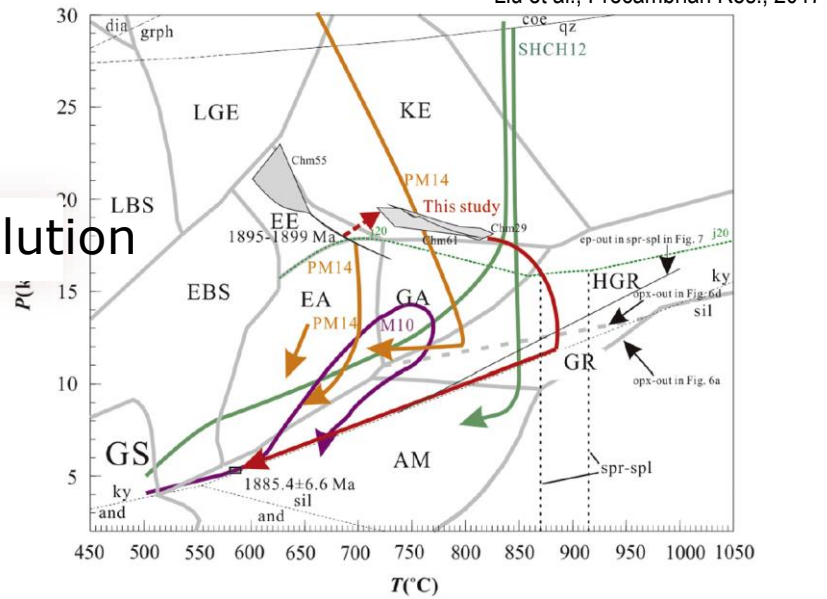
Salma:

~ 1.0 GPa, 850-900 °C

Li et al., EPSL, 2023



Liu et al., Precambrian Res., 2017



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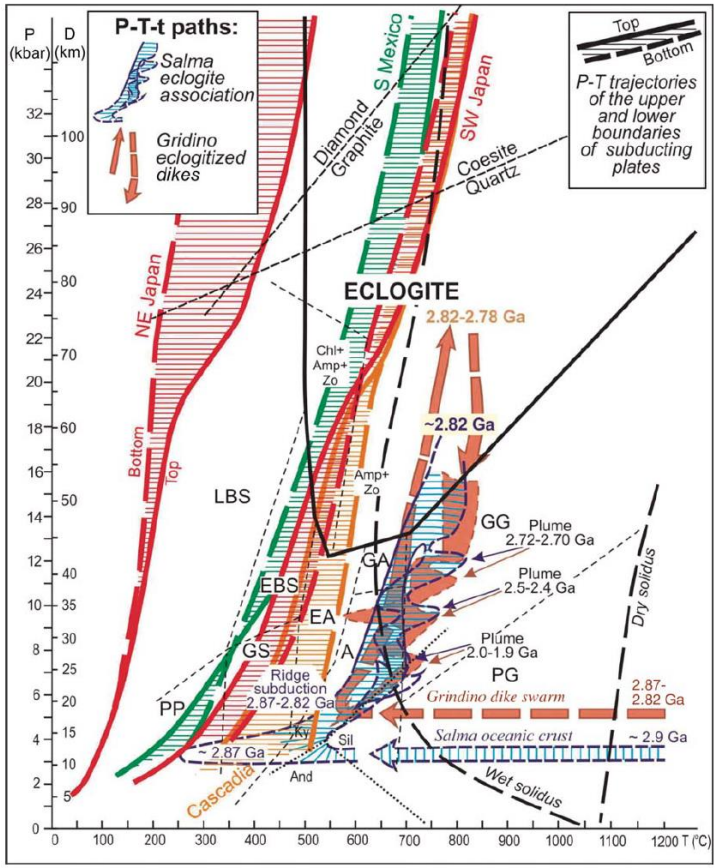

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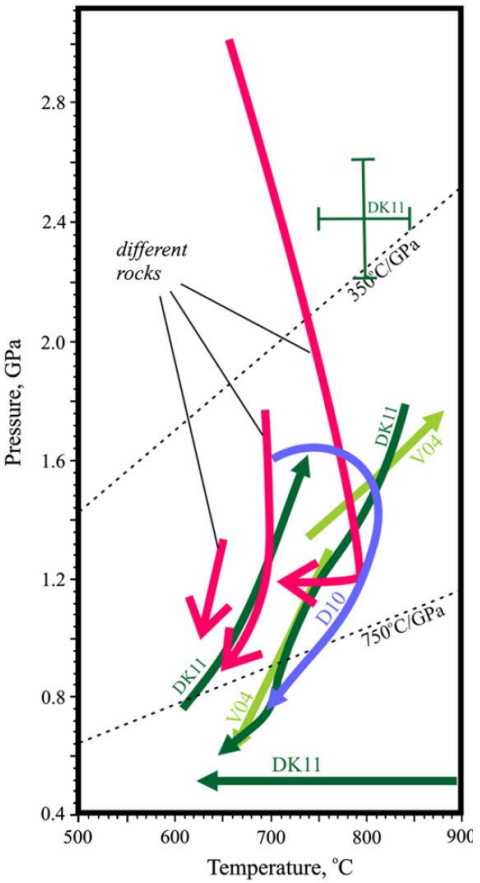

Table 1
Variety of correlations of major magmatic and metamorphic events in the Gridino terrain.

Eclogite facies timing

2

Scenario	Major events			Method and data source
	2.8–2.7 Ga	~2.4 Ga	1.9–1.8 Ga	
I	HP metamorphism 1	Mafic dike swarm, HP metamorphism 2.	Amphibolite facies metamorphism	Zircon, U–Pb method, NORDSIM, SHRIMP (Volodichev et al., 2004; Slabunov et al., 2011; Volodichev et al., 2012)
II	(U?)HP metamorphism followed by granulite facies metamorphism	Leucokratic Bt-Cpx-Opx-Pl-Q veins in metagabbroids	Amphibolite facies metamorphism	Zircon, U–Pb method, SHRIMP (Dokukina et al., 2009, 2012a; Dokukina and Konilov, 2011)
III	Mafic dike swarm	No events	Eclogite facies metamorphism followed by amphibolite facies metamorphism	Zircon, U–Pb, SHRIMP — both events (Skublov et al., 2011); Lu–Hf mineral isochrones, eclogitic event (Herwartz et al., 2012).

Perchuk & Morgunova, Gondwana Res., 2014

Geological Facts

Archean Belomorian Orogen, 2.8 – 2.7 Ga

- Island-arc system
- Granitoid/paragneiss
- Sanukitoid intrusion
- Volcanic intrusions

(Calc-alkaline-, adakite-)

- Greenstone belts
- Leucogranite, K-granite, volcanic molasse

Eclogite ?

Paleoproterozoic LIPs 2.5-2.4, 2.3, 2.2, 2.1 Ga

- Gabbro-norite
- Pyroxenite (?)

Paleoproterozoic Svecofennia & Lapland-Kola Orogen 2.0 – 1.8 Ga

- Subduction-collision

Eclogite

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- Subduction-collision

Eclogite

Eclogite Info

2.9 Ga (T_{DM} = 3.1 Ga) Protolith (basite)

2.82 Ga, 2.72 Ga – Eclogite-Granulite facies **(Zrn U-Pb)**

2.5-2.4 Ga – Granulite-facies (LIPs)

1.9-1.8 Ga – Eclogite-Granulite facies **(Zrn U-Pb, Lu-Hf)**

1.7 Ga – Amphibolite facies **(Ttn U-Pb)**

Fact

- Tectonic mélange of TTG + greenstone belts + eclogite/amphibolite, ultra-/mafic dykes, granulite-charnockite/enderbite

2.74-2.73 Ga TTG gneiss (Salma)	*Glebovitsky, 2005; Slabunov et al., 2006; Slabunov, 2008; Li et al., 2017b*
2.9-3.1 Ga protolith of eclogite (Salma)	*Mints et al., 2010; Konilov et al., 2011; Li et al., 2017b*
1.9 Ga mafic eclogite & eclogite facies (Salma)	*Li et al., 2017a, b; Yu et al., 2019a, b; Melnik et al., 2021*
Peak eclogite facies PT: **22-23 Kbar, 650-670 °C** (Salma)	*Li et al., 2023, 2025*
2.72 Ga eclogite (Gridino)	*Volodichev et al., 2004, 2021; Li et al., 2015*

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- Tectonic mélange of TTG + greenstone belts + eclogite/amphibolite, ultra-/mafic dykes, granulite-charnockite/enderbite
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- Peak eclogite facies PT: **22-23 Kbar, 650-670 °C** (Salma) — *Li et al., 2023, 2025*
- **2.72 Ga** eclogite (Gridino) — *Volodichev et al., 2004, 2021; Li et al., 2015*

Artefact

- ✓ ***2.8 Ga*** Ophiolite-like complex (mafite-ultramafite belts) — *Slabunov et al., 2019*
- ✓ ***2.7 Ga*** (HP) granulite facies (Salma) — *Kaulina et al., 2010; Konilov et al., 2011; Li et al., 2017b*
- ✓ ***2.82-2.72 Ga*** eclogite facies (Salma) — *Mints et al., 2010; Konilov et al., 2011; Shchipansky et al., 2012b; Balagansky et al., 2015*
- ✓ ***1.9 Ga*** amphibolite facies against eclogite (Salma) — *Konilov et al., 2011; Dokukina et al., 2016; Imayama et al., 2017*
- ✓ ***UHT*** overprint (~ 900 °C) on eclogite (Salma) — *Dokukina et al., 2016; Liu et al., 2017; Li et al., 2018, 2021*

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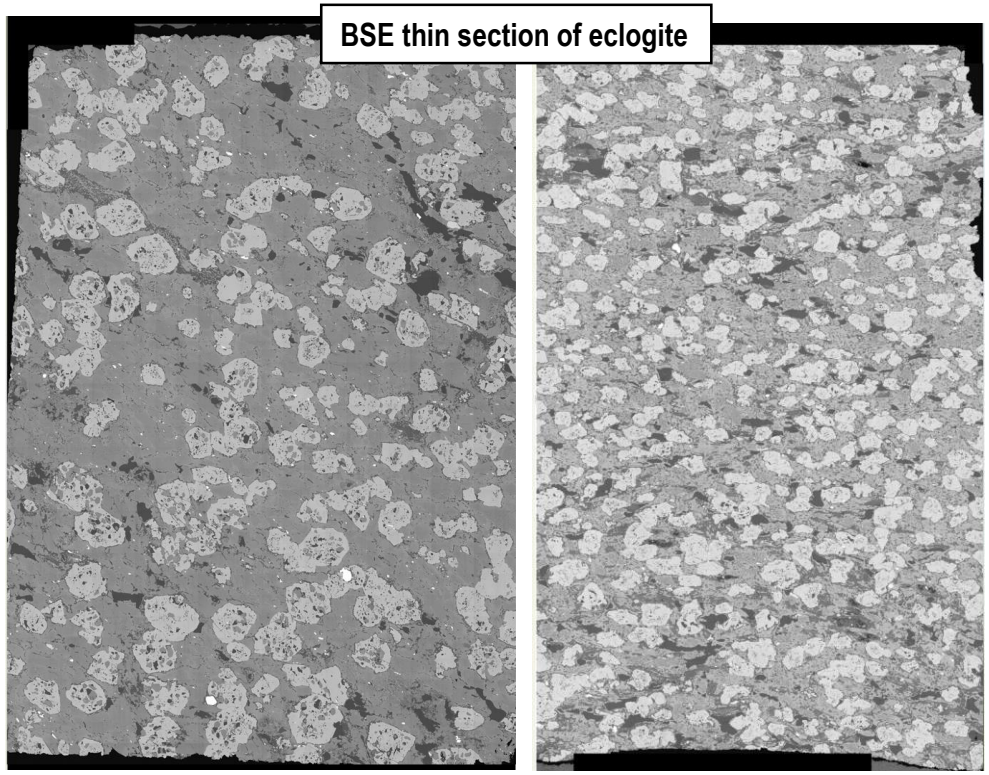
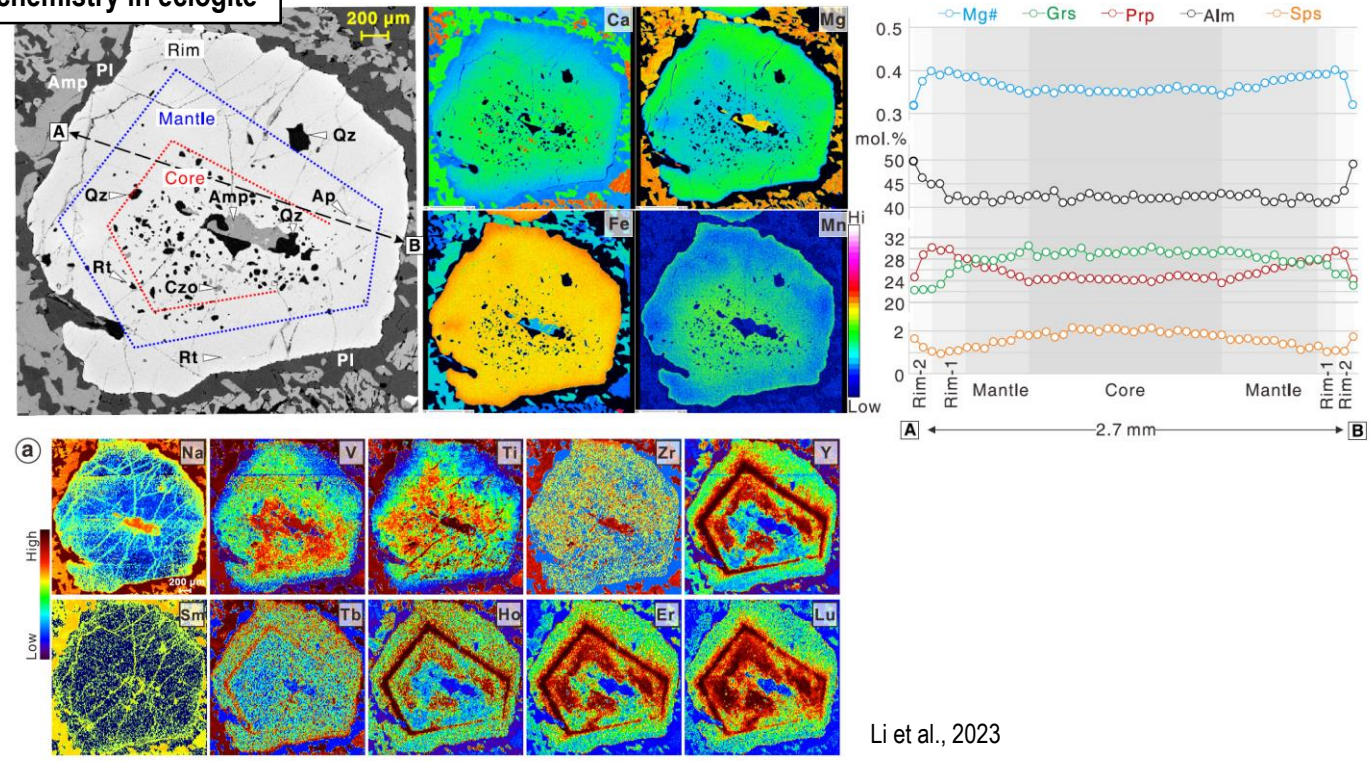
Metamorphic Petrology

Метаморфическая Петрология

BSE thin section of eclogite

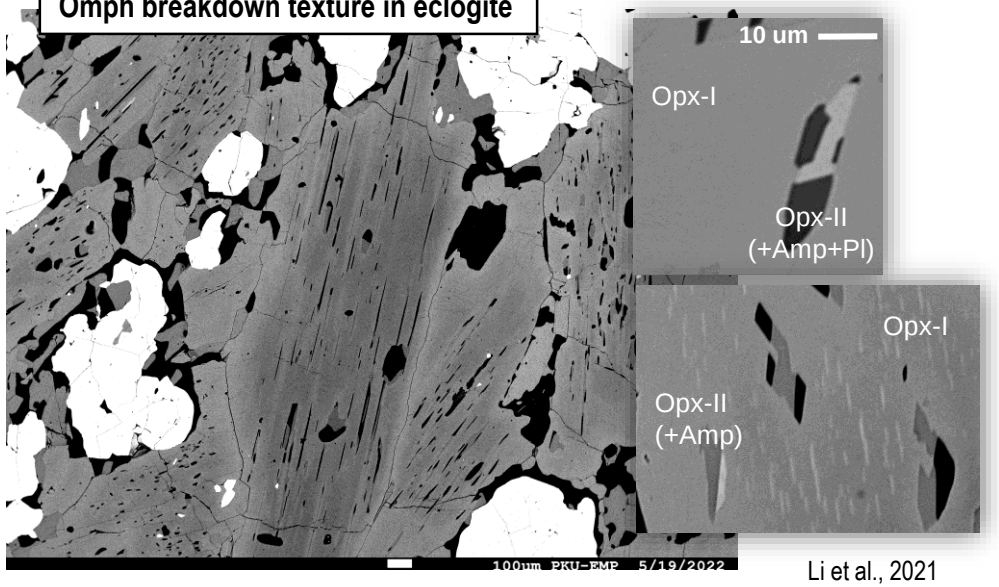


Garnet chemistry in eclogite



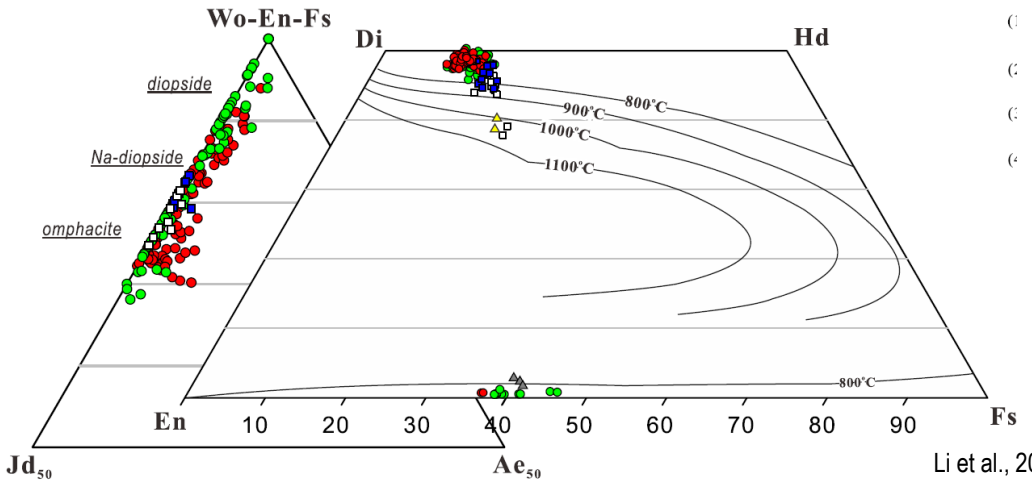
Li et al., 2023

Omph breakdown texture in eclogite



Li et al., 2021

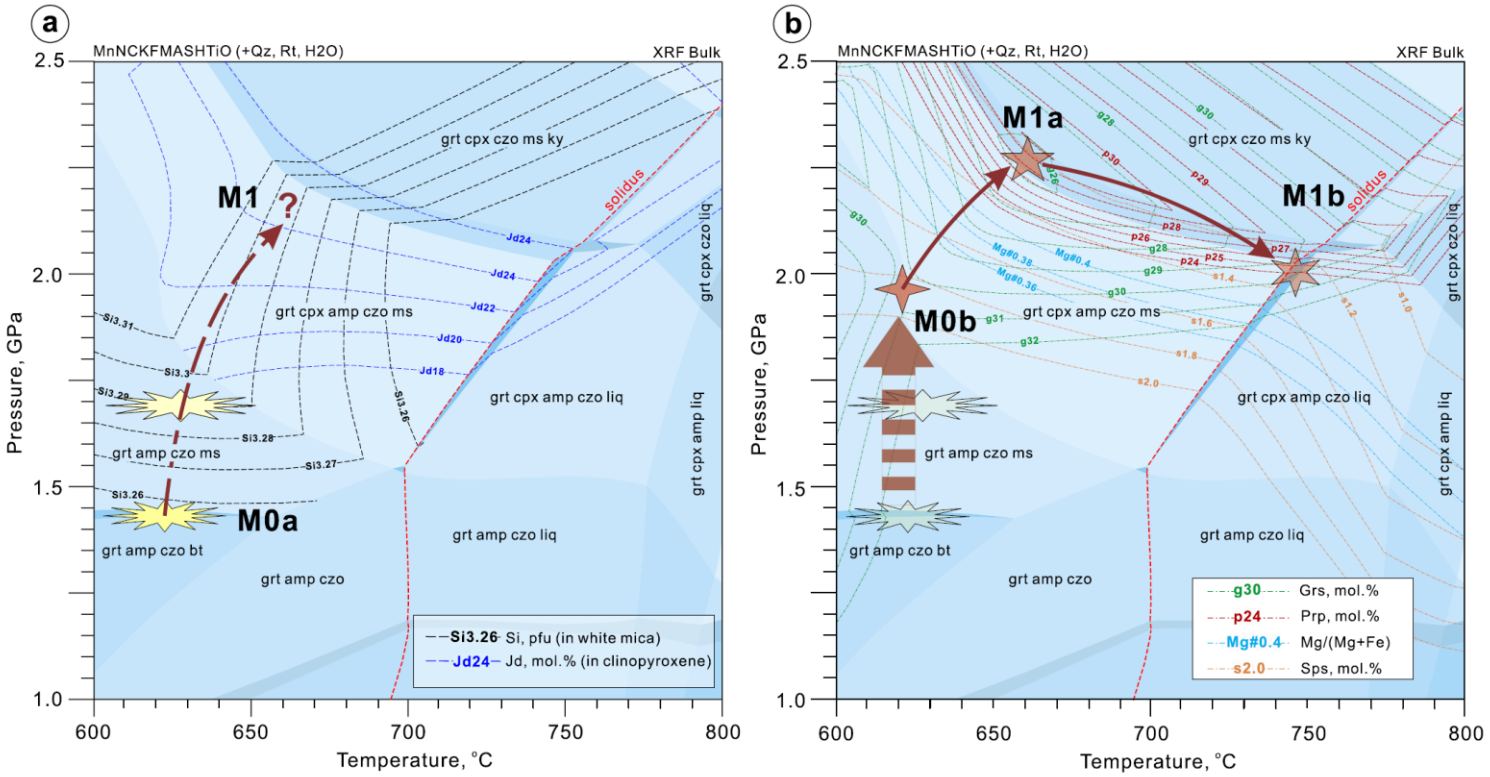
Pyroxene chemistry in eclogite



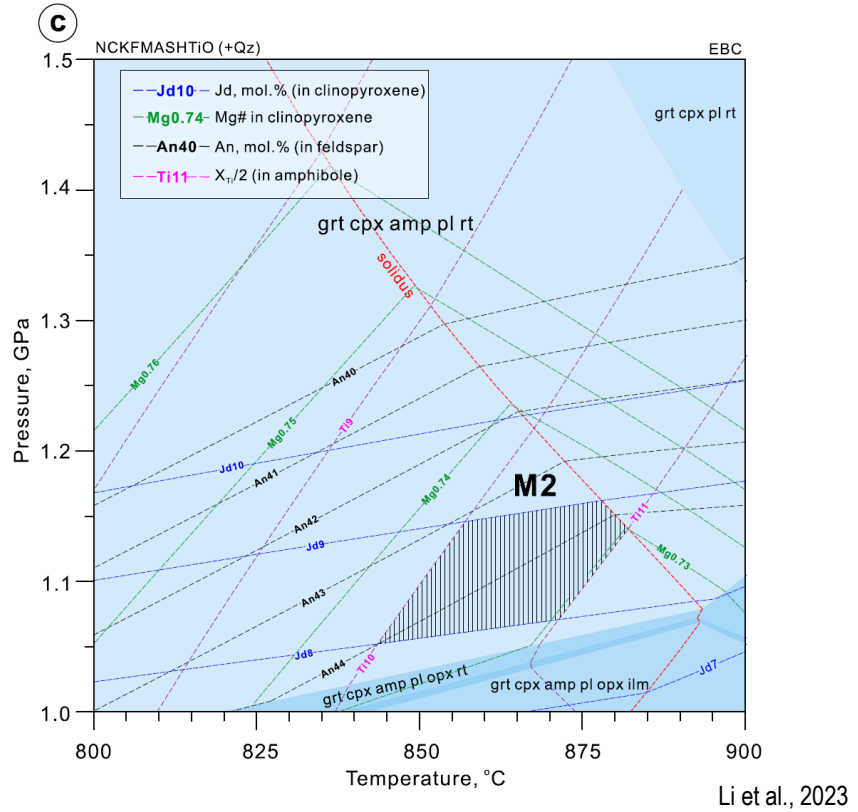
Li et al., 2021

Phase equilibrium modeling

Bulk chemistry by XRF analyses



Effective Bulk Chemistry of domainal equilibria on thin section



Li et al., 2023

Limitation:

(1)closed system

(2)Isochemical reaction

(3)Systematic and random errors are inevitable

VS.

Geothermobarometer:

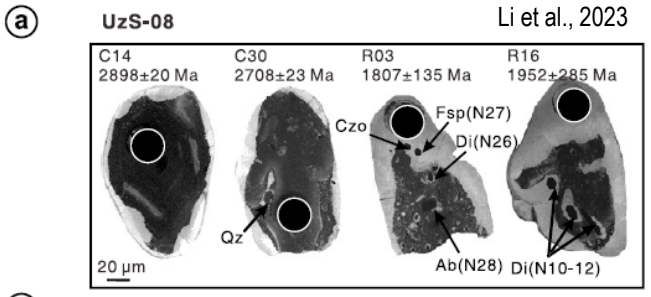
(1) Equilibrated paragenesis

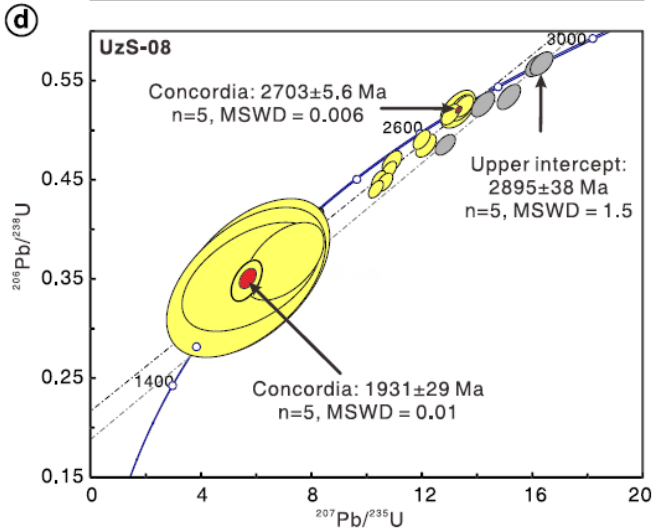
(2) Domainal equilibrium

(3) Analytical error (by EPMA)

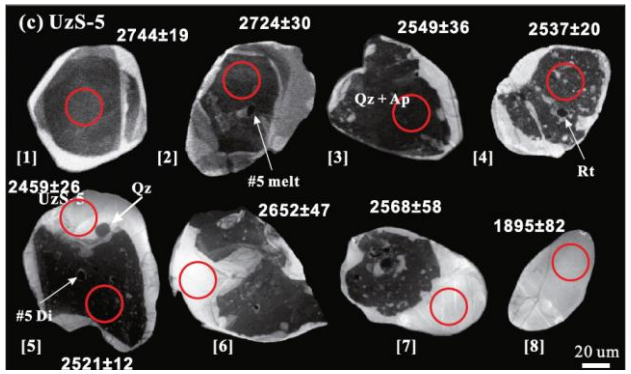
Zircon U-Pb dating

Li et al., 2023

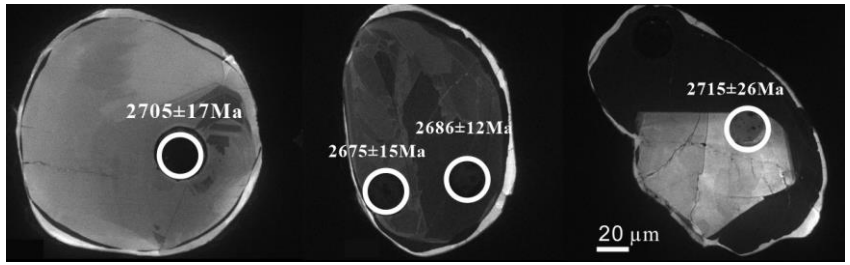




Li et al., 2017a



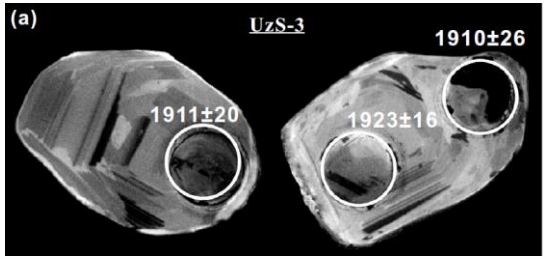
Li et al., 2015



Gridino eclogite

- **Metamorphic zircon: 2.71-2.68 Ga**

Li et al., 2017b



Salma eclogite

- **Metamorphic zircon: 1.92-1.91 Ga**

Salma retrogressed eclogite

- **dark-CL Core: 2.8-2.7 Ga + 2.5 Ga**
- **bright-CL Rim: 1.9-1.8 Ga**

Accurate interpretation of U-Pb age is somehow problematic

(1) Crystal texture (CL-BSE image)

(2) Mineral inclusions in-situ (omphacite, garnet etc.)

(3) REE pattern, Th/U ratio

(4) REE differentiation coefficient with garnet, omphacite, amphiole

(5) Lu-Hf-O isotope

……

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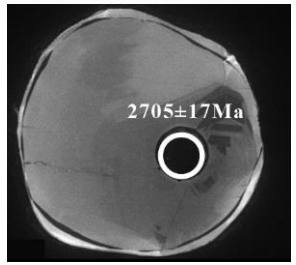
Preliminary Conclusions

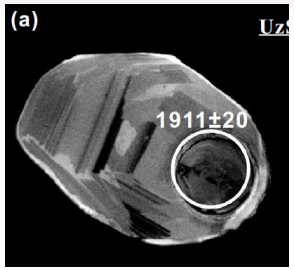
Предварительные заключения

(1) 2.7 Ga mafic eclogite in Gridino

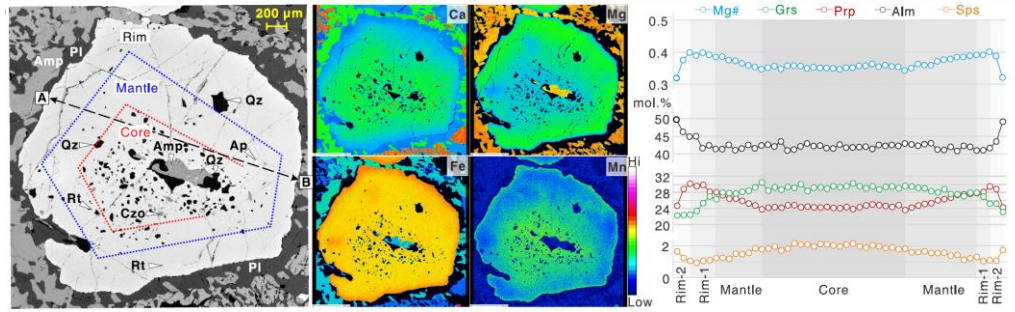
Li et al., 2015,PR



(2) 1.9 Ga mafic eclogite in Salma



(3) 1.9 Ga cold subduction mafic eclogite in Salma

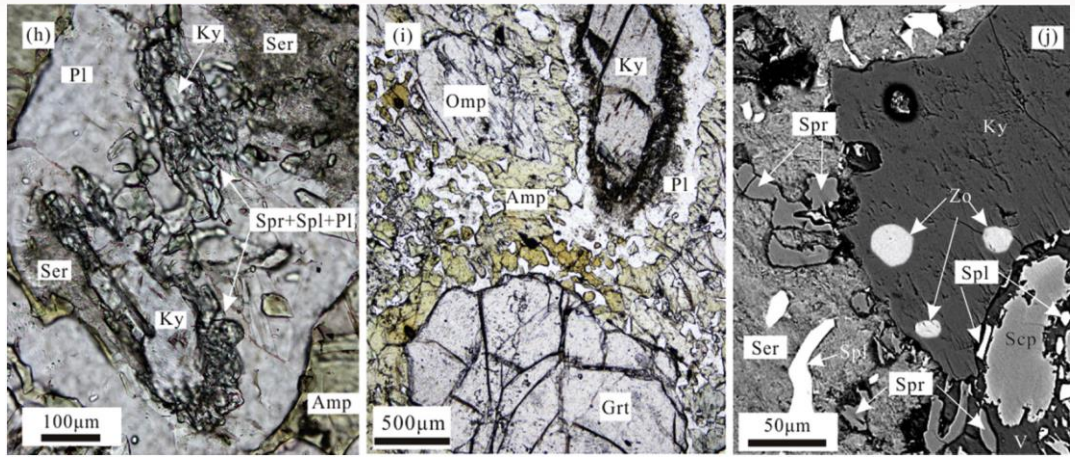


Li et al., 2017, Sci Bull.

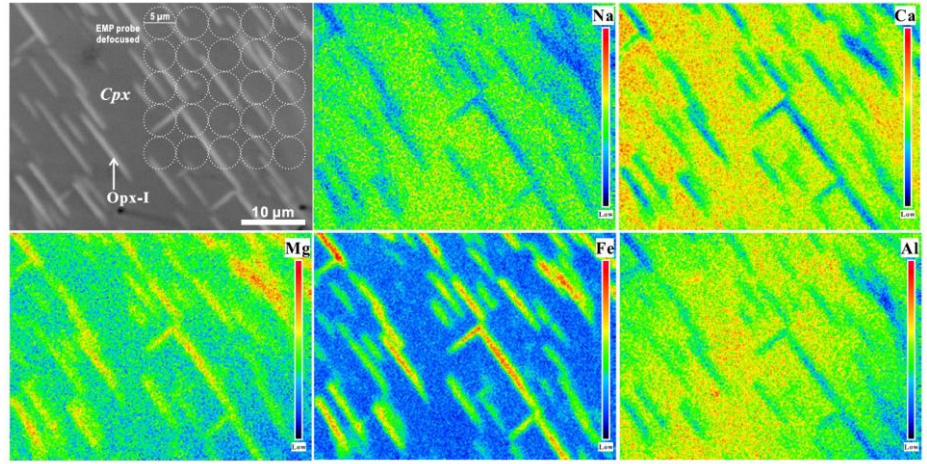
Li et al., 2023, EPSL

Li et al., 2025, EPSL

(4) UHT overprint on 1.9 Ga(?) mafic eclogite in Sal



Sapphirine + Spinel within Cpx-Pl symplectite



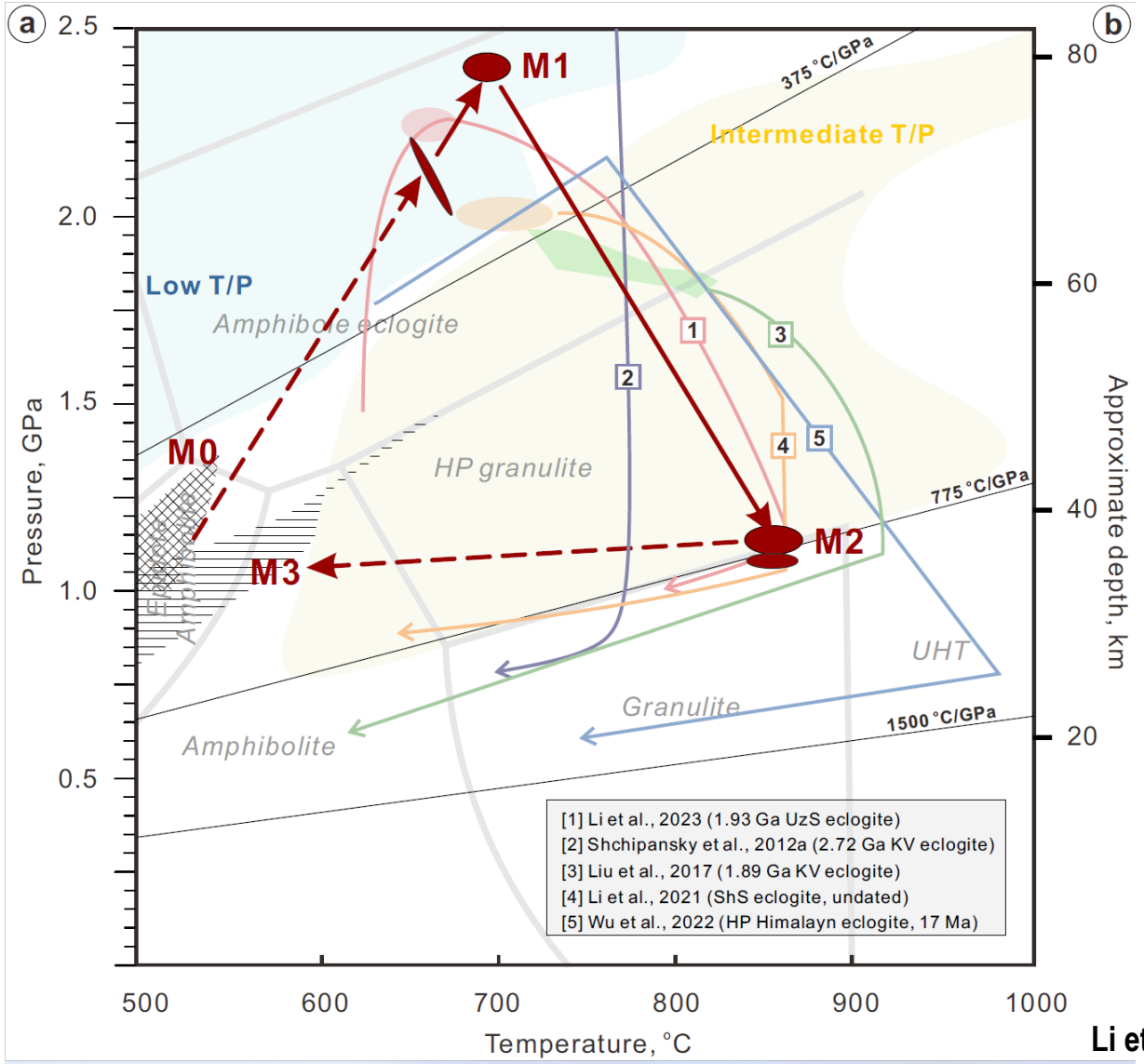
Opx lamellae exsolution within Cpx

Li et al., 2018, 2021, JMG

Metamorphic PT paths of

[1-4] Belomorian eclogites (1.9 Ga, 2.7 Ga?)

[5] Himalayan eclogite (17 Ma)

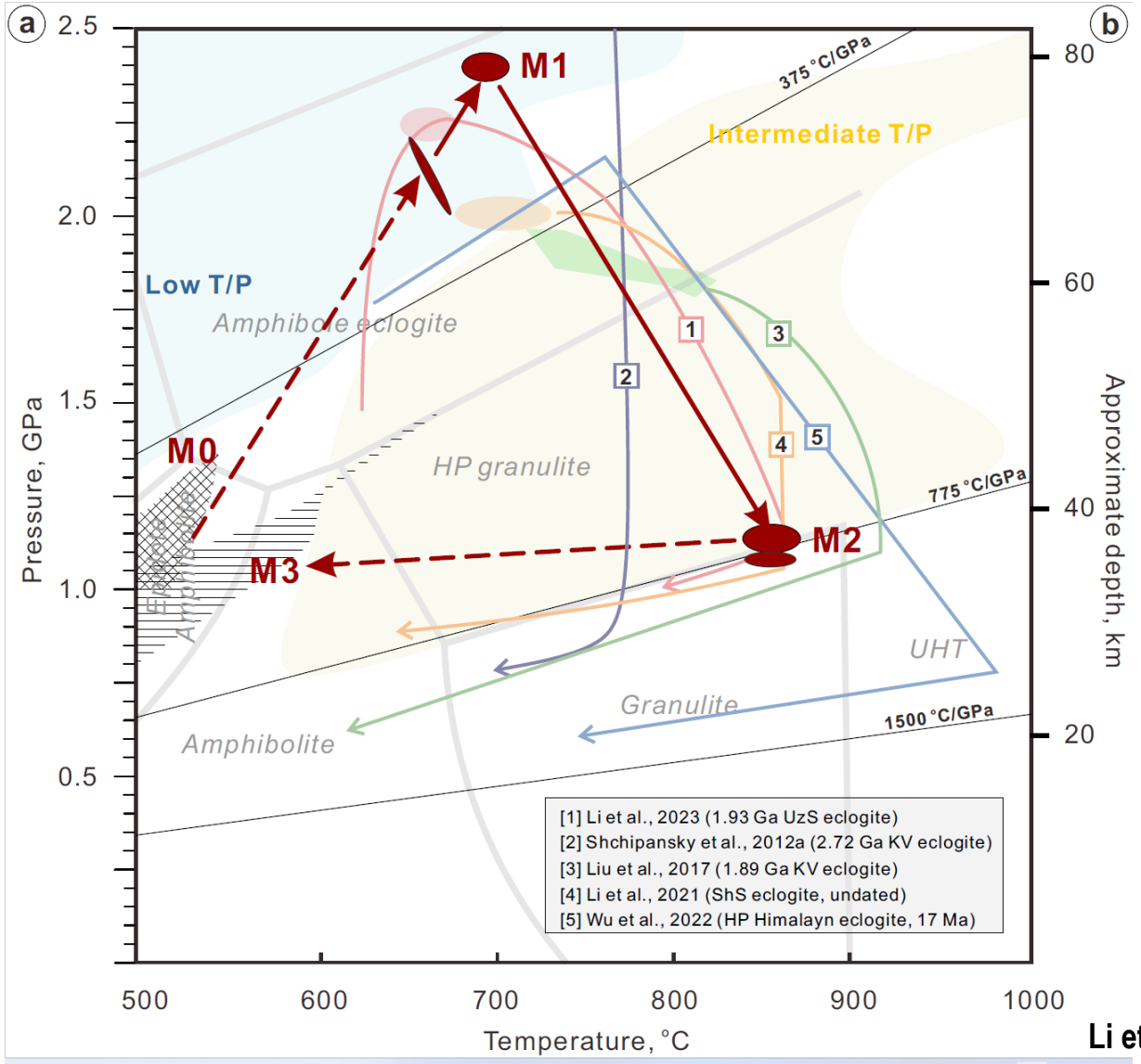


Li et al., 2025, EPSL

Metamorphic PT paths of

[1-4] Belomorian eclogites (1.9 Ga, 2.7 Ga?)

[5] Himalayan eclogite (17 Ma)

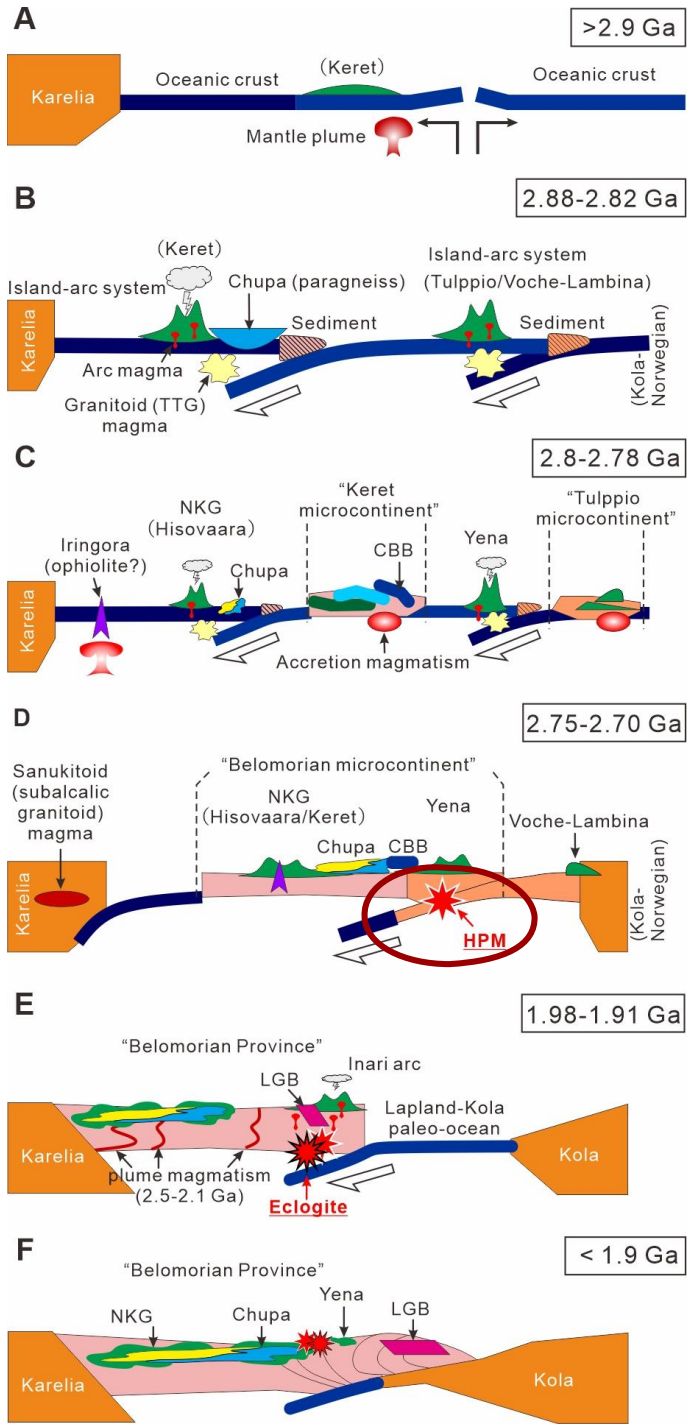


Li et al., 2025, EPSL

Tectonic mode

If Archean subduction was true……

Yo-Yo tectonics??? **?**



in prep.

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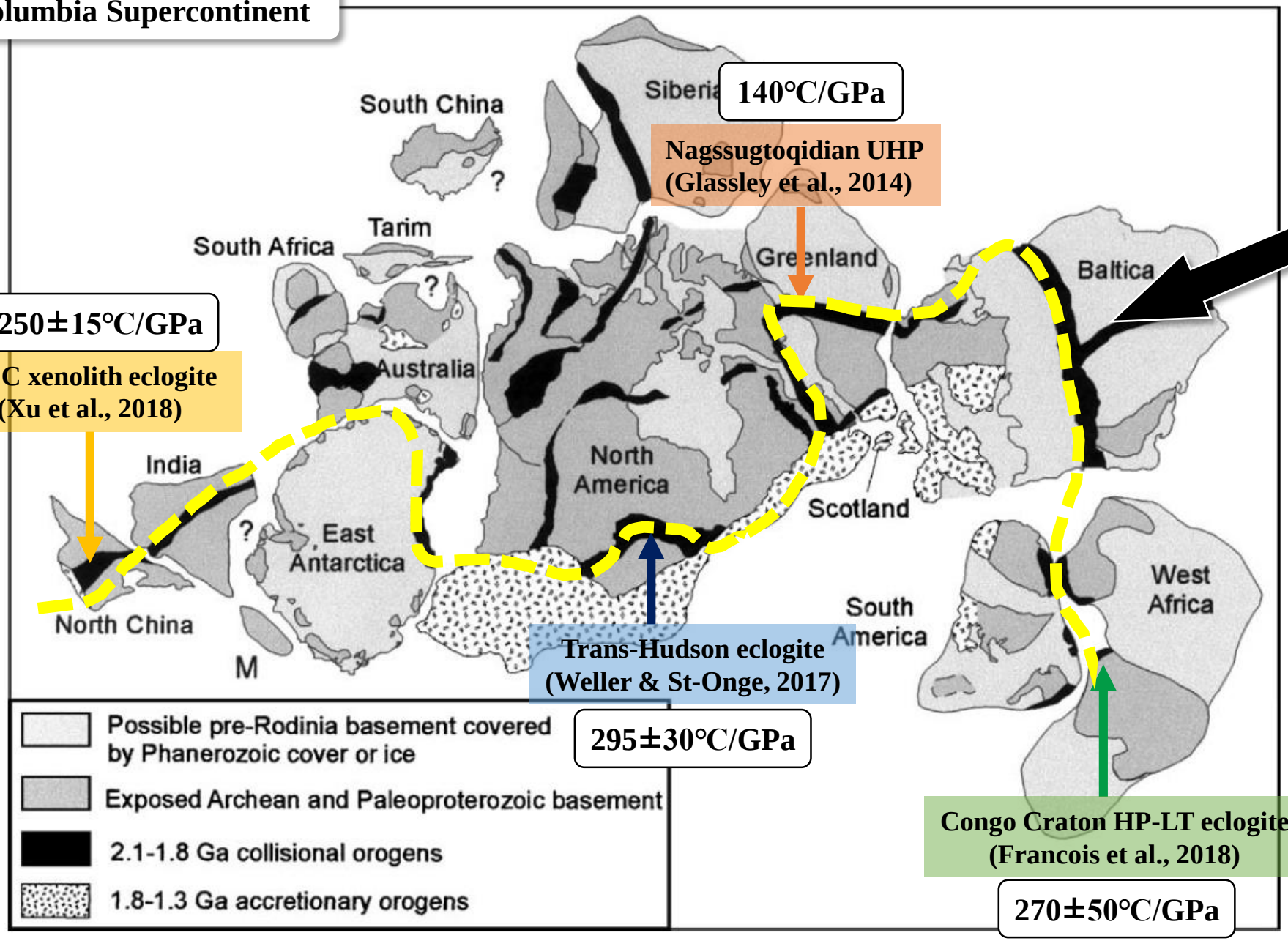
5

Future Perspectives

Перспективы

Columbia Supercontinent

PALEOPROTERZOIC EVENT



140°C/GPa

Nagssugtoqidian UHP
(Glassley et al., 2014)

250±15°C/GPa

NCC xenolith eclogite
(Xu et al., 2018)

Trans-Hudson eclogite
(Weller & St-Onge, 2017)

295±30°C/GPa

Congo Craton HP-LT eclogite
(Francois et al., 2018)

270±50°C/GPa

Belomorian Salma eclogite

300±10°C/GPa

- Low T/P cold subduction
- Global scale
- Mega-orogen 2.1-1.8 Ga (Himalaya counterpart?)

Zhao et al., 2004

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

journal homepage: www.elsevier.com/locate/epsl

Orosirian cold eclogite from Baltica marks the onset of modern plate tectonics

Xiaoli Li *, Lifei Zhang *, Chunjing Wei, Guibing Zhang

The Key Laboratory of Orogenic Belts and Crustal Evolution, MOE, School of Earth and Space Sciences, Peking University, Beijing, China, 100871

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Earth and Planetary Science Letters

journal homepage: www.elsevier.com/locate/epsl

Cold subduction recorded by the 1.9 Ga Salma eclogite in Belomorian Province (Russia)

Li Xiaoli [a,*], Zhang Lifei [a,*], Wei Chunjing [a], Bader Thomas [a], Guo Jinghui [b]

[a] *MOE Key Laboratory of Orogenic Belts and Crustal Evolution, School of Earth and Space Sciences, Peking University, Beijing, 100871, China*
[b] *Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, 100029, China*

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Short Communication

1.9 Ga eclogite from the Archean-Paleoproterozoic Belomorian Province, Russia

Xiaoli Li *, Huanglu Yu, Lifei Zhang, Chunjing Wei, Thomas Bader

The Key Laboratory of Orogenic Belts and Crustal Evolution MOE, School of Earth and Space Sciences, Peking University, Beijing 100871, China

Contents lists available at ScienceDirect

Precambrian Research

journal homepage: www.elsevier.com/locate/precamres

Neoarchean-Paleoproterozoic granulite-facies metamorphism in Uzkaya Salma eclogite-bearing mélange, Belomorian Province (Russia)

Xiaoli Li [a,*], Lifei Zhang [a], Chunjing Wei [a], Alexander I. Slabunov [b], Thomas Bader [a]

[a] *The Key Laboratory of Orogenic Belts and Crustal Evolution MOE, School of Earth and Space Sciences, Peking University, Beijing 100871, China*
[b] *Institute of Geology, Karelian Research Center RAS, Petrozavodsk 185910, Russia*

ORIGINAL ARTICLE

WILEY Journal of METAMORPHIC GEOLOGY

Age and *P–T* conditions of the Gridino-type eclogite in the Belomorian Province, Russia

H. L. Yu[1] | L. F. Zhang[1] | C. J. Wei[1] | X. L. Li[1] | J. H. Guo[2]

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Lithos

journal homepage: www.elsevier.com/locate/lithos

Garnet Lu—Hf geochronology and P-T path of the Gridino-type eclogite in the Belomorian Province, Russia

Huanglu Yu [a], Lifei Zhang [a,*], Pierre Lanari [b], Daniela Rubatto [b], Xiaoli Li [a]

[a] *MOE Key Laboratory of Orogenic Belt and Crustal Evolution, School of Earth and Space Sciences, Peking University, Beijing 100871, China*
[b] *Institute of Geological Sciences, University of Bern, Bern 3012, Switzerland*

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Precambrian Research

journal homepage: www.elsevier.com/locate/precamres

The metamorphic evolution of Salma-type eclogite in Russia: Constraints from zircon/titanite dating and phase equilibria modeling

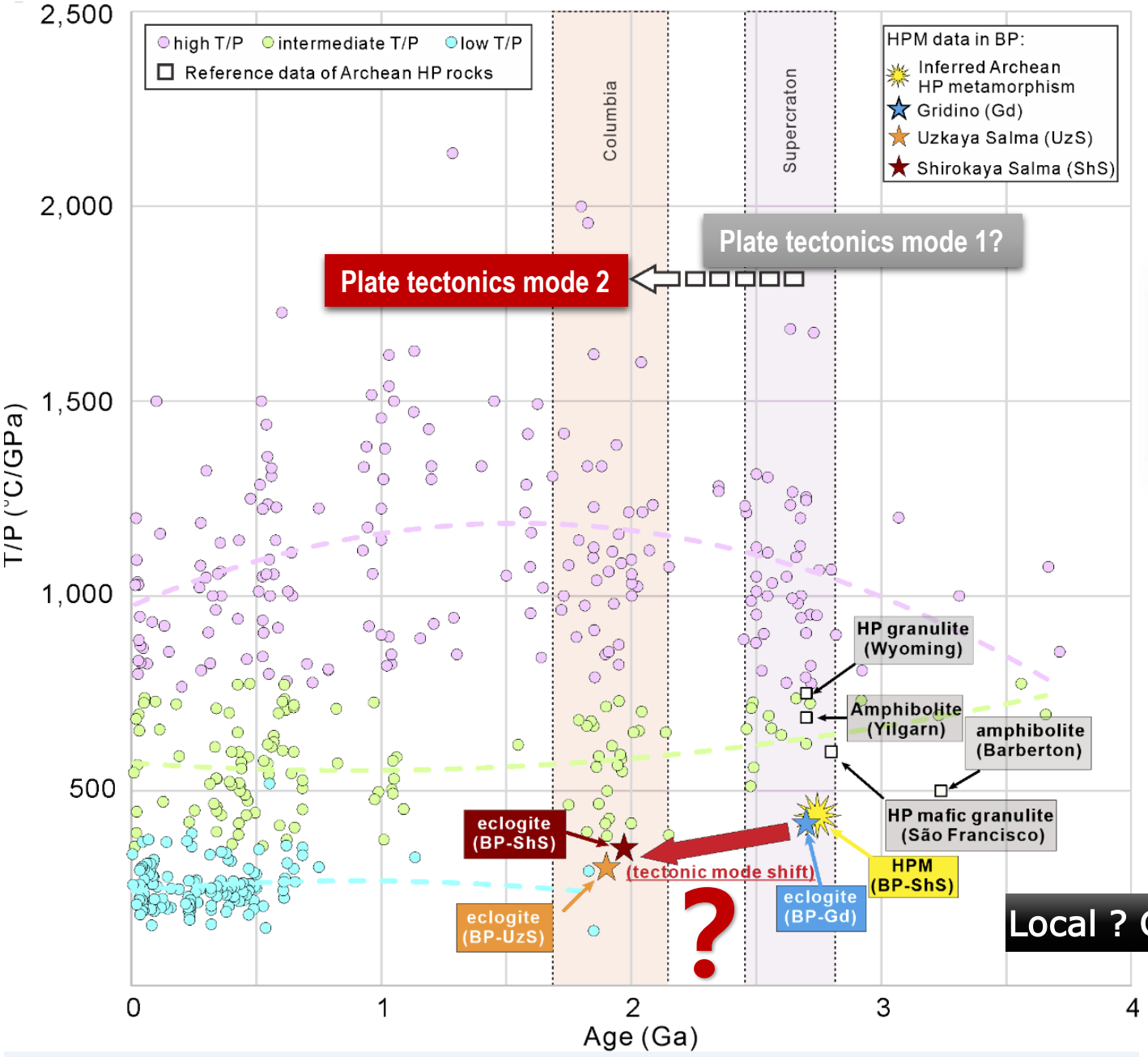
Huanglu Yu[a], Lifei Zhang[a,*], Lijuan Zhang[a], Chunjing Wei[a], Xiaoli Li[a], Jinghui Guo[b], Thomas Bader[a], Yunfei Qi[a]

[a] *MOE Key Laboratory of Orogenic Belt and Crustal Evolution, School of Earth and Space Sciences, Peking University, Beijing 100871, China*
[b] *State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics CAS, Beijing 100029, China*

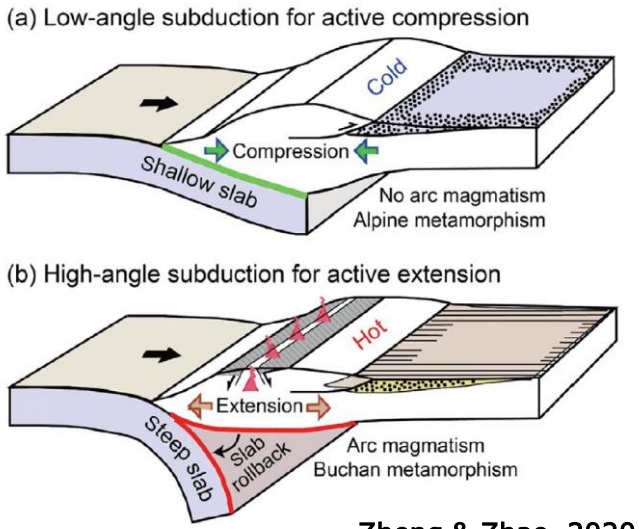
2.7 Ga Belomorian Gridino/Salma eclogite?

Plate tectonics Ancient vs. Modern style

Large-scale (global) horizonal vertical motion (subduction-collision)



- ✓ Modern-style
- ✓ Ancient-style



Zheng & Zhao, 2020

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Precambrian Research

journal homepage: www.elsevier.com/locate/precamres

Metamorphic *PT* path and zircon U–Pb dating of Archean eclogite association in Gridino complex, Belomorian province, Russia

Xiaoli Li[a,*], Lifei Zhang[a], Chunjing Wei[a], Alexander I. Slabunov[b]

[a] School of Earth and Space Sciences, Peking University, Beijing 100871, China
[b] Institute of Geology, Karelian Research Center RAS, Petrozavodsk 185910, Russia

ORIGINAL ARTICLE

WILEY Journal of METAMORPHIC GEOLOGY

Quartz and orthopyroxene exsolution lamellae in clinopyroxene and the metamorphic *P–T* path of Belomorian eclogites

Xiaoli Li[1] | Lifei Zhang[1] | Chunjing Wei[1] | Alexander I. Slabunov[2,3] | Thomas Bader[1]

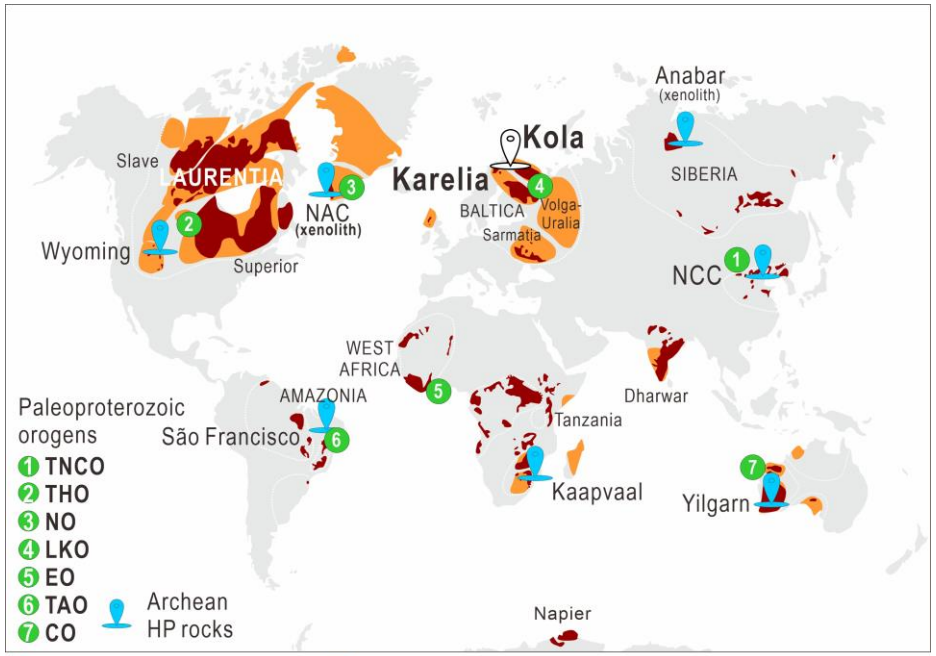
ORIGINAL ARTICLE

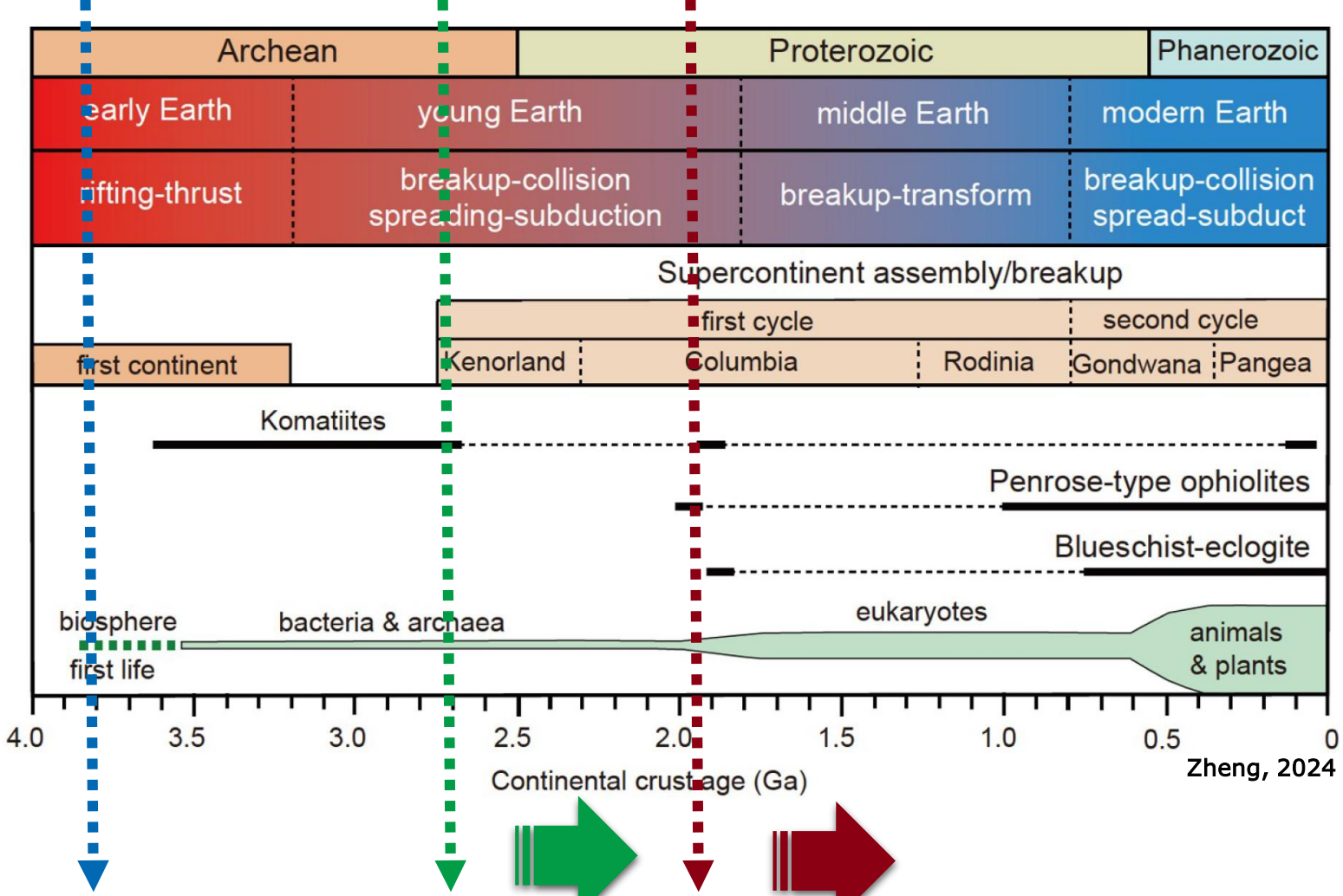
Journal of METAMORPHIC GEOLOGY WILEY

The metamorphic PT history of Precambrian Belomorian eclogites (Shirokaya Salma), Russia

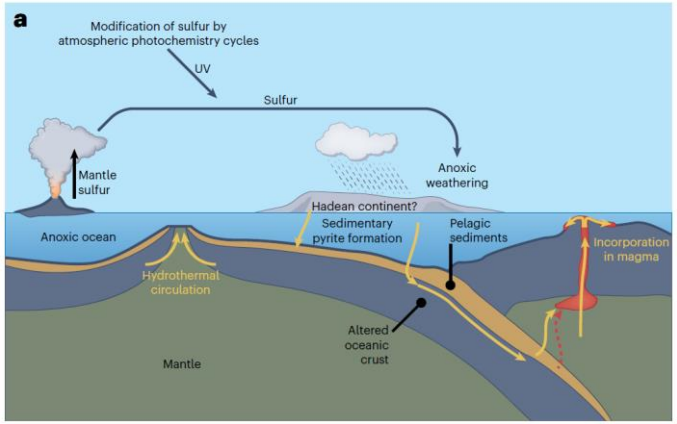
Xiaoli Li | Lifei Zhang | Thomas Bader

Maybe there will be more results incoming……





Zheng, 2024



S-Nd isotopes

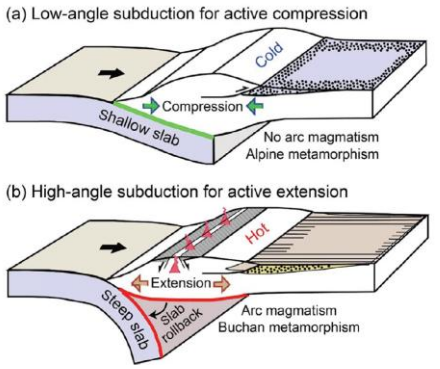
Uncertain eclogite?

(in BP)

Cold eclogite

(in BP)

+ BS, UHP



nature geoscience

Article

https://doi.org/10.1038/s41561-025-01677-5

Early Archaean onset of volatile cycling at subduction zones

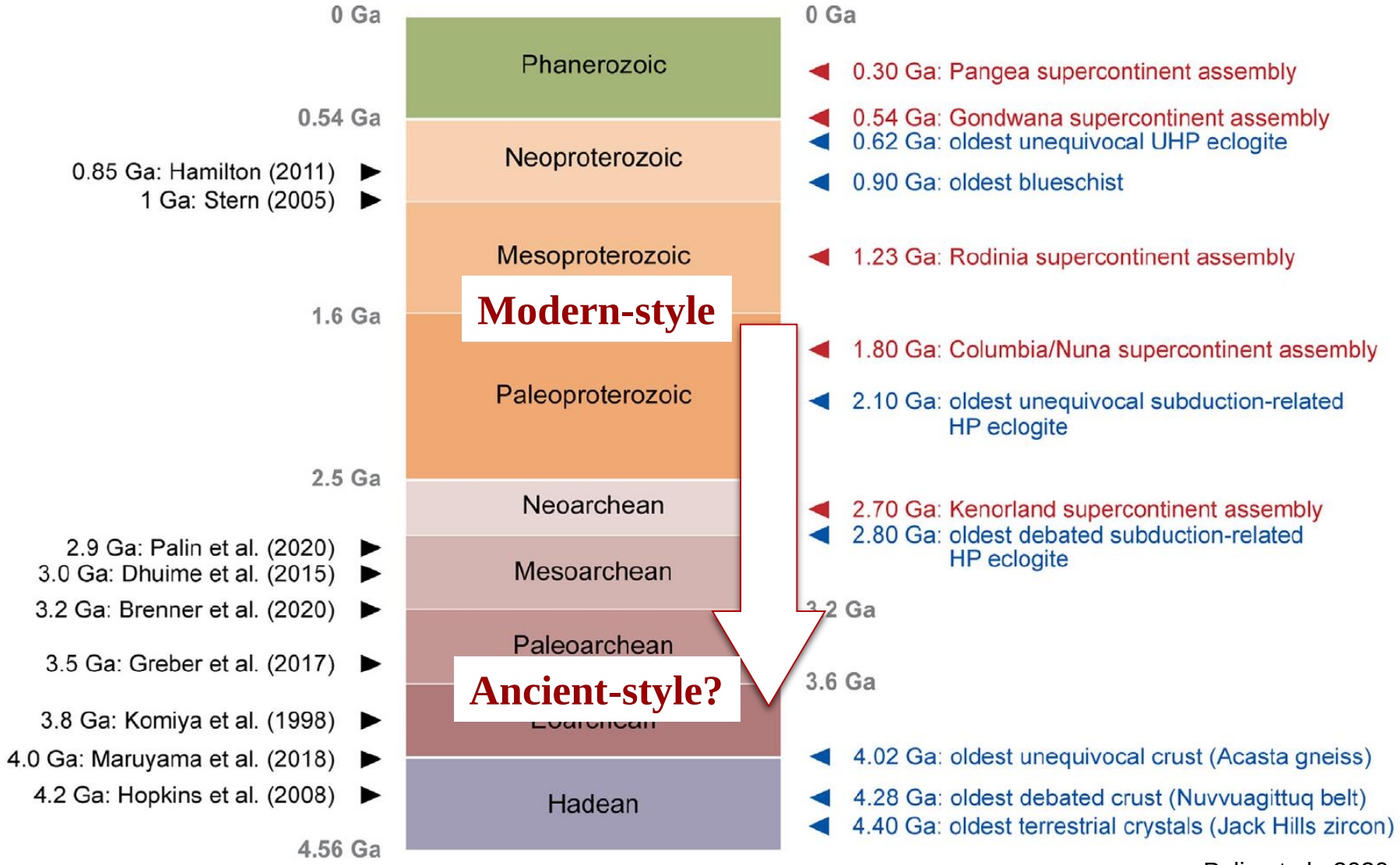
Received: 20 September 2024

Accepted: 11 March 2025

G. Caro, T. Grocolas, P. Bourgeois, P. Bouilhol, S. J. Mojzsis & G. Paris

To be Continued

When Plate Tectonics started



Palin et al., 2020

Other Research Profile:

ISSN 0145-8752, Moscow University Geology Bulletin, 2012, Vol. 67, No. 1, pp. 8–17. © Allerton Press, Inc., 2012.
Original Russian Text © X. Li, V.V. Maslennikov, A.Yu. Lein, A.A. Ul'yanov, 2012, published in Vestnik Moskovskogo Universiteta. Geologiya, 2012, No. 1, pp. 9–17.

Associations of Trace Elements in the Sulfides of Black Smokers from the Broken Spur, Menez Gwen, and Snake Pit Hydrothermal Fields

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Received October 25, 2011

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www.scibull.com

Article

Application of microprobe-based flank method analysis of Fe^{3+} in garnet of North Qilian eclogite and its geological implication

Xiaoli Li [a,*], Shuguang Song [a], Lifei Zhang [a], E. Heidi Höfer [b]

[a] *The Key Laboratory of Orogenic Belts and Crustal Evolution MOE, School of Earth and Space Sciences, Peking University, Beijing 100871, China*
[b] *Institut für Geowissenschaften, Facheinheit Mineralogie, Johann Wolfgang Goethe-Universität, D-60054, Germany*

ISSN 0145-8752, Moscow University Geology Bulletin, 2010, Vol. 65, No. 4, pp. 254–258. © Allerton Press, Inc., 2010.
Original Russian Text © Syaoli Li, A.Yu. Lein, A.A. Ul'yanov, 2010, published in Vestnik Moskovskogo Universiteta. Geologiya, 2010, No. 4, pp. 44–48.

SHORT COMMUNICATIONS

Trace Elements and Their Distribution in Sulfides from Black Smokers of the Broken Spur Hydrothermal Vent Field (Mid-Atlantic Ridge)

Syaoli Li[a], A. Yu. Lein[b], and A. A. Ul'yanov[a]

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[b] *Institute of Oceanology, Russian Academy of Sciences, Nakhimovskii pr., Moscow, 117997 Russia*

Received December 8, 2009

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May 2023 Vol.66 No.5: 985–996
https://doi.org/10.1007/s11430-022-1039-3

Electron microprobe analysis of Hf and Ti in ultrahigh temperature zircon: Optimized approaches and perspectives

Xiaoli LI*, Bin WANG & Chunjing WEI

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THANKS