

(神戸大CPS; Dec. 11, 2017)

Zirconophile: trilogy
ジルコン好き三題噺

東大・駒場・宇宙地球

磯崎 行雄

material to look for

ジルコン ZrSiO_4

*The most promising recording-medium
for Earth-History studies*

特長: 珪長質マグマから晶出する火成鉱物

花崗岩類に普遍的 (大陸地殻)

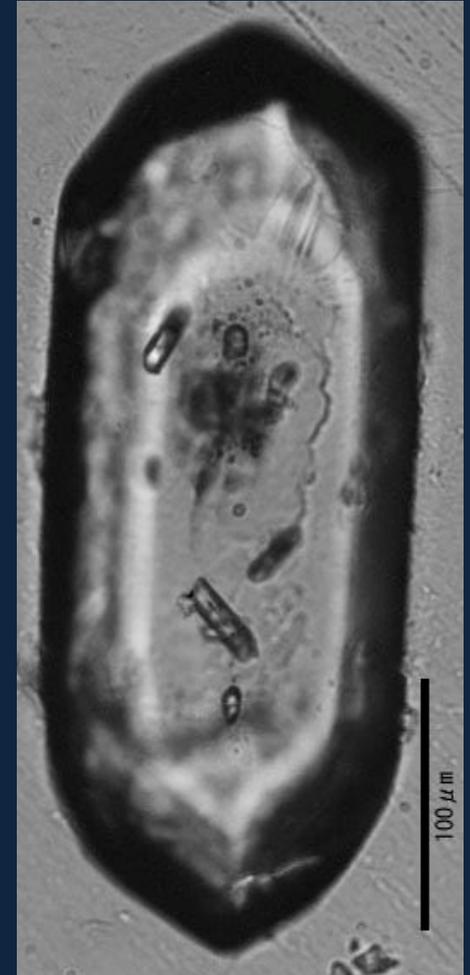
玄武岩にまれ (海洋地殻)

超塩基性岩に極めてまれ (マントル)

with enriched inconpartible elements

年代測定に有用

硬い: 機械的摩滅 (削剝・変質・変成) に高耐性

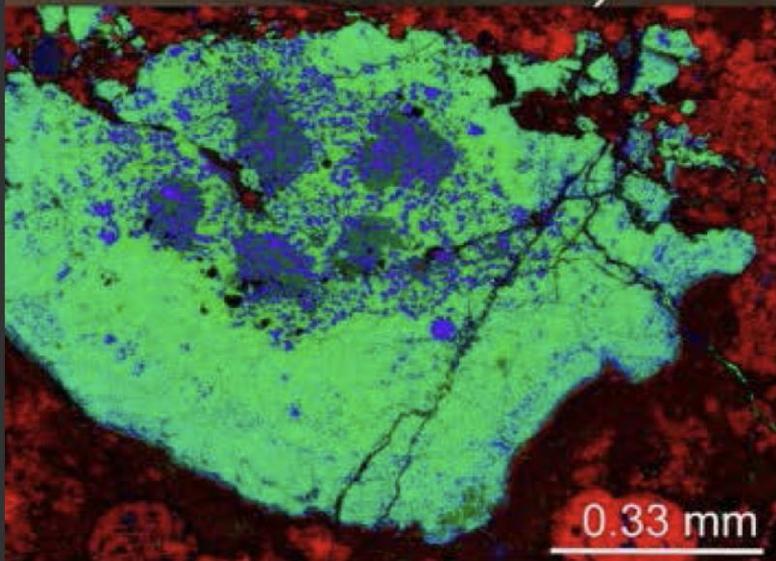
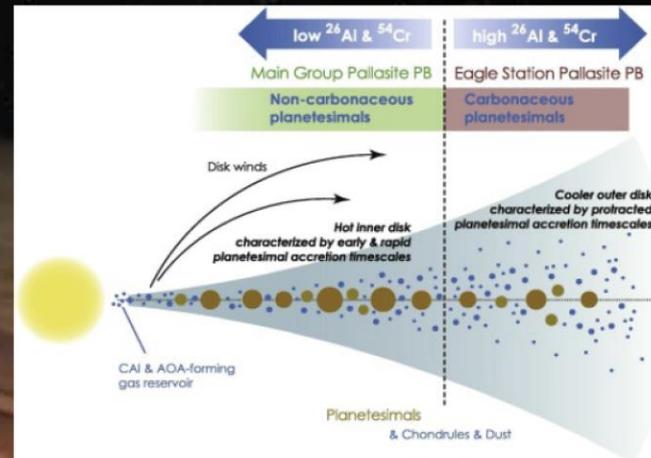
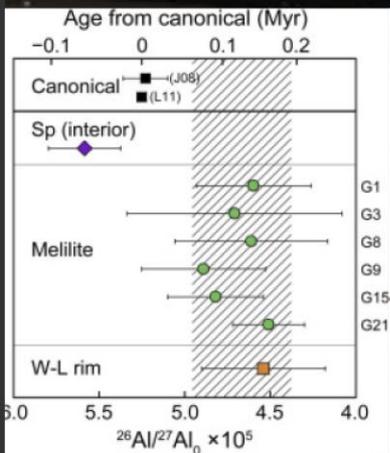


menu

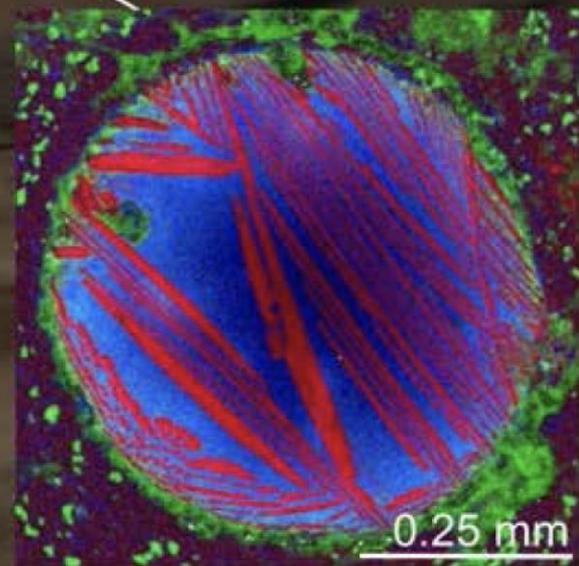
1. AZS マシン と43.7億年前事件 (冥王代)
2. 新大陸成長モデル (太古代・原生代)
3. 大陸縁リフティングの原動力 (顕生代)

episode 1: Hadean

AZSマシンと冥王代ジルコン



Calcium-Aluminum-Rich Inclusion



Chondrule

Early Solar System chronology

CAI formed in $< 10^5$ yrs at **4567.80 \pm 0.5 Ma (t_0)**

chondrules formed in 0.5- 5 Ma after t_0

^{182}W : Moon formed in 30-150 Ma after t_0

List of the oldest on the Earth

fossil: 3500 Ma

biomarker: 3950 Ma

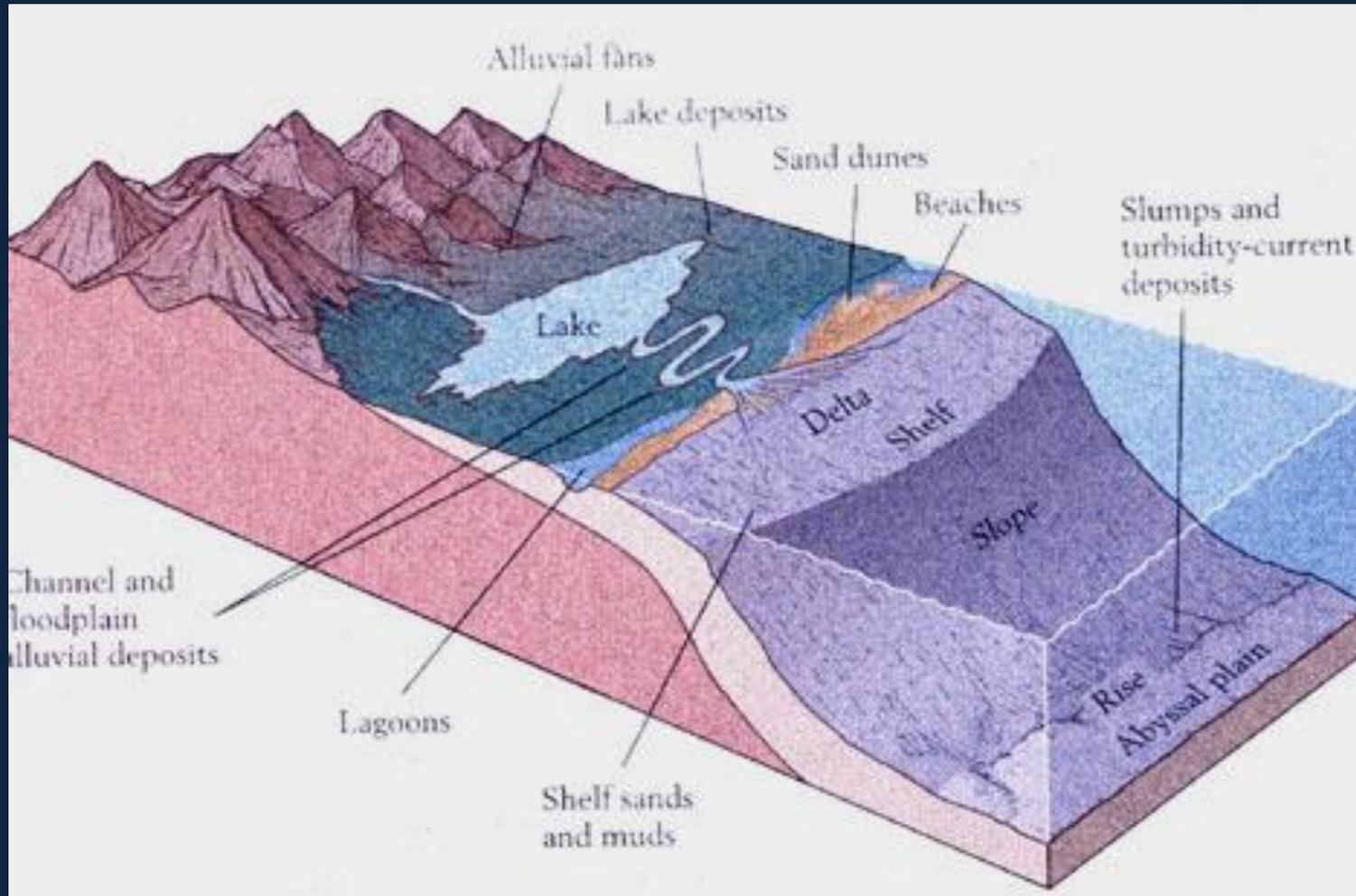
sediment: 3950 Ma

rock: 4100 Ma *これより古い岩石はない！*

mineral: 4370 Ma

堆積システム：削剥・運搬・堆積

陸源碎屑岩類 (terrigenous clastic rocks; 砂岩や礫岩) から
後背地 (provenance) の解読



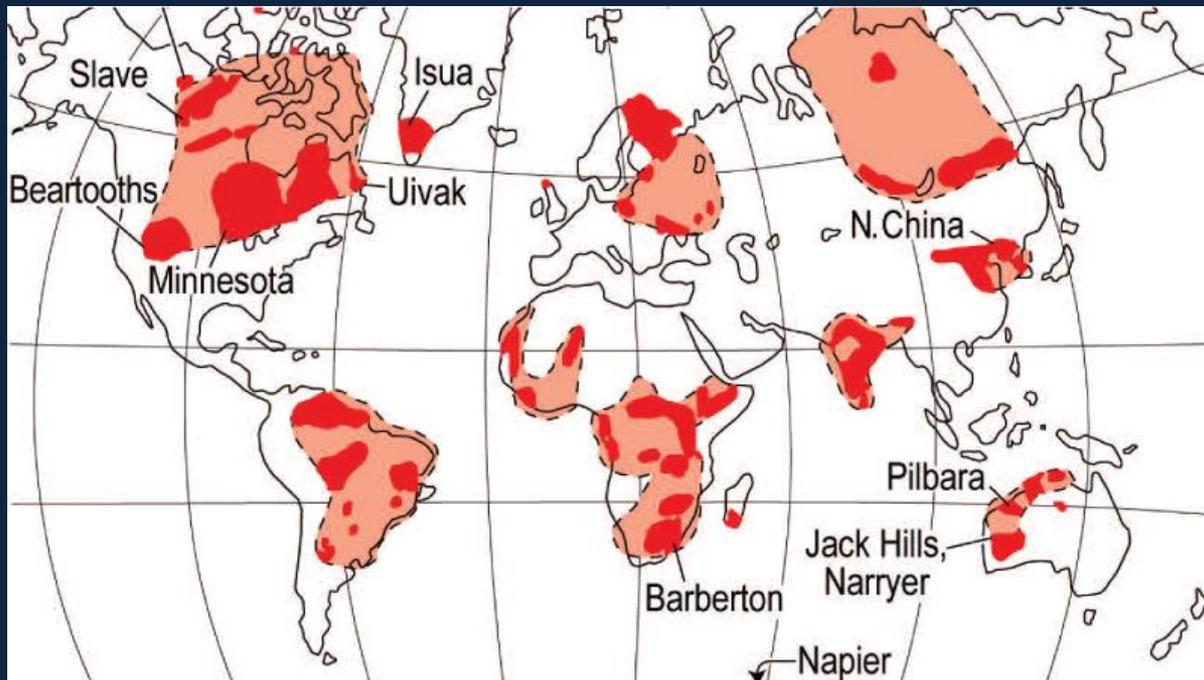
冥王代物質の探索：太古代岩石の分布地域

World record: *4.4 Ga mineral-bearing conglomerate in W. Australia*

Late 20th century: advance in dating technique, grain-by-grain (> 10 micrometer)

Early 21st century: the world record @ 4.4 Ga from Western Australia

even after the old rocks are gone,
hard mineral grains remain in younger sediments



3.0 Ga Jack Hills 礫岩

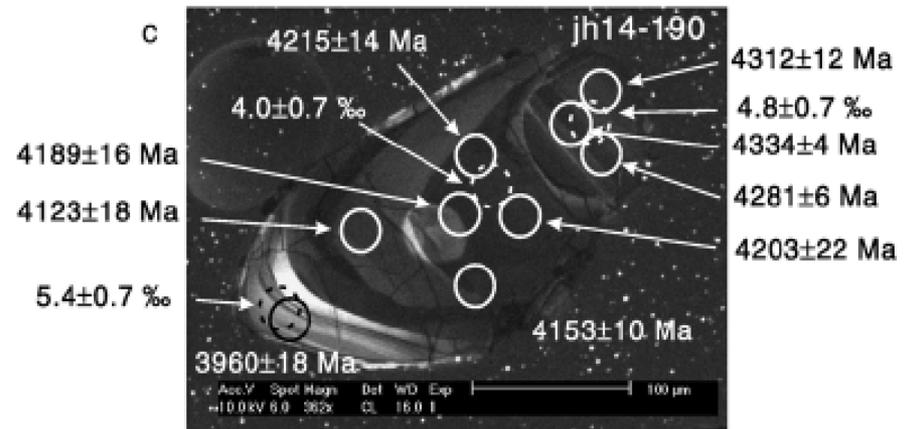
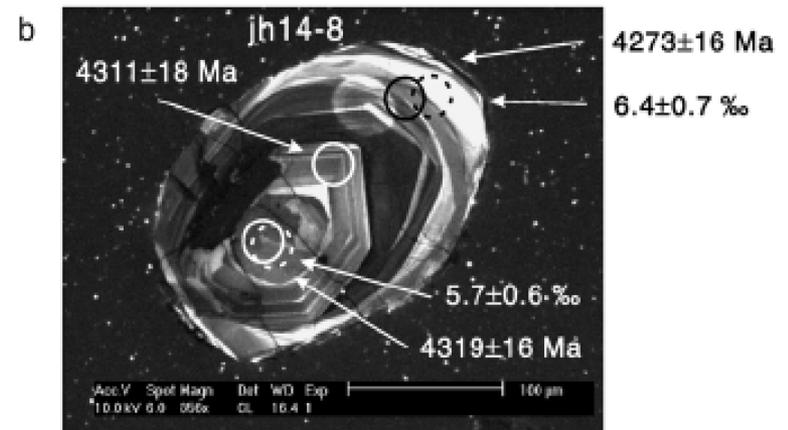
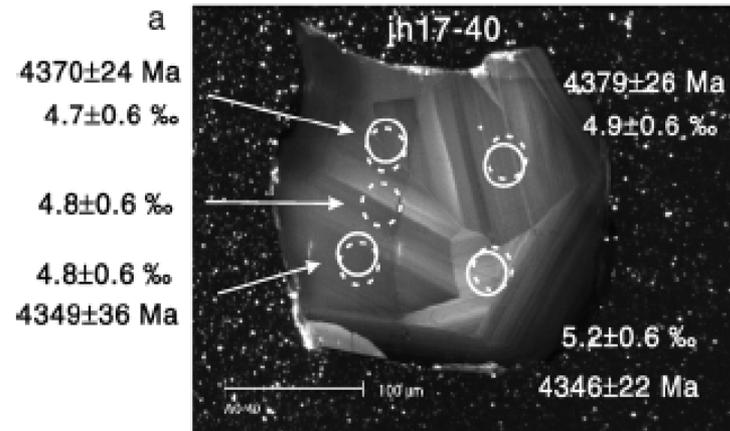
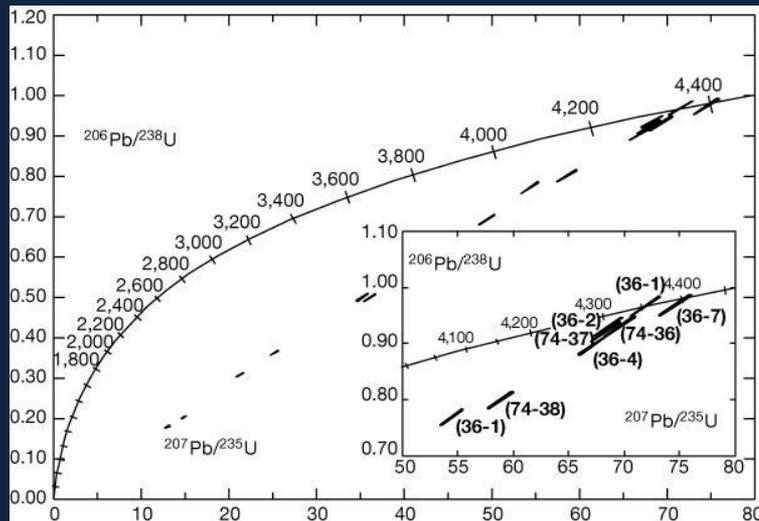


世界記録

@ 4379 ± 26 Ma

Hadean zircon from Jack Hills
by ANU group

10万粒から3粒！



地球最古物質の探索

微小領域 U-Pb 年代測定の改良／低価格化
LA-ICPMSの普及が決定的

でも、10万粒に3粒では効率的とはいえない...

Why? 最大の障害は.....

岩石からのジルコン分離作業 still primitive, dependent on *pain-staking human labor*,
In particular, **hand-pick under binocular** .
これまでの地球最古ジルコン: 10万粒から3粒.

① break down



② crush + sieve



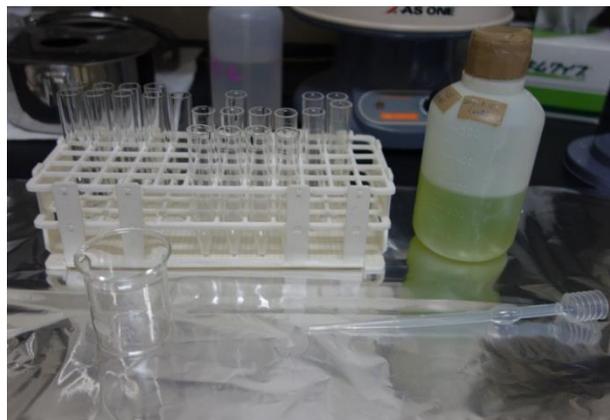
③ panning



④ magnetic



⑤ heavy liquid



⑥ **hand-pick under binocular**
これが律速...



micro-UFO-catcherをつくって、A. リンカーンになろう！



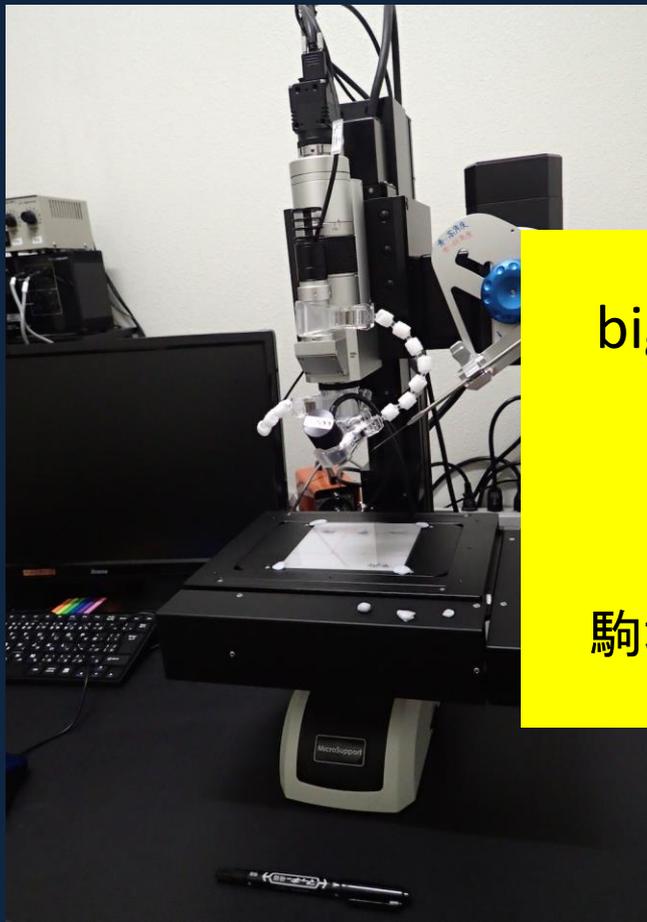
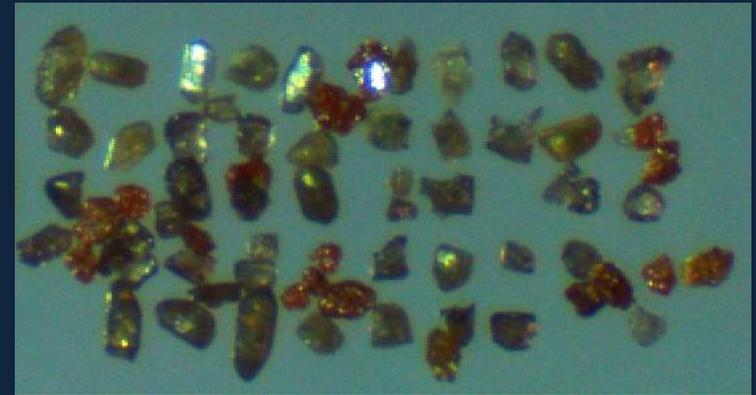
- 既存のマイクロピンセットを改良
（連続自動運転化）
- 画像処理ソフトを改良
（色調などの光学情報を学習）

High-Reliability Automatic Zircon Separator (Hi-Re AZS)

高忠実度自動ジルコン選別装置

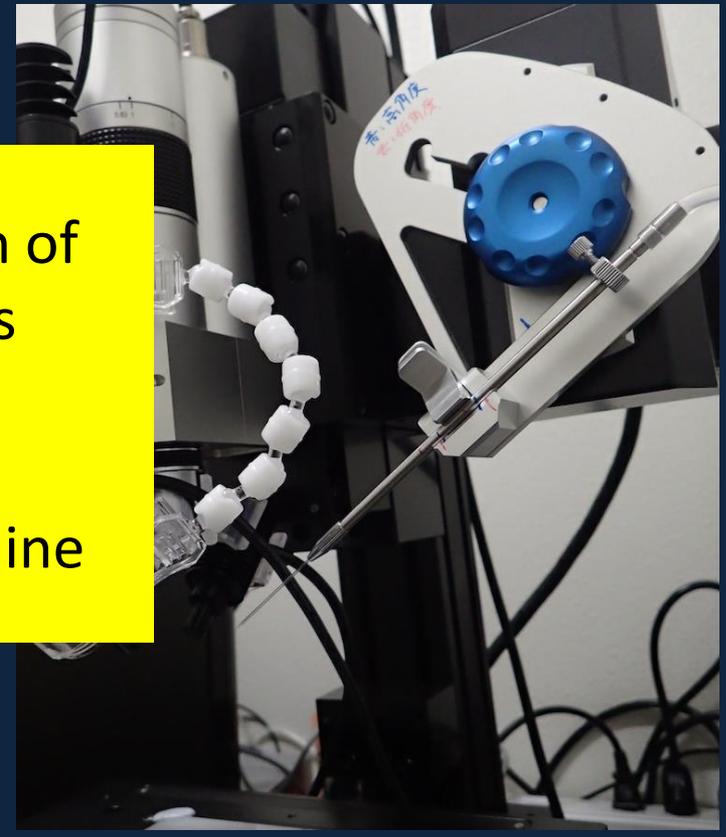
Empirism : dark-color in older grains

Limit in human hand-picking ----->
Robotics replacing human labor



big customization of
micro-tweezers

駒場 special machine



レビュー1 レビュー2 使用レンズ: 02_x1.0

画像処理: 設定1 種別: 全て 特徴量: 絶対最大長 50 位まで 具順 陰順 抽出 詳細条件を使用 詳細条件設定 輪郭線 画像サイズ: 小

1: 139.51µm 2: 111.97µm 3: 106.23µm 4: 100.00µm 5: 100.00µm 6: 100.00µm 7: 100.00µm 8: 100.00µm 9: 100.00µm 10: 100.00µm 11: 100.00µm 12: 100.00µm

13: 100.00µm 14: 100.00µm 15: 100.00µm 16: 100.00µm 17: 100.00µm 18: 100.00µm 19: 100.00µm 20: 100.00µm 21: 100.00µm 22: 100.00µm 23: 100.00µm 24: 100.00µm

25: 100.00µm 26: 100.00µm 27: 93.17µm 28: 87.01µm 29: 85.67µm 30: 85.67µm 31: 85.67µm 32: 83.45µm 33: 77.64µm 34: 72.77µm 35: 71.50µm 36: 68.39µm

全選択 全解除 連続採取 単採取 採取 採取エリア設定 採取エリア名: area1

No.	選択	採取	画像ファイル名	画像処理	絶対最大長[µm]	対角幅[µm]	面積[µm ²]	円相当径[µm]	円形度	粗状度	HLS平均	HLS最小	HLS最大	RGB平均	RGB最小	RGB最大	重心座標[µm]	採取先座標[µm]
1			00000018	設定1	139.51	62.50	6240.11	89.14	0.60	1.57	52.3,110.4,86.3	0,78,38	359,144,168	148.5,102.0,73.7	95,60,49	215,160,103	26244.75,-6526.55	
2			00000008	設定1	111.97	59.43	3925.39	70.70	0.50	1.58	68.9,99.1,99.7	0,72,19	359,162,255	138.0,91.0,61.5	97,60,10	255,247,108	24683.68,-11497.01	
3			00000019	設定1	106.23	80.90	3992.90	71.30	0.47	1.49	64.2,89.7,93.8	0,60,12	359,124,148	123.2,77.4,58.4	71,43,35	188,124,103	27564.45,-7904.57	
4			00000001	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	80.1,80.4,109.3	0,42,7	359,169,255	115.9,71.3,47.4	62,29,0	255,194,107	32466.32,-14740.21	
5			00000001	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	154.2,76.4,81.6	0,48,6	359,157,235	97.7,60.5,63.1	56,36,8	234,156,154	33655.76,-14184.31	
6			00000001	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	125.8,73.0,74.6	0,49,10	359,156,142	91.9,61.9,60.1	55,37,26	164,165,154	32587.44,-13730.89	
7			00000003	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	158.8,107.2,61.5	0,64,9	359,168,219	123.3,99.4,96.1	55,52,34	241,176,175	2499.16,-14333.38	
8			00000004	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	70.3,134.3,65.5	0,95,7	359,173,165	163.1,129.6,107.3	98,84,71	222,169,153	21630.92,-14504.18	
9			00000006	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	99.6,96.3,67.3	0,56,7	359,168,145	117.5,87.6,76.7	78,44,26	192,178,155	21050.17,-12555.74	
10			00000008	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	67.2,111.4,131.9	0,78,7	359,159,235	166.8,91.5,58.5	76,51,11	246,164,140	24854.52,-11622.20	
11			00000009	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	192.4,120.0,62.6	0,80,3	359,196,255	138.1,112.3,108.4	61,62,49	255,252,159	30621.60,-12852.01	
12			00000009	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	207.3,88.6,73.7	0,55,3	359,166,255	100.6,75.2,85.8	39,36,0	255,213,166	27686.82,-11513.50	
13			00000010	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	65.7,150.5,88.0	0,95,2	359,248,255	181.0,146.8,120.4	78,78,39	255,255,241	31022.22,-12619.09	
14			00000015	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	172.4,108.5,54.7	0,73,5	359,168,111	125.9,98.4,96.5	82,51,42	187,178,166	19233.40,-9504.18	
15			00000015	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	113.0,113.3,70.6	0,61,4	359,162,149	134.5,101.5,97.8	36,41,50	213,177,183	18553.28,-9178.10	
16			00000016	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	74.5,102.9,81.9	0,58,4	359,169,240	131.0,95.6,75.9	74,42,16	250,206,155	19161.97,-7383.07	
17			00000017	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	30.6,143.5,115.0	5,119,42	355,172,215	193.3,143.2,94.3	155,106,72	241,181,144	22466.32,-6923.44	
18			00000021	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	139.0,78.0,65.2	0,49,6	359,165,137	93.5,65.9,67.1	61,43,28	165,176,160	32127.81,-5060.08	
19			00000022	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	190.0,89.1,51.9	0,55,2	359,156,163	102.8,79.5,82.2	50,39,32	187,156,147	28363.84,-6206.05	
20			00000023	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	121.6,99.2,99.0	0,60,5	359,153,255	137.7,82.8,66.0	65,41,9	255,180,118	24379.29,-5752.63	
21			00000025	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	125.8,89.7,101.0	0,47,2	359,183,255	124.0,75.0,59.2	58,37,0	255,255,152	20866.94,-4578.72	
22			00000026	設定1	100.00	100.00	7854.00	100.00	1.00	1.00	176.8,84.3,99.4	0,41,0	359,157,255	114.5,67.4,62.2	53,17,0	255,209,138	18817.25,-3684.31	

座標保存

XYステップ フォーカス ズーム

移動量X: 10000µm 移動量Y: 1000µm 移動量Z: 1500µm

X: 0µm Y: 0µm Z: 68693µm

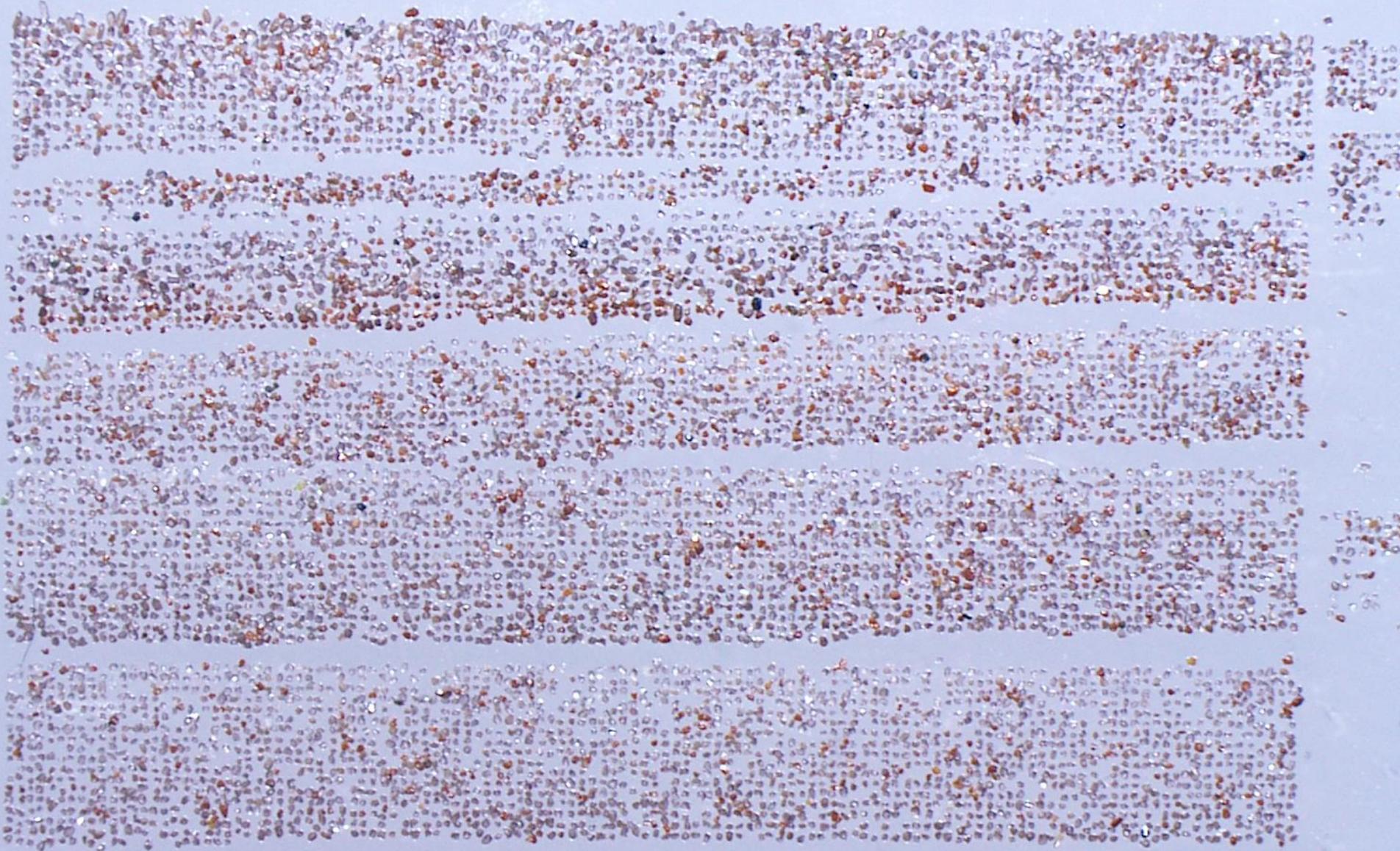
速度: 4 速度: 3

観察位置 採取位置

ON

Stage: (+32.292mm, -2.803mm) Focus: (+68.928mm) Arms: (+0.032mm, +10.046mm, +12.603mm) ントローラ

10,000 grains collected in 1 week
(the most difficult part was in aligning grains after pick-up)



効率の2段階向上

1) AZS (automatic zircon separator) の開発

- 1) 長時間単調作業の代行
- 2) 画像登録され、測定用に配列された試料の迅速収集
(1分で1粒を確実にピック・配列)

2) 古そうな粒子だけを事前に選ぶテクニックとして無研磨簡便測定を新考案

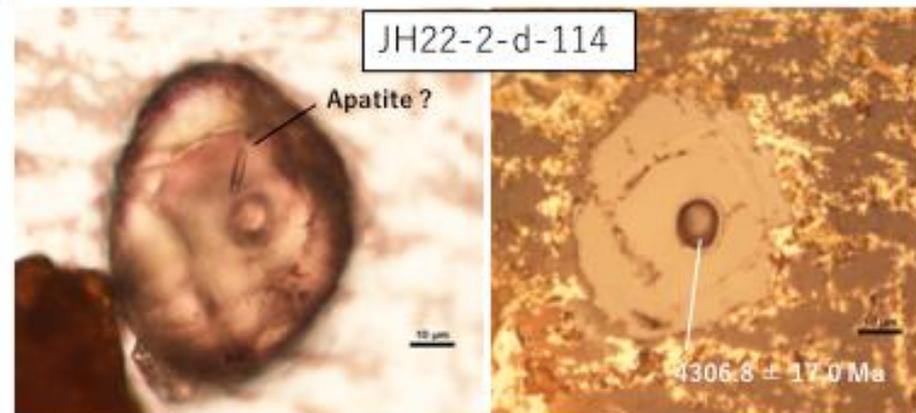
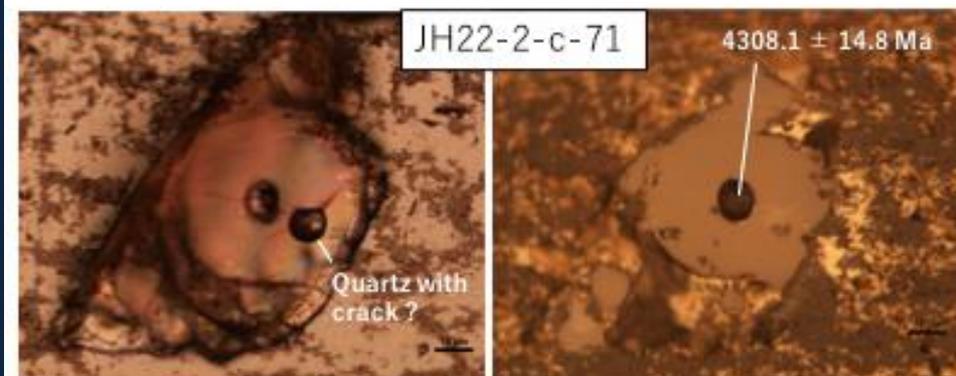
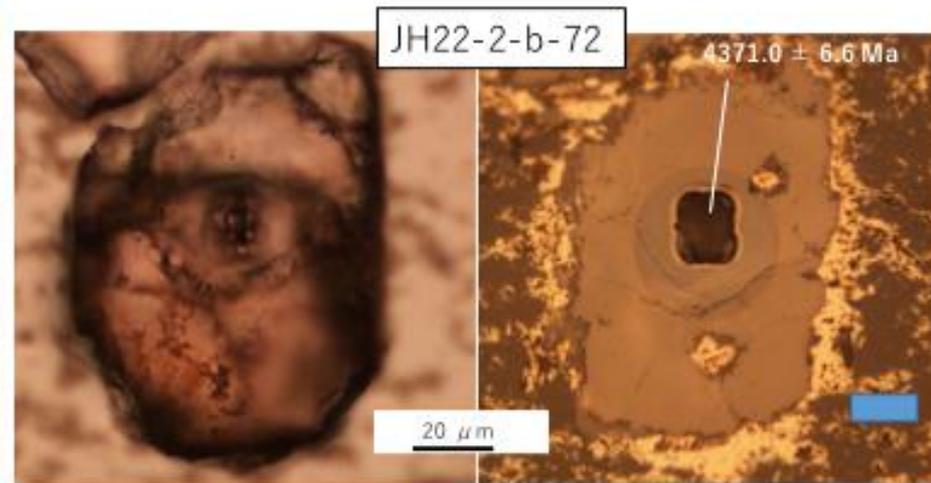
TANDEM-LA-LIBS 分析装置で簡便迅速分析

(手間のかかる精密年代測定は、少数精鋭粒子のみに対して行えばよい。)

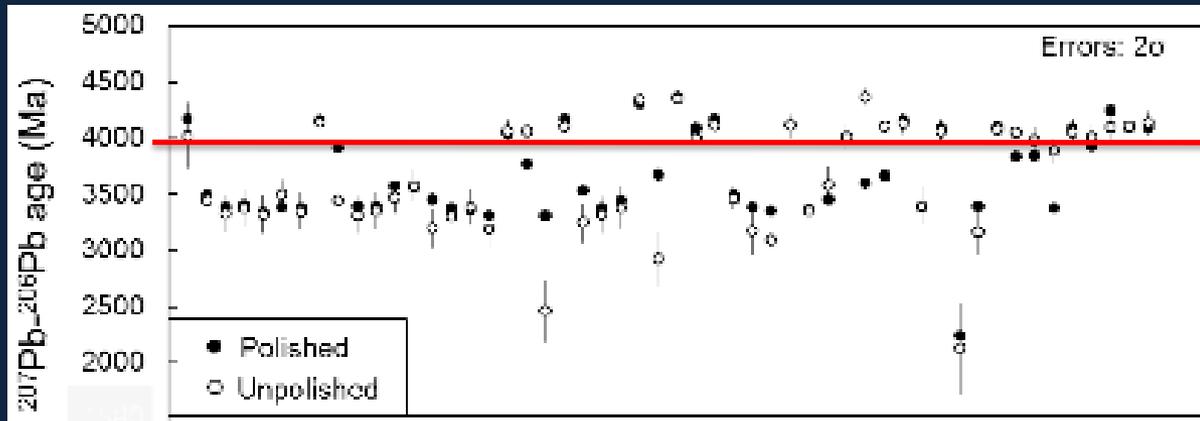
あわせて2桁の効率向上を達成！

従来10万粒中から3粒だったが、
約3000粒の中から10粒とれた！

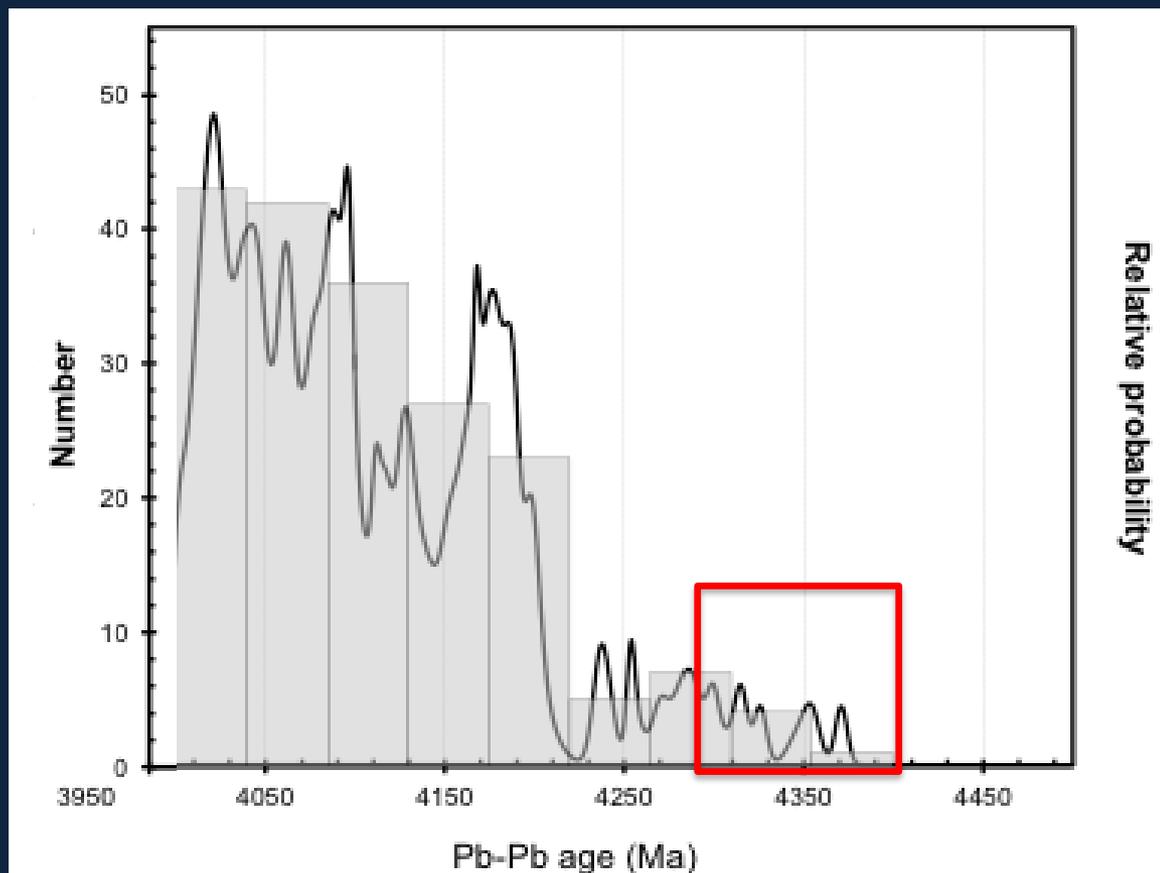
見つけた！ > 4.3 Ga zircons captured by AZS machine
from the Jack Hills conglomerate, W. Australia



Short-cut method for getting approximate ages before resin-mounting



冥王代 (> 4.0 Ga) ジルコン200粒



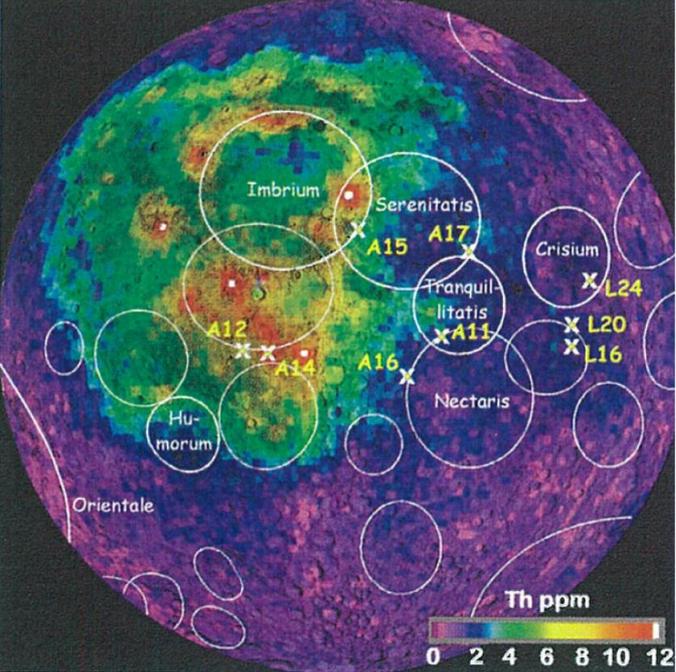
最古粒子 (> 4.3 Ga)

10粒獲得!

Isozaki et al. (2018 in press)

もっと古いのは?

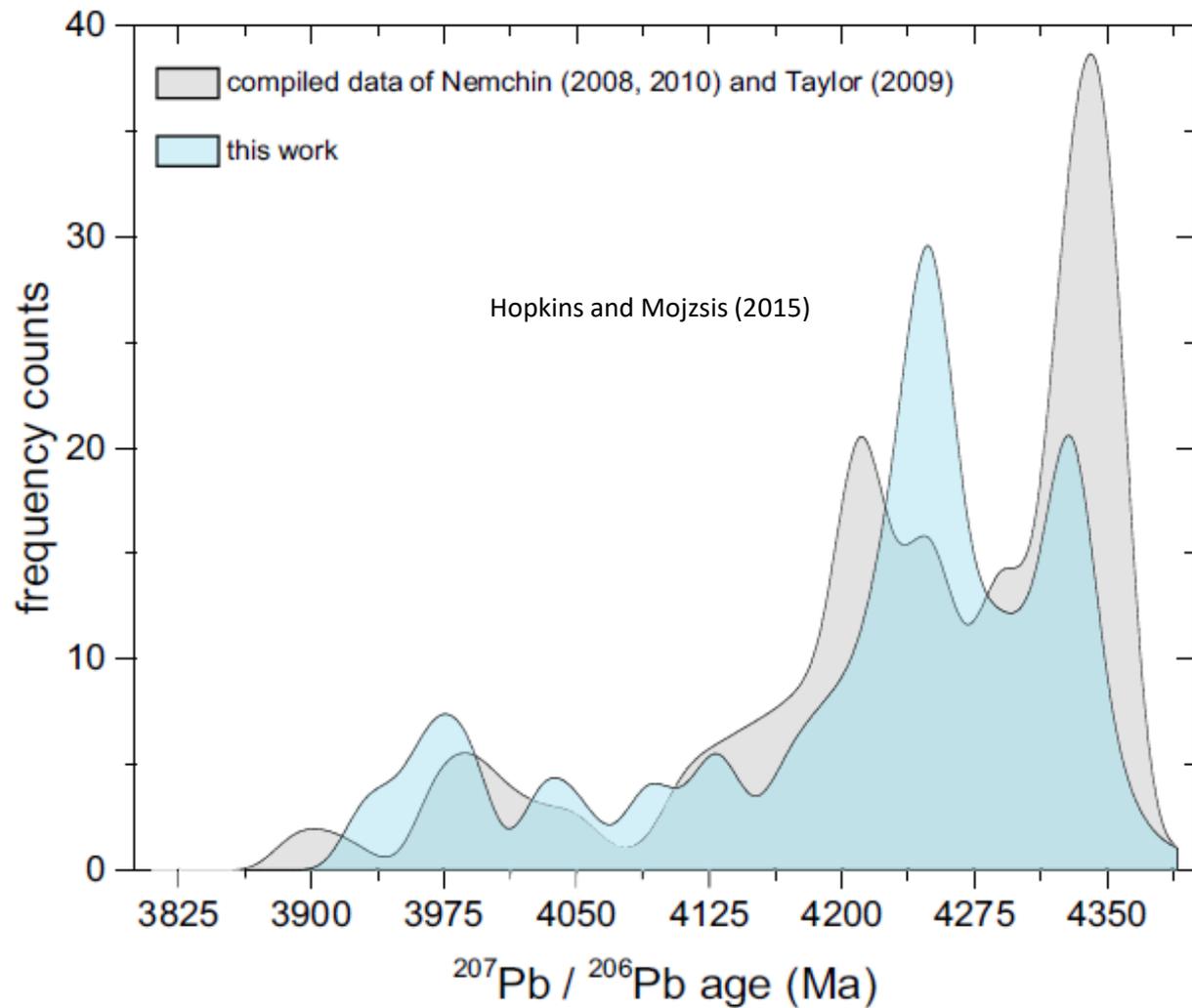
Age limit or much older one??



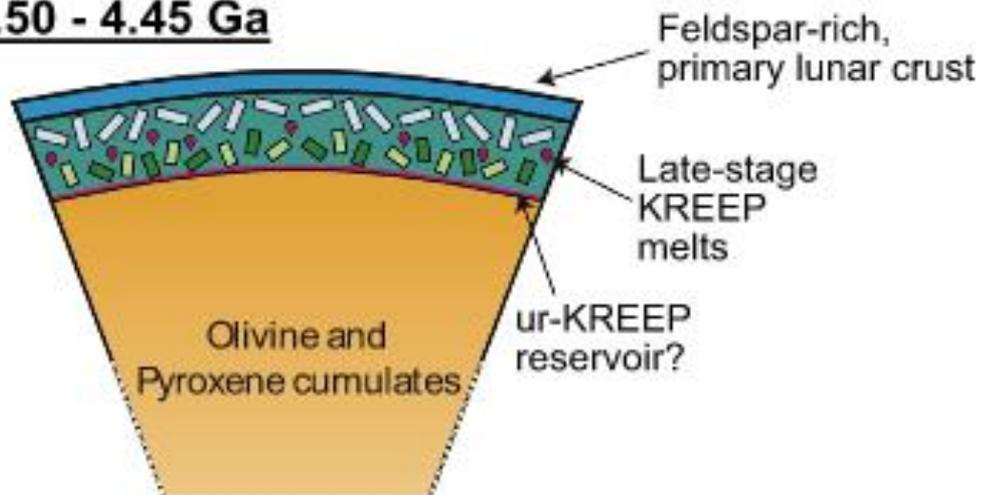
> 3000 km large crater
ejecta

Possible age limit @4.37 Ga common in Earth and Moon implications?

Age spectrum of lunar zircons from Apollo samples



1. 4.50 - 4.45 Ga

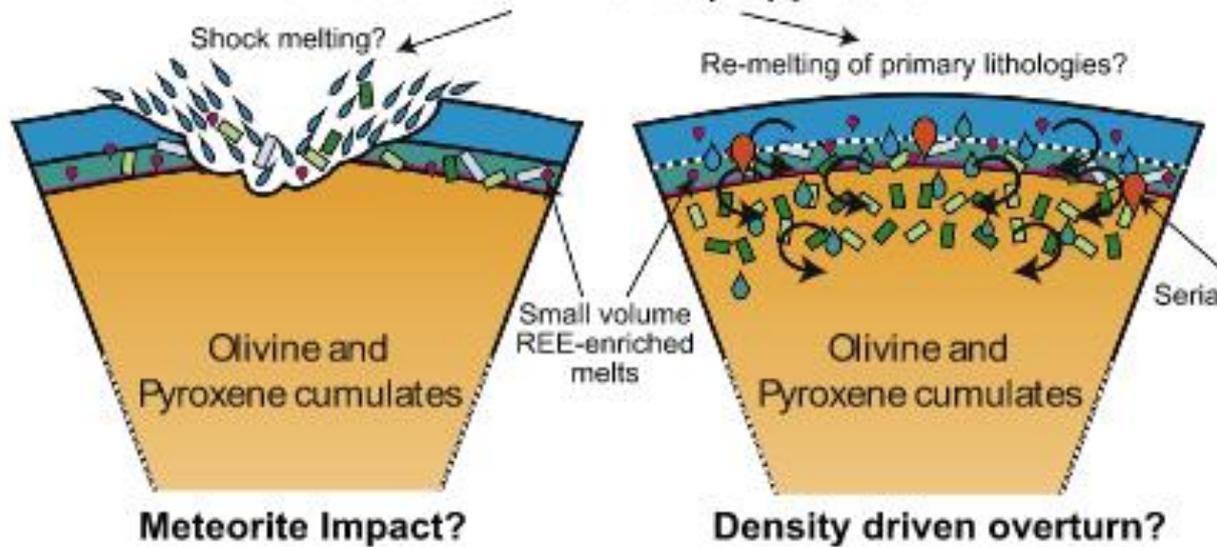


General belief

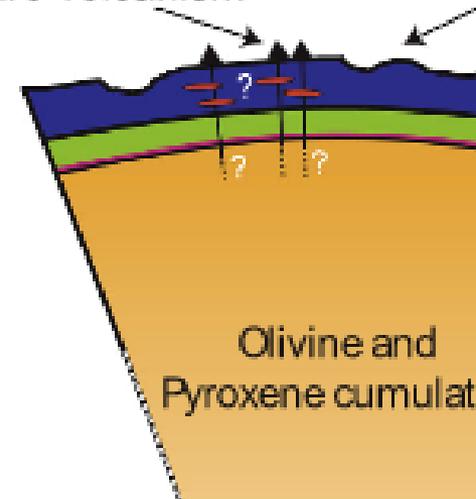
1. consolidation of magma ocean > 4330 Ma
2. magmatism/resurfacing @4250 Ma
3. later impact @3950 Ma

2. c. 4.34 Ga

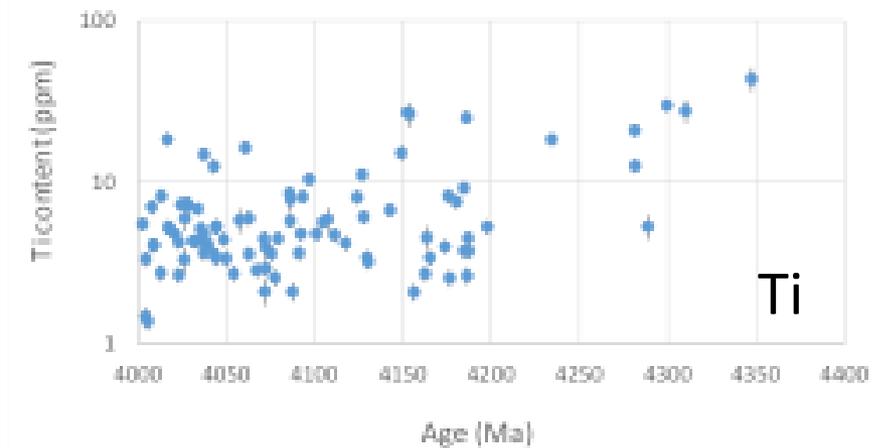
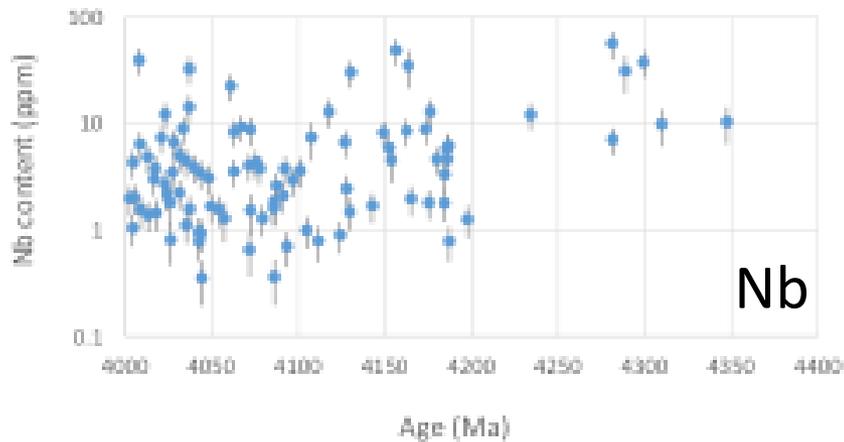
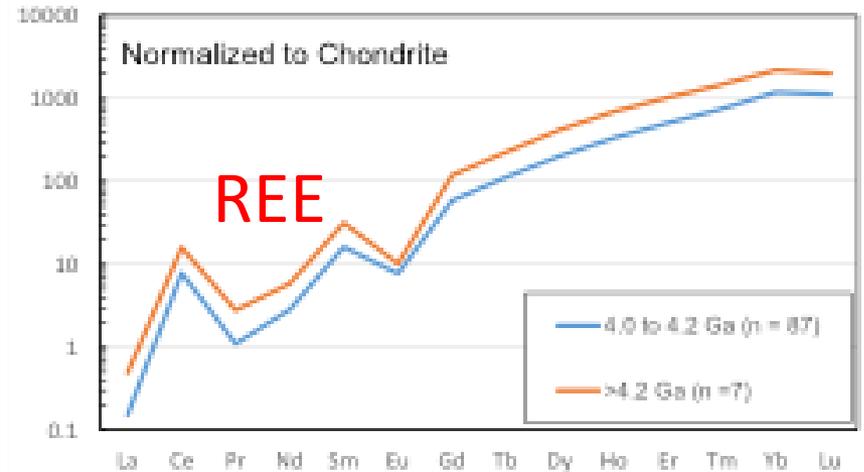
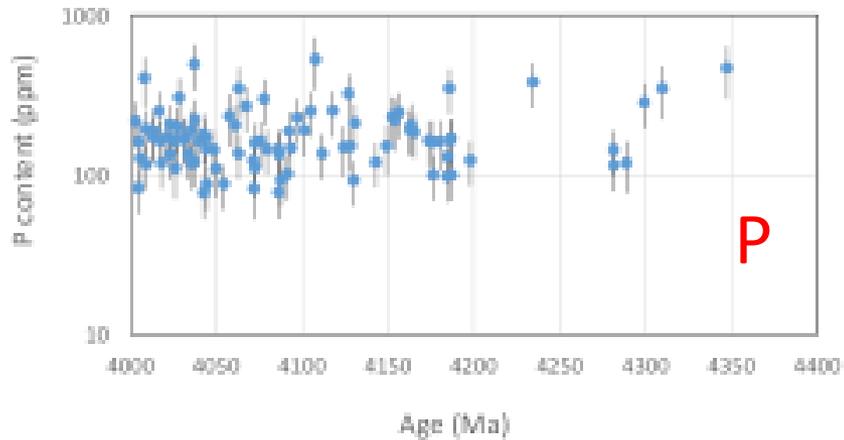
Resurfacing, reworking of primary lunar crustal lithologies.
Formation of NWA 3163 (PS) protolith?



Mare volcanism



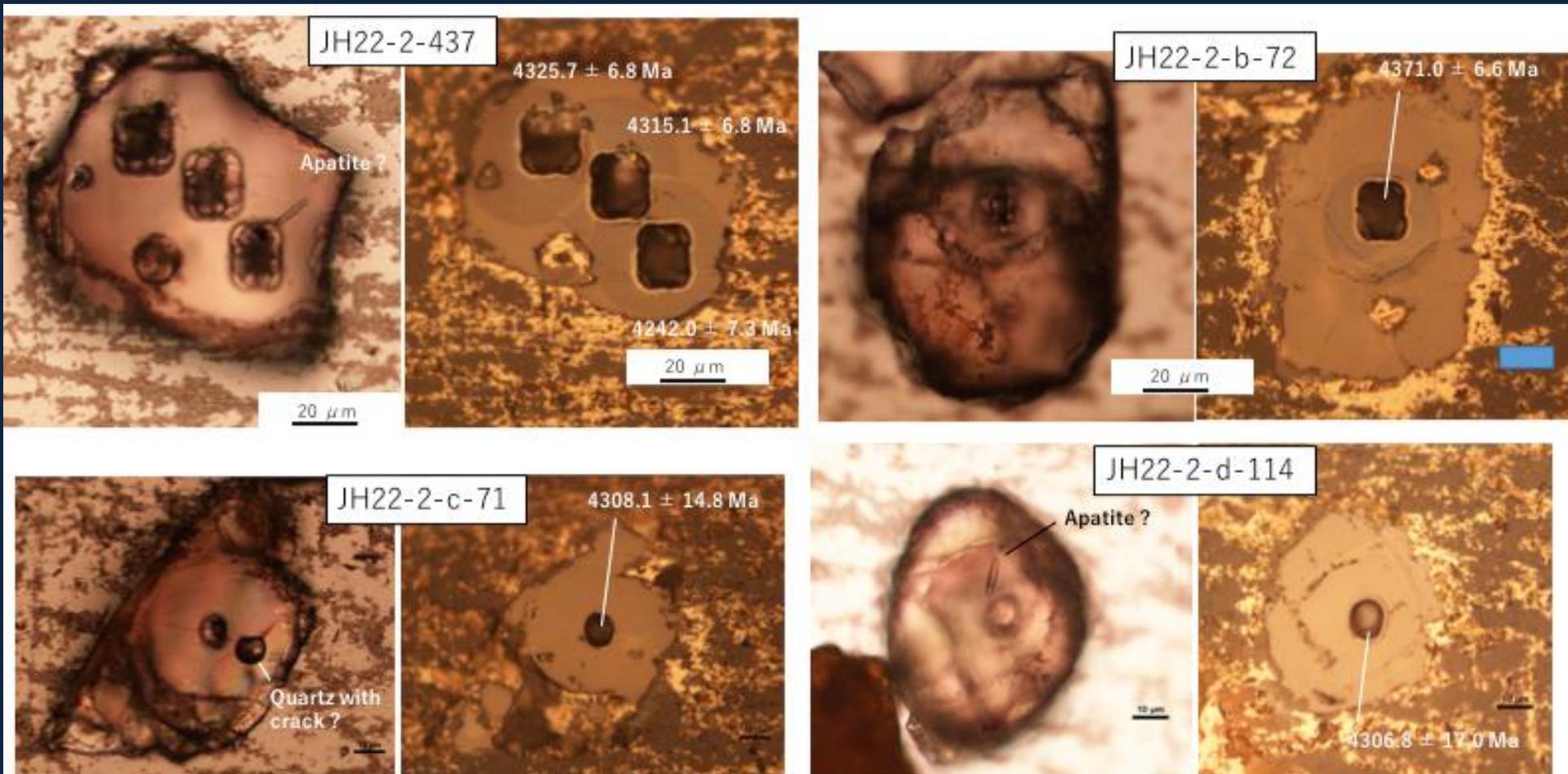
geochemical trend in > 4.0 Ga zircons



Not yet clear but may have a particular secular trend

----> faint memory of lost primordial continental crust?? ...

The oldest 4.3 Ga zircons containing mineral inclusions, such as apatite $\text{Ca}_5(\text{PO}_4)_3(\text{F}, \text{Cl}, \text{OH})_2$ w/ boessential elements e.g., P and OH

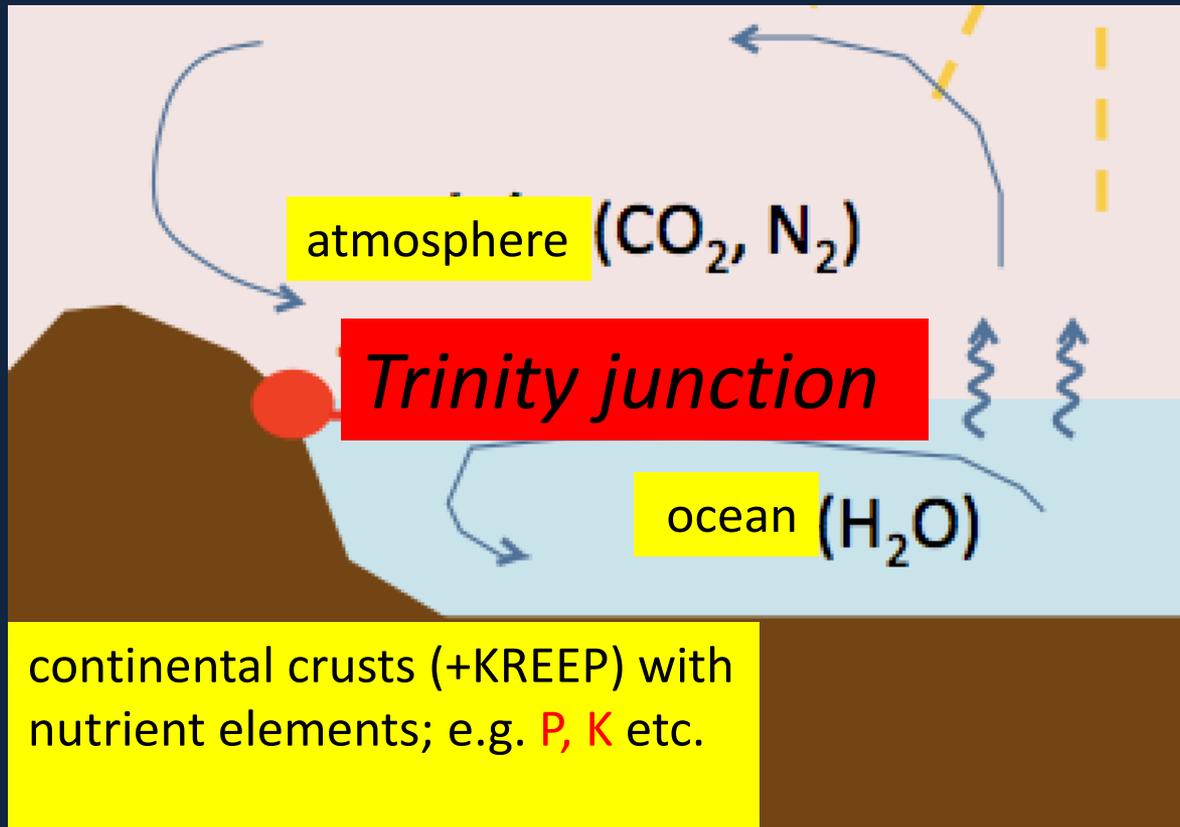


continental crusts were inevitable for life!

“habitable trinity” model

(Dohm and Maruyama, 2014)

co-existence with direct contact among atmosphere, ocean, and continent



continents as
nutrient source

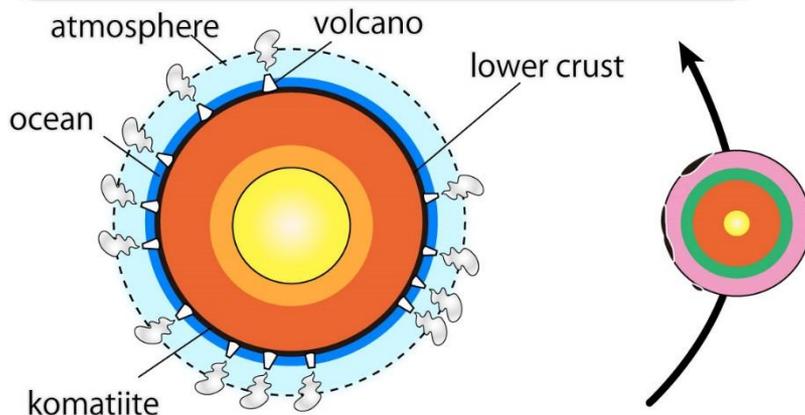
atmpsph.-ocean
contact for resolving
nutrients into water
thru surface erosion

Models on formation process of the Earth

conventional views:

No continent on the Early Earth
but solely with komatiitic/basaltic oceanic
crusts occupied
the surface of the young planet

In contrast,



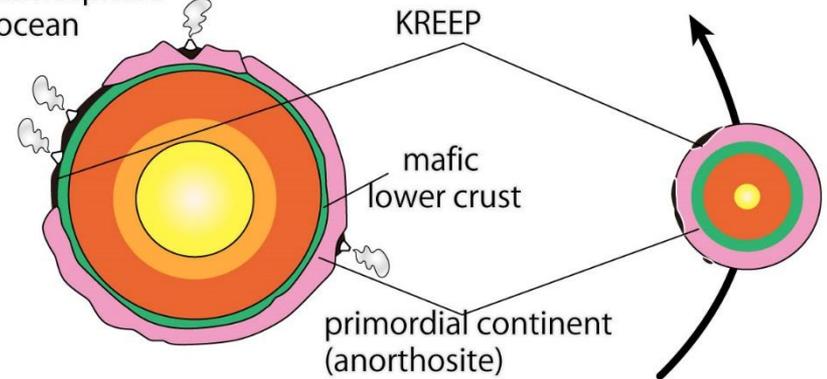
2 step formation of the Earth.

III ABEL model

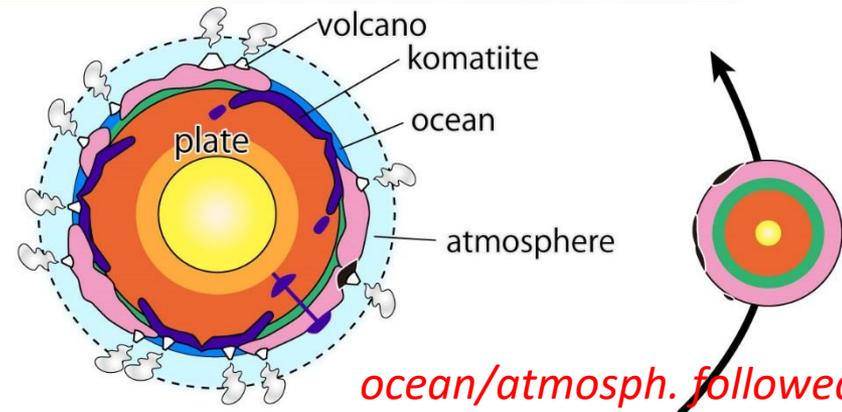
solid Earth first

4.53Ga 1st step: completely dry Earth was formed

no atmosphere
no ocean



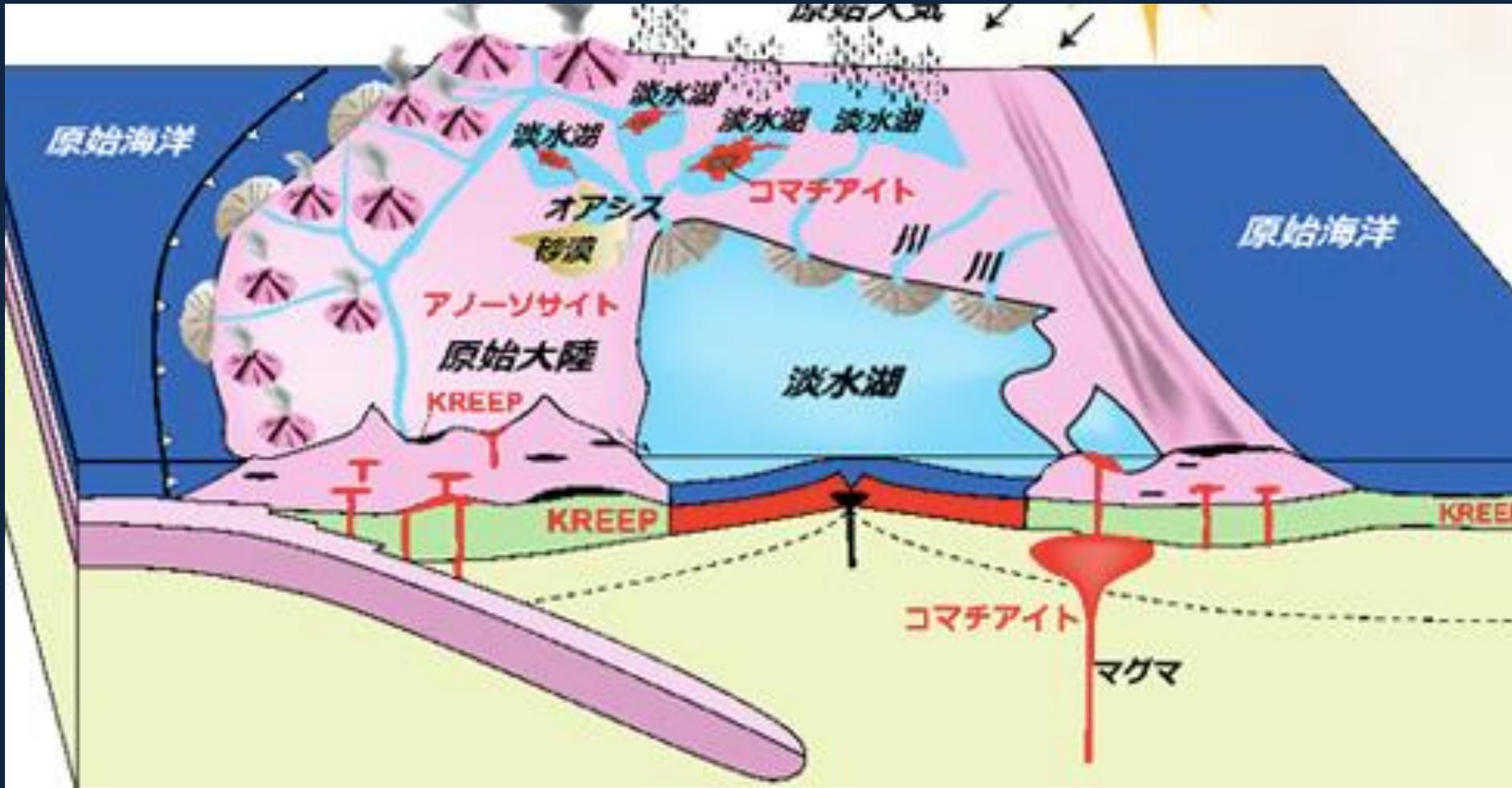
4.4Ga 2nd step: ABEL bombardment delivered
oceanic and atmospheric components



ocean/atmosph. followed

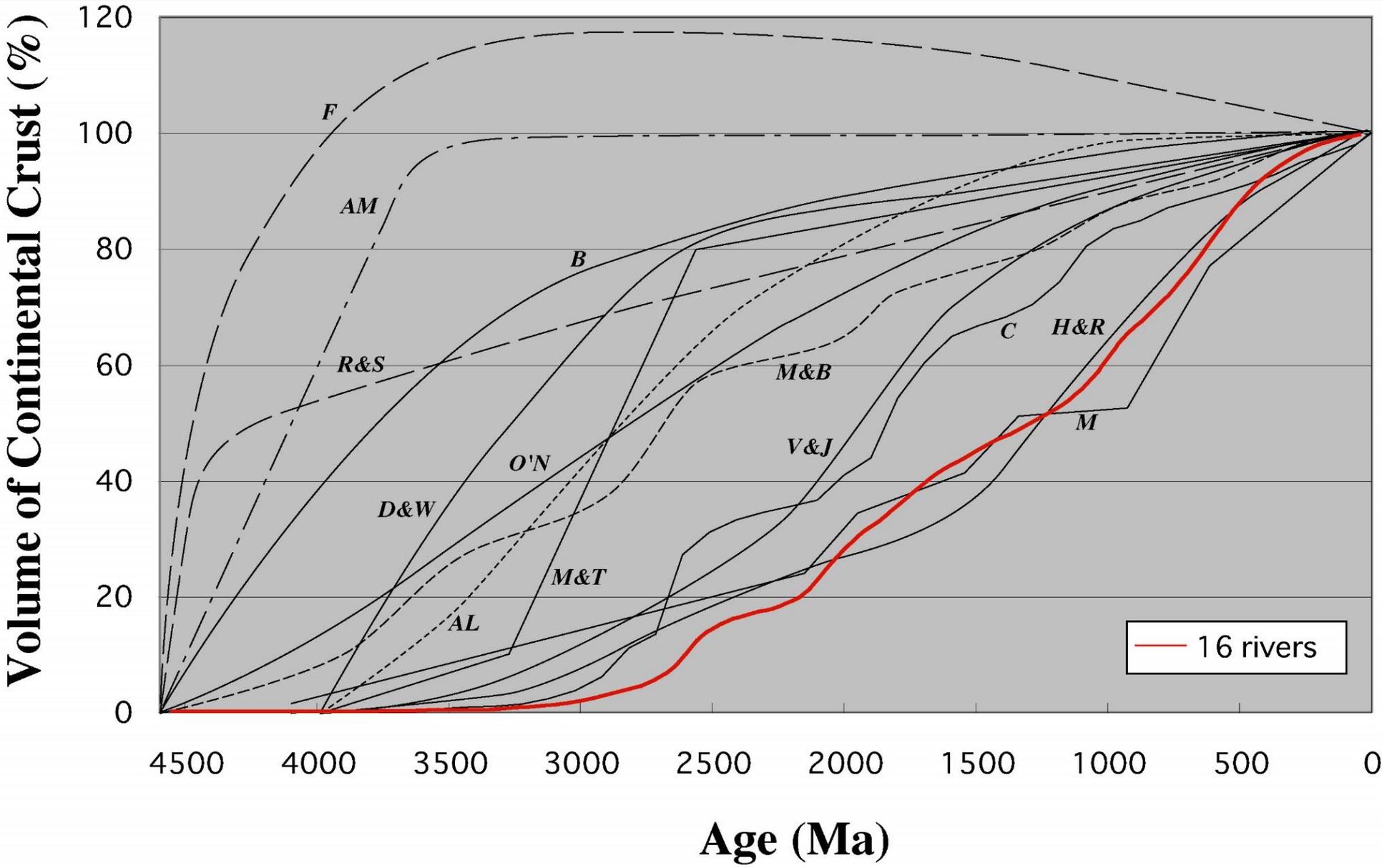
4.4-4.2 Earth with the earliest life

bio-essential elements + variety in on-land fresh-water settings



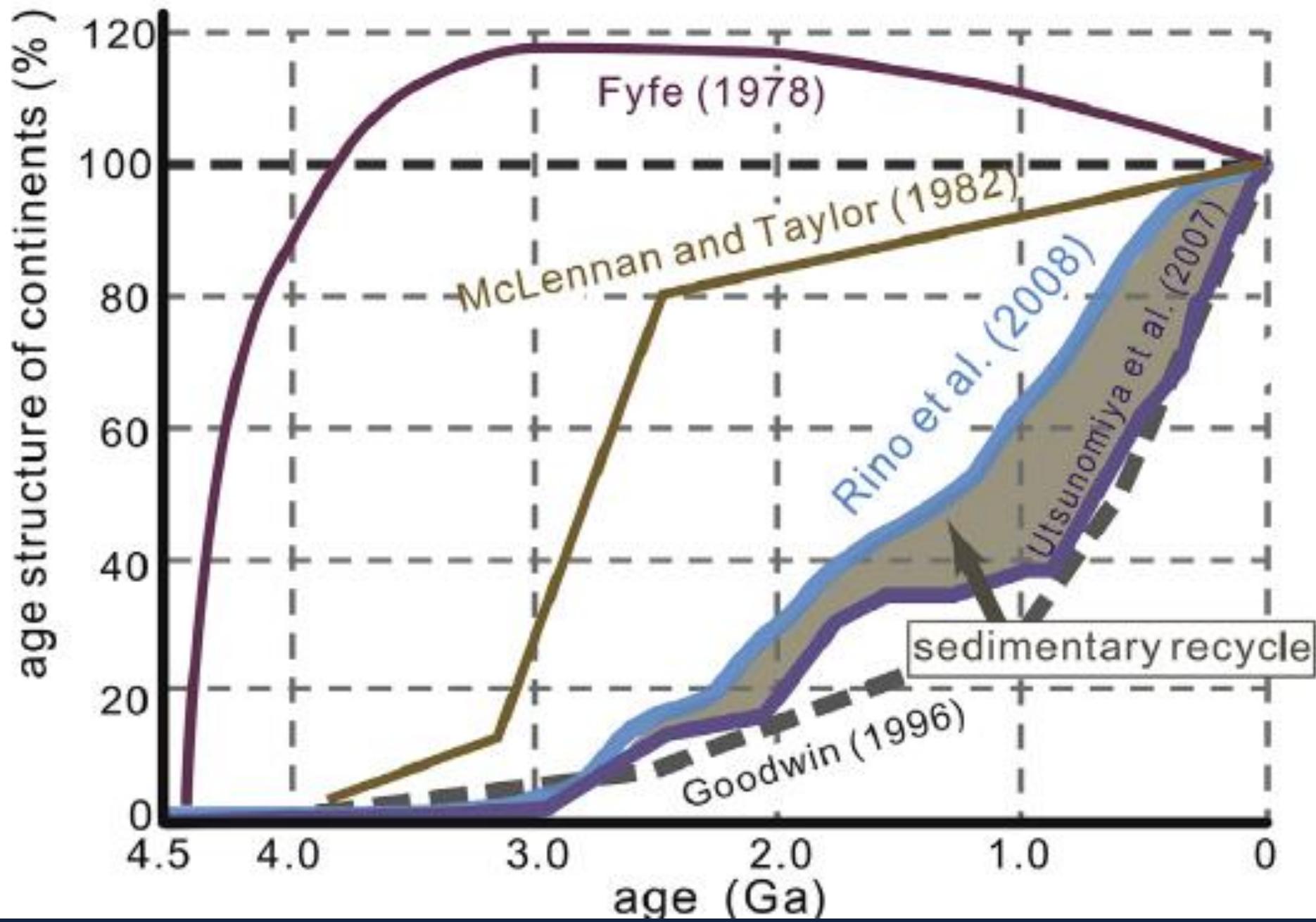
episode 2: Archean-Proterozoic

新しい大陸成長曲線

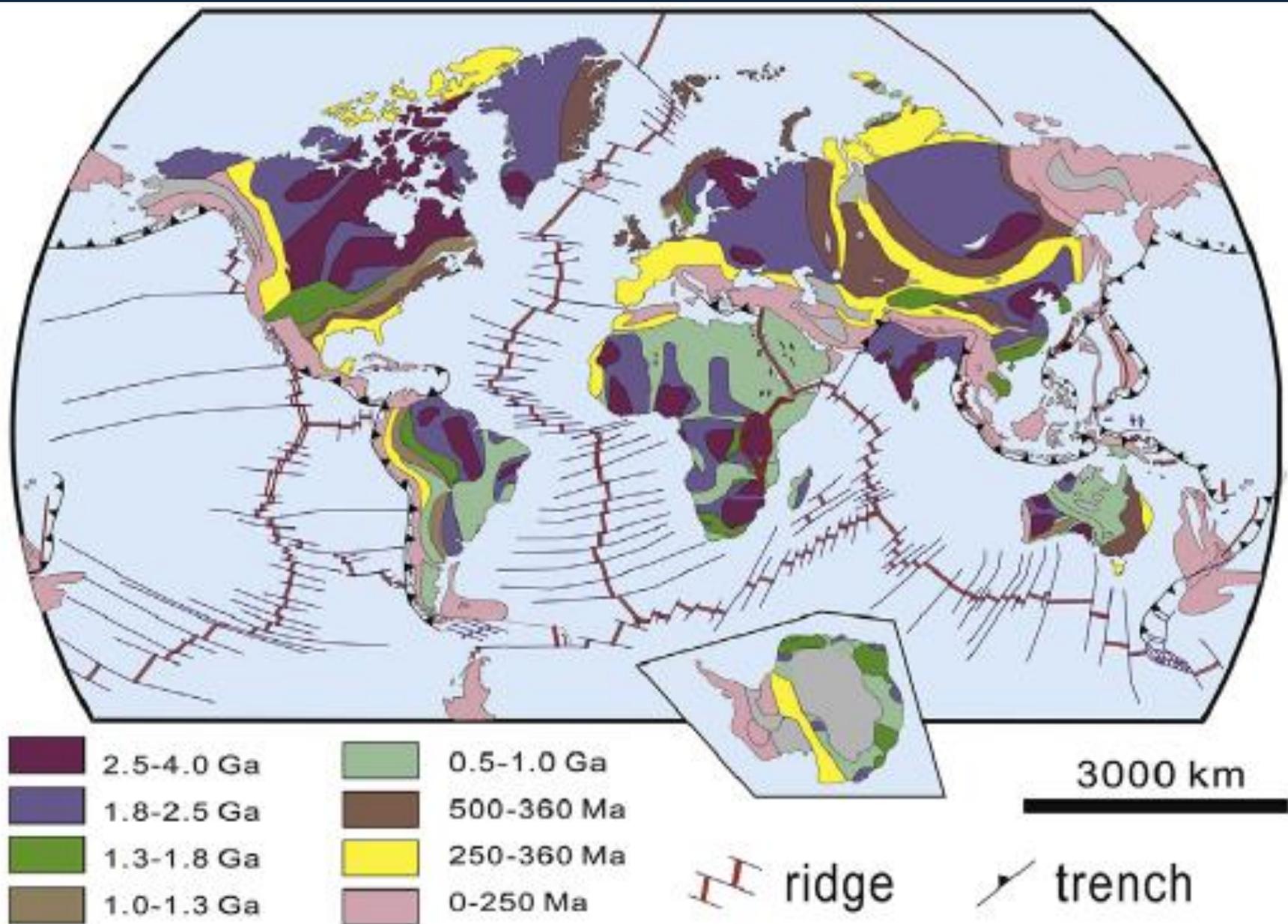


これまでに提案された多様な大陸成長曲線 (Rino et al., 2008のコンパイル)

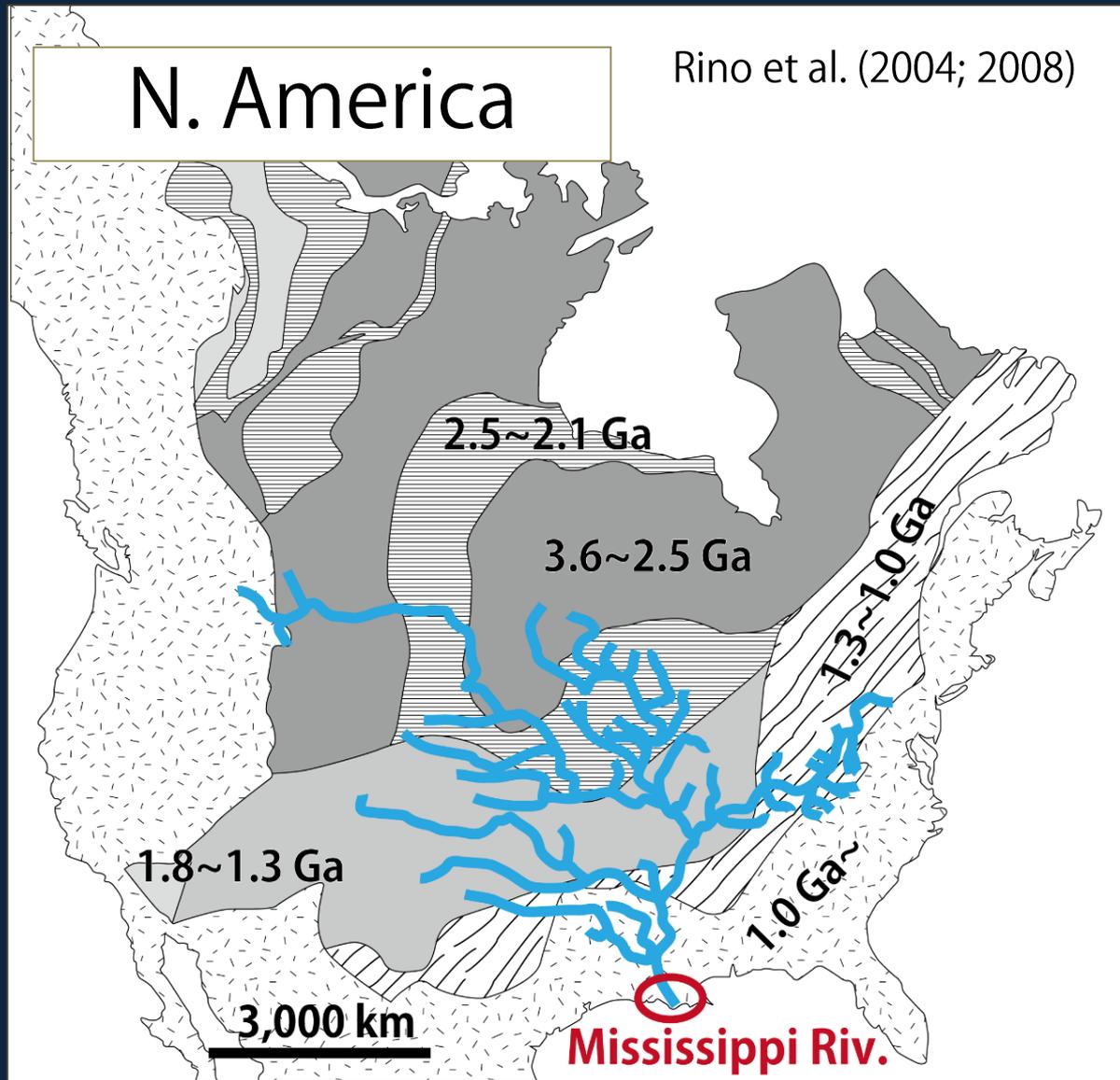
B. Previous models of continental growth



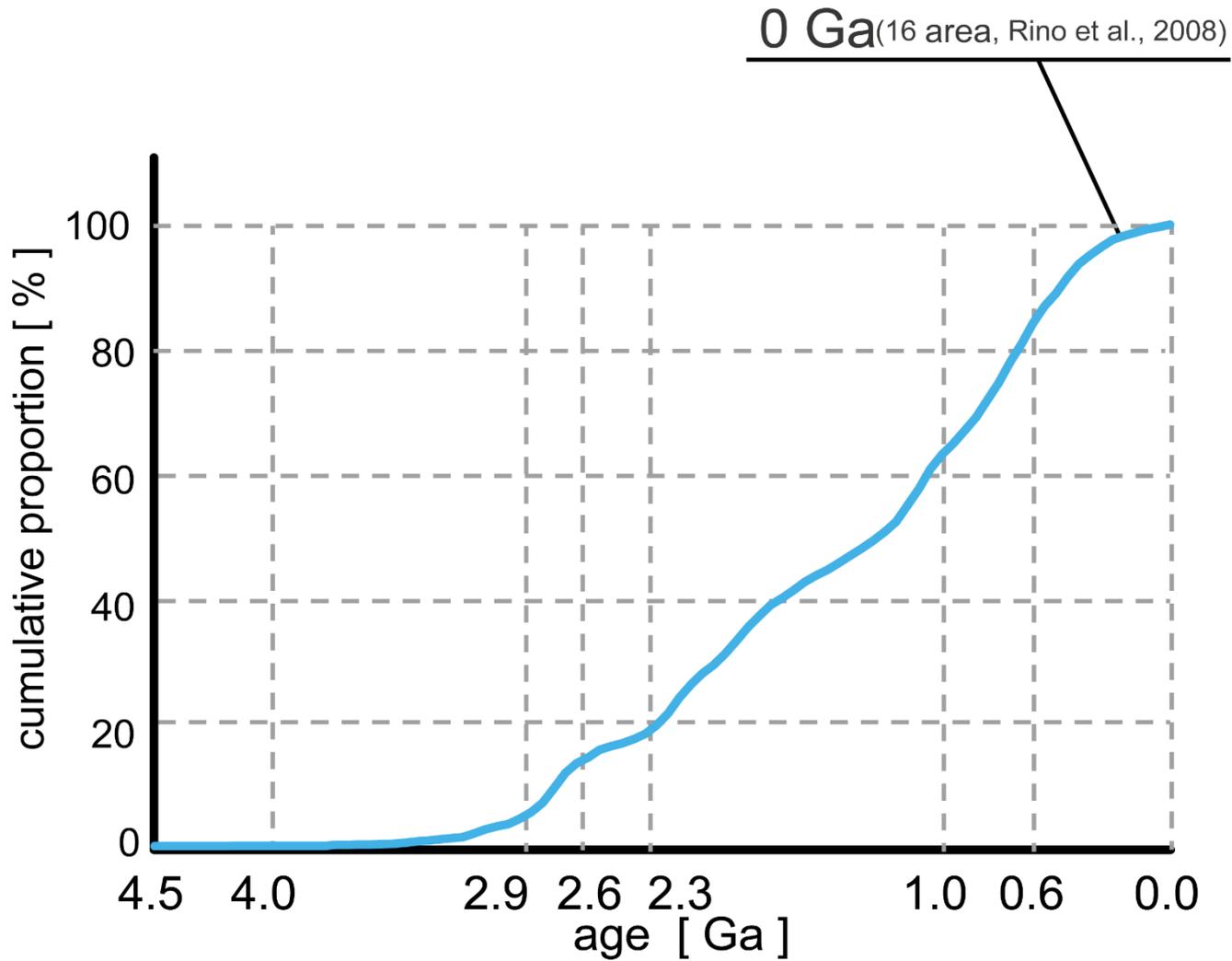
世界に現存する地殻の年代区分（海洋はすべて約2億年前よりも若い）



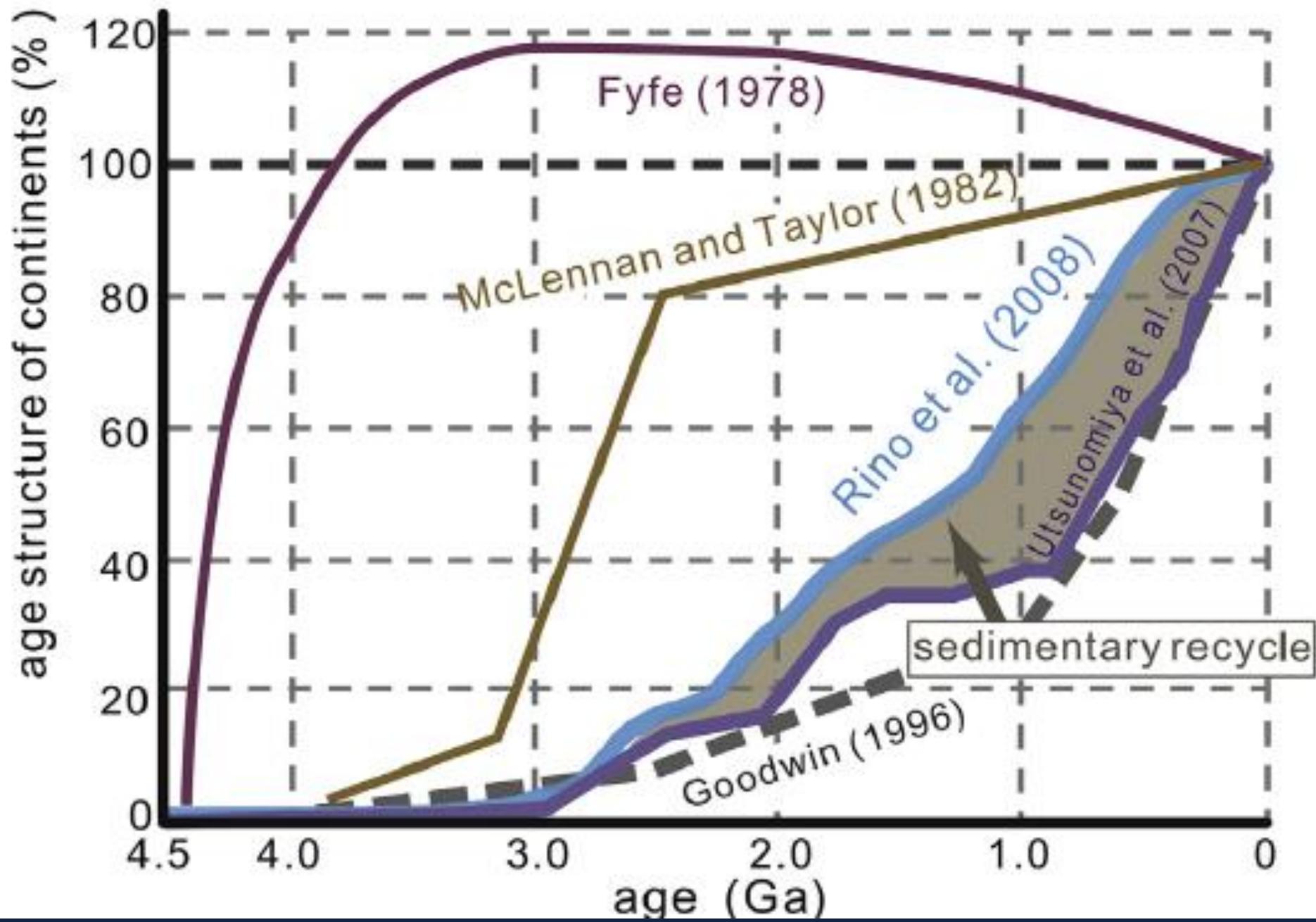
Detrital zircon age spectra in river sand
reflect age structure of continents



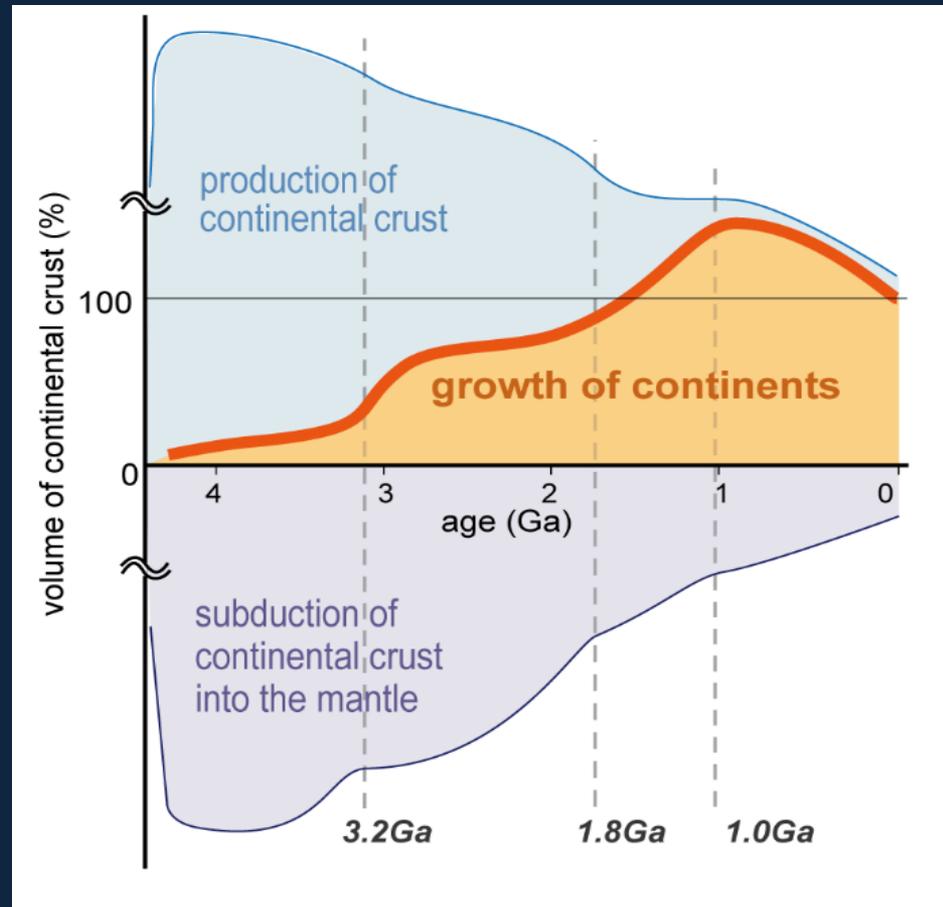
detrital zircon age spectra of modern river sands



B. Previous models of continental growth



Secular change in lifetime of granitic crust and the continental growth: a new view from detrital zircon ages of sandstones



the compilation

Data integration with previous studies

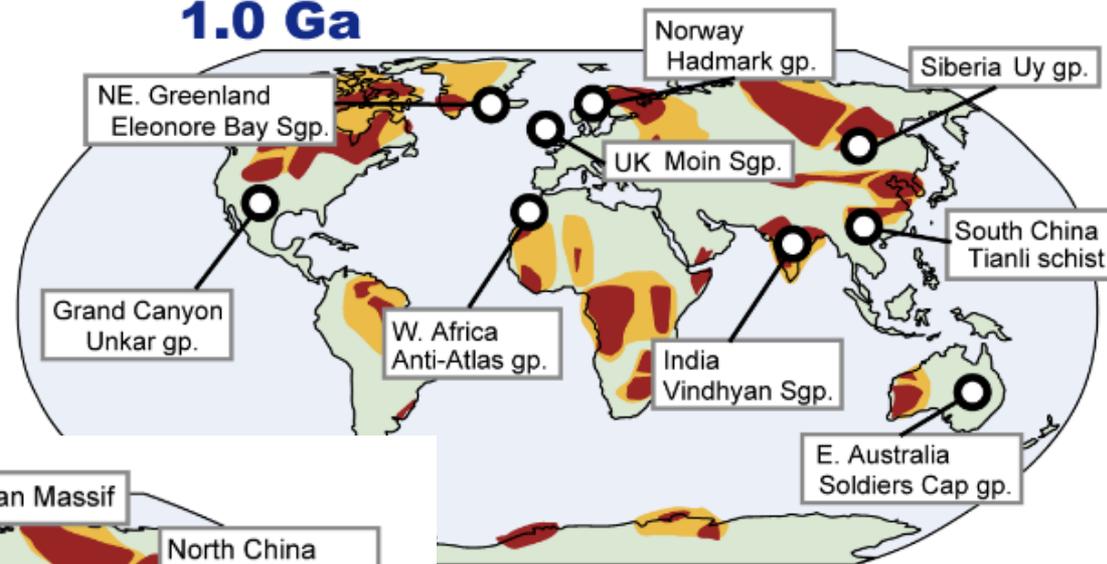
=> Compilation of 5 periods (2.9, 2.6, 2.3, 1.0, & 0.6 Ga)

Previous studies only

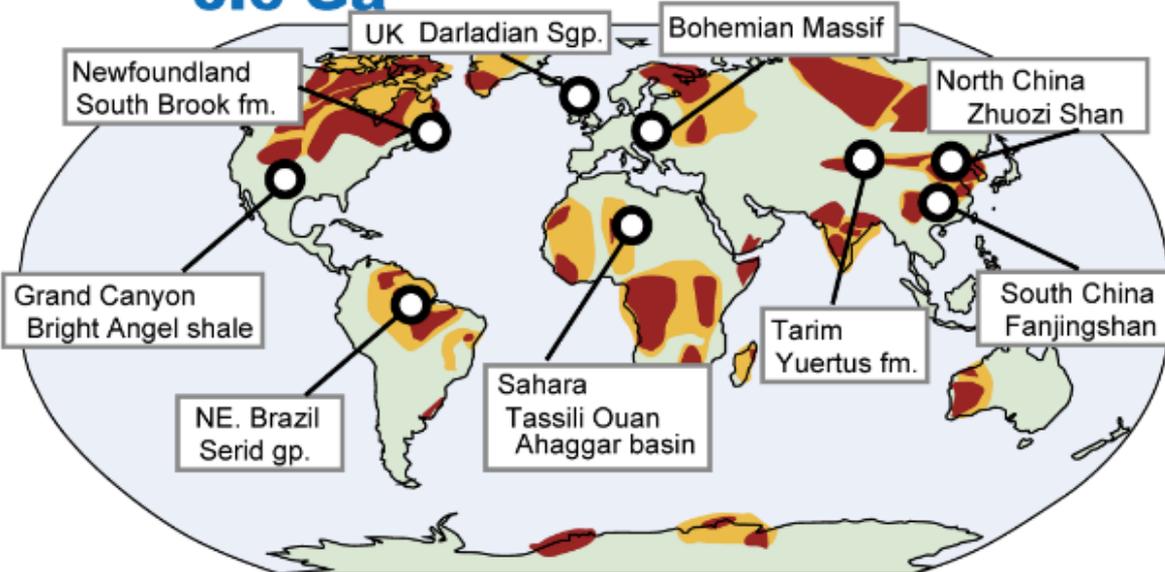
1.0 Ga : 9 samples

0.6 Ga : 9 samples

1.0 Ga



0.6 Ga



the compilation

Data integration with previous studies

=> Compilation of 5 periods (2.9, 2.6, 2.3, 1.0, & 0.6 Ga)

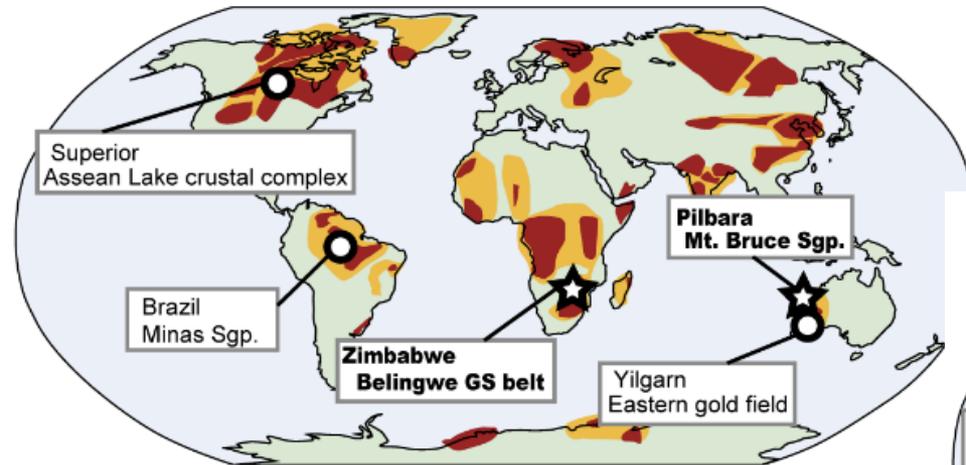
This study + Previous studies

2.9 Ga 2+4 samples

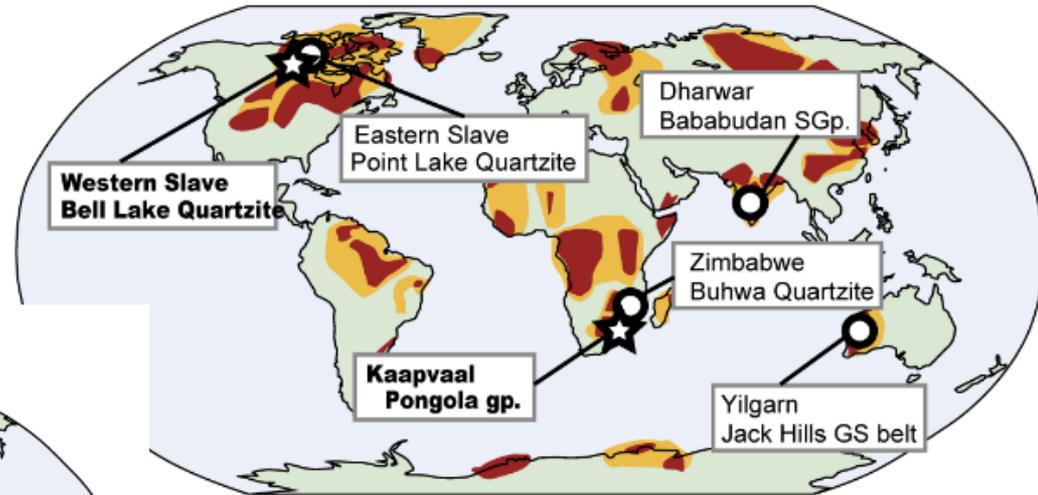
2.6 Ga 2+3 samples

2.3 Ga 3+3 samples

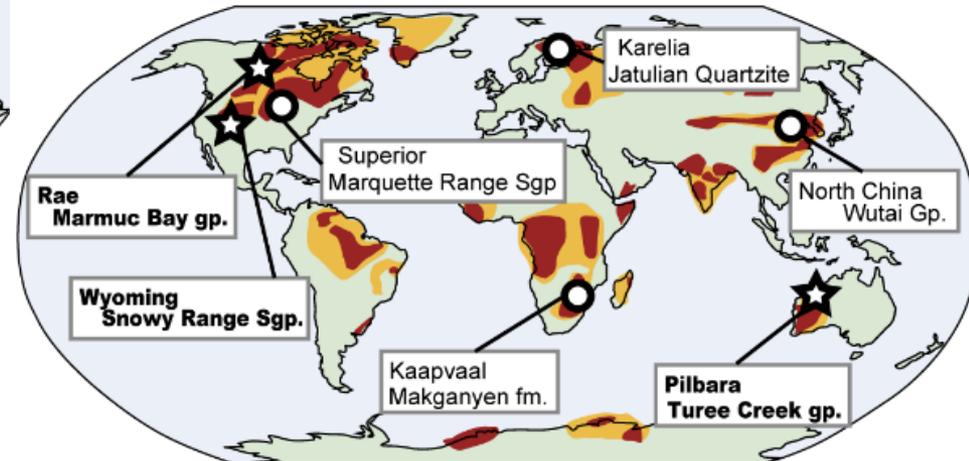
2.6 Ga

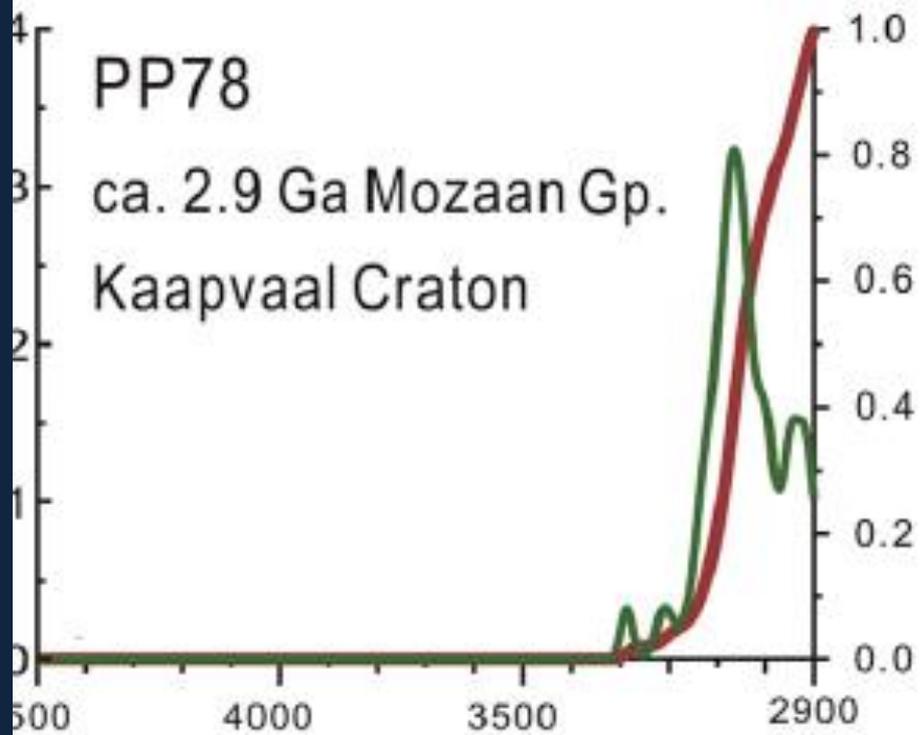


2.9 Ga



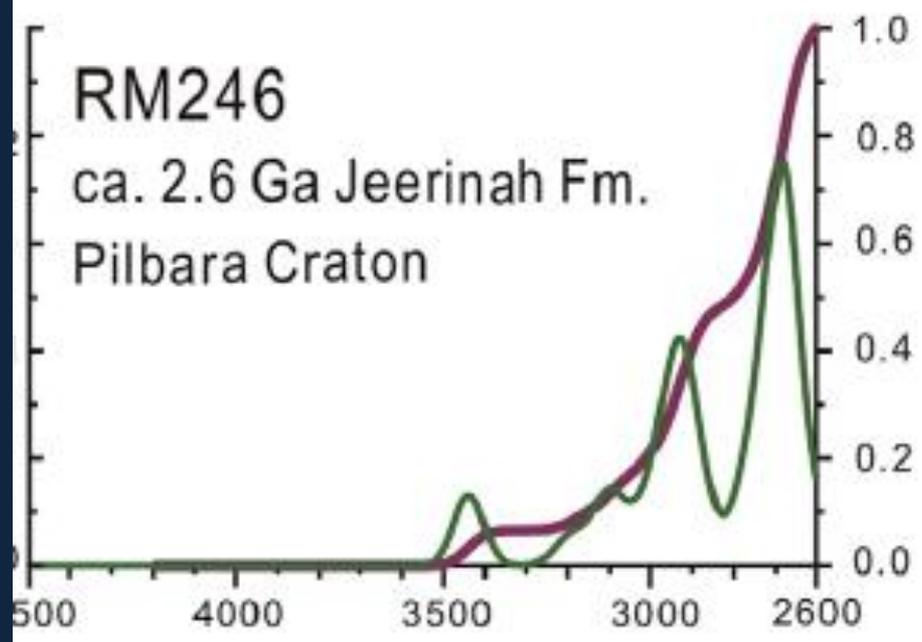
2.3 Ga





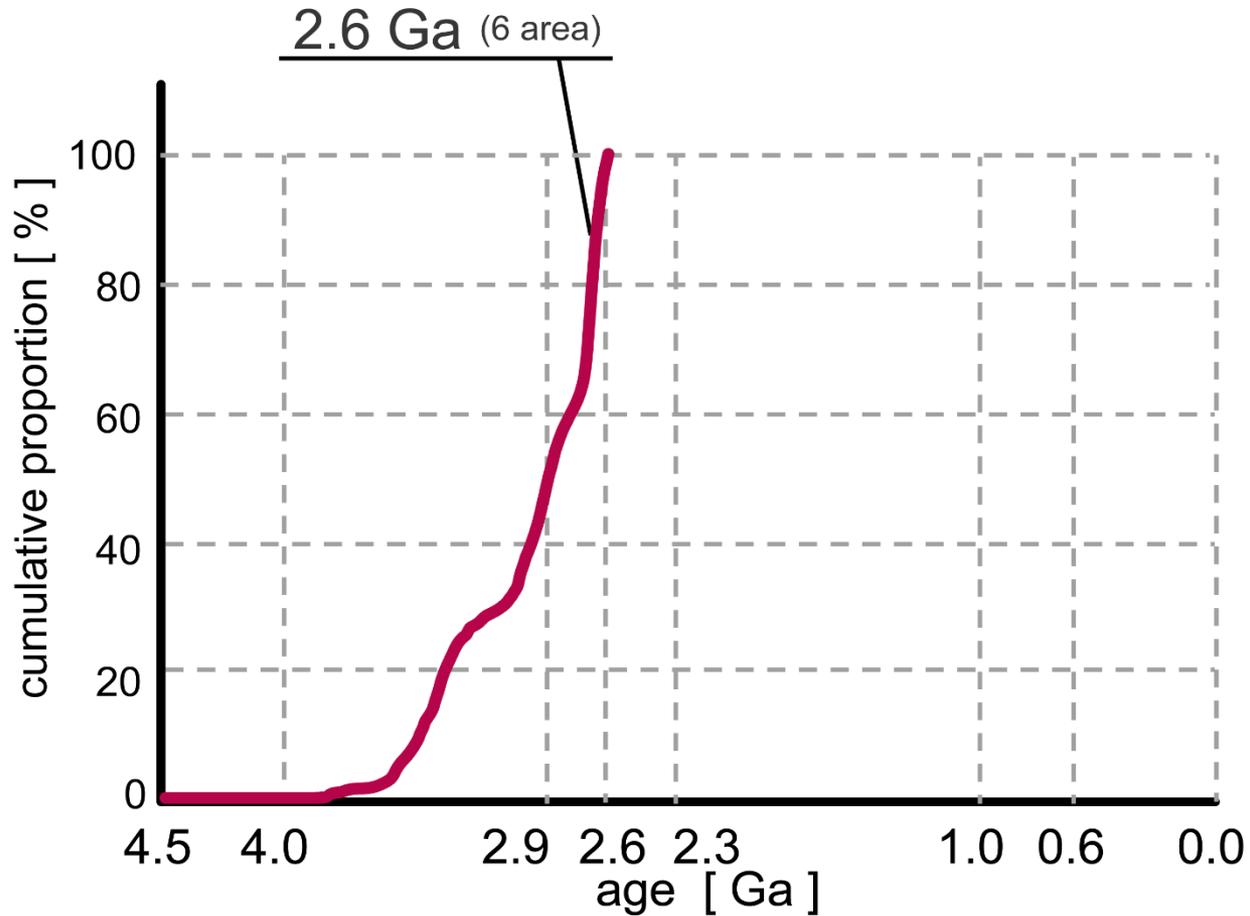
緑線 : ヒストグラム

赤線 : 累積曲線

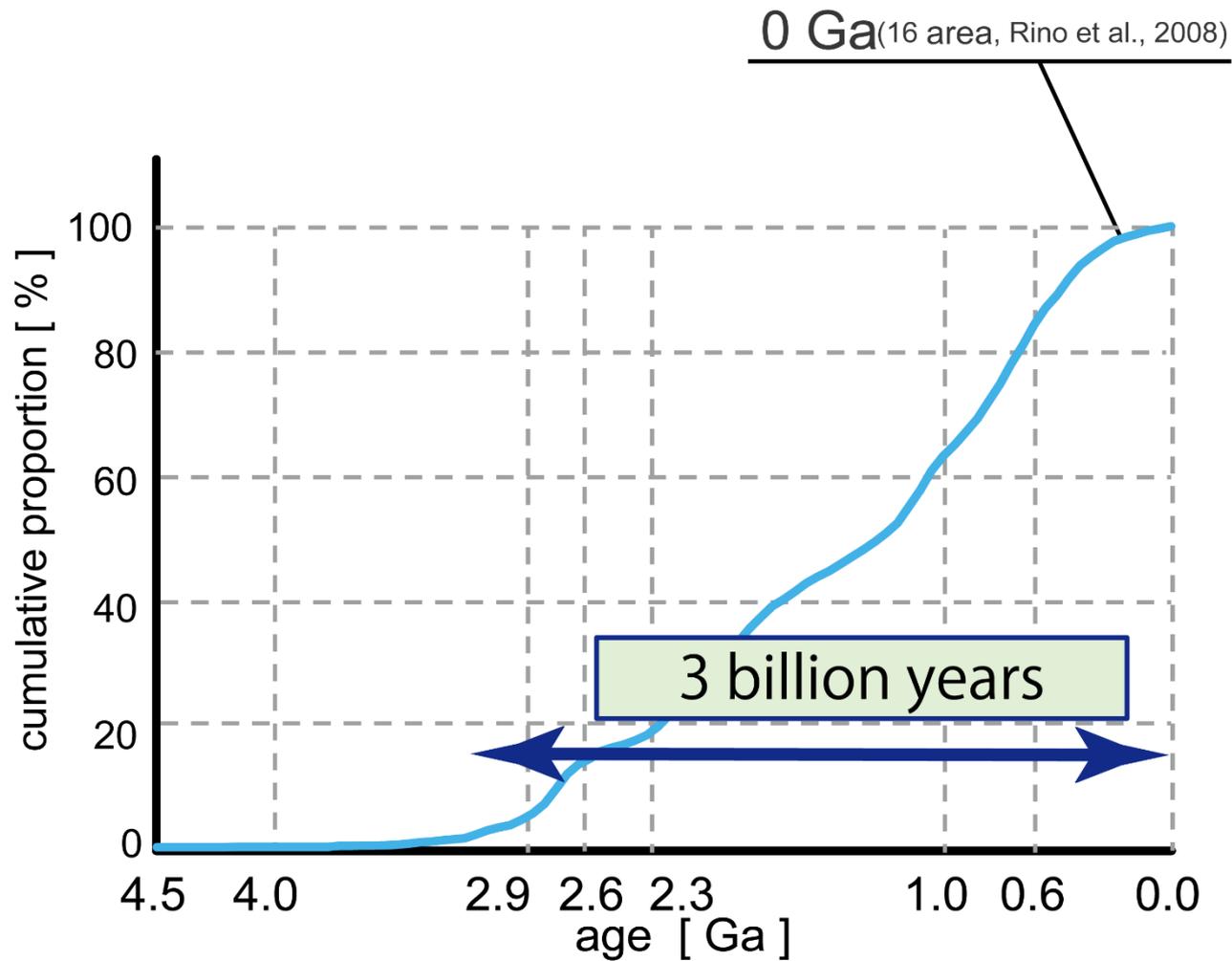


frequency distribution

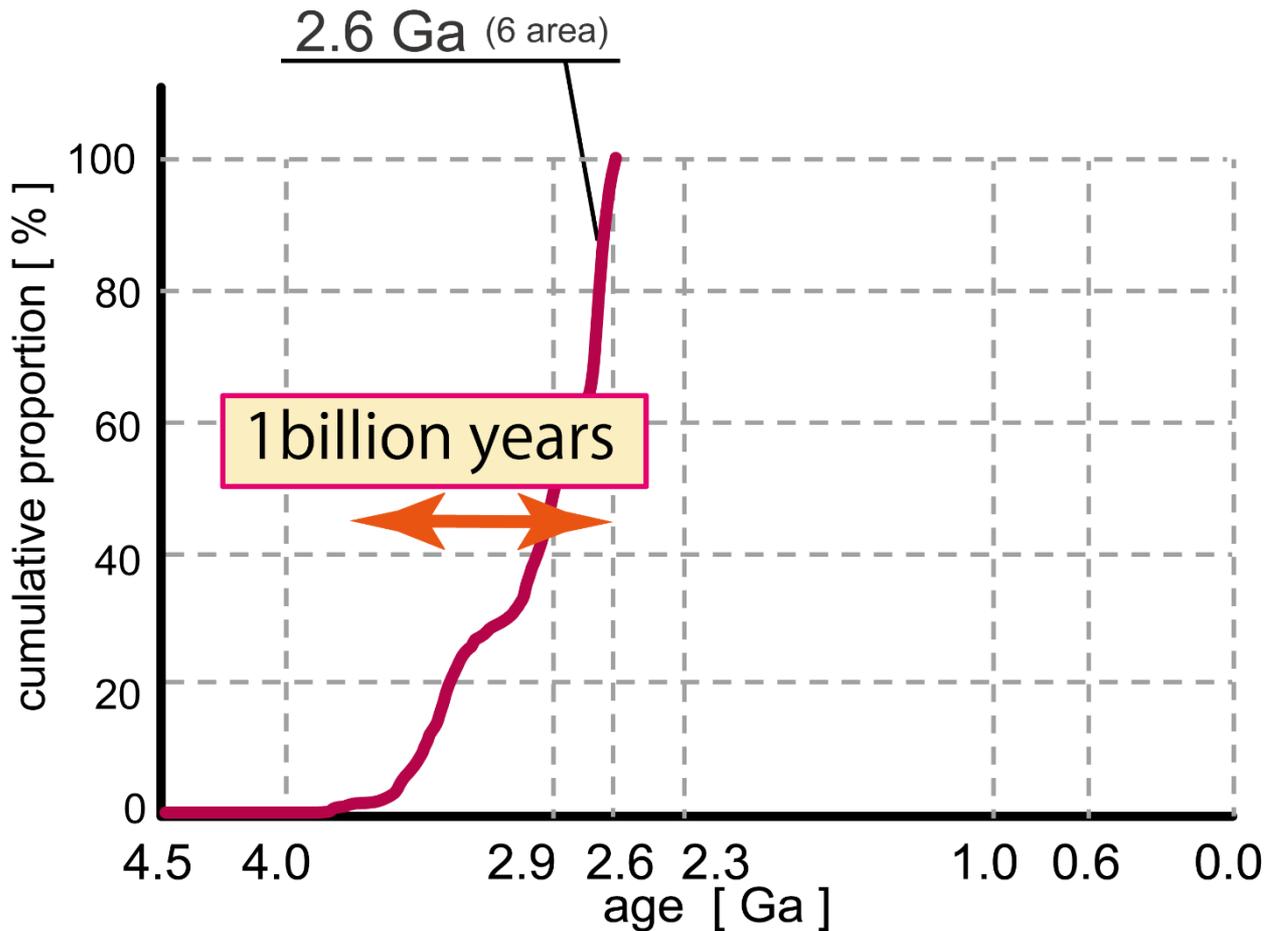
detrital zircon age spectra of 2.6 Ga sandstone



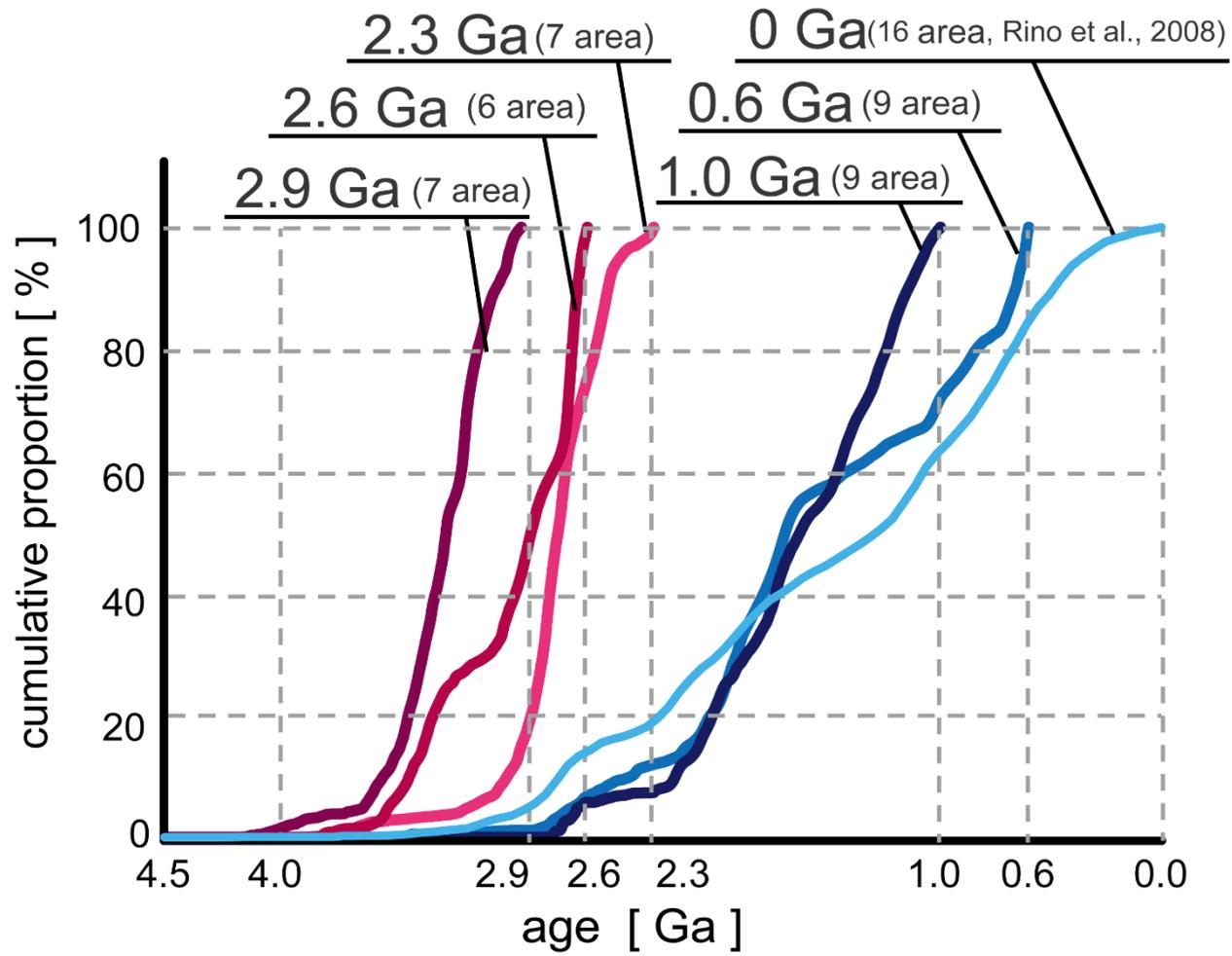
detrital zircon age spectra of modern river sands



- Compilation of detrital zircon age spectra for 5 periods: 2.9, 2.6, 2.3, 1.0 and 0.6 Ga
- Clear difference between 2.9-2.3 Ga & 1.0-0 Ga

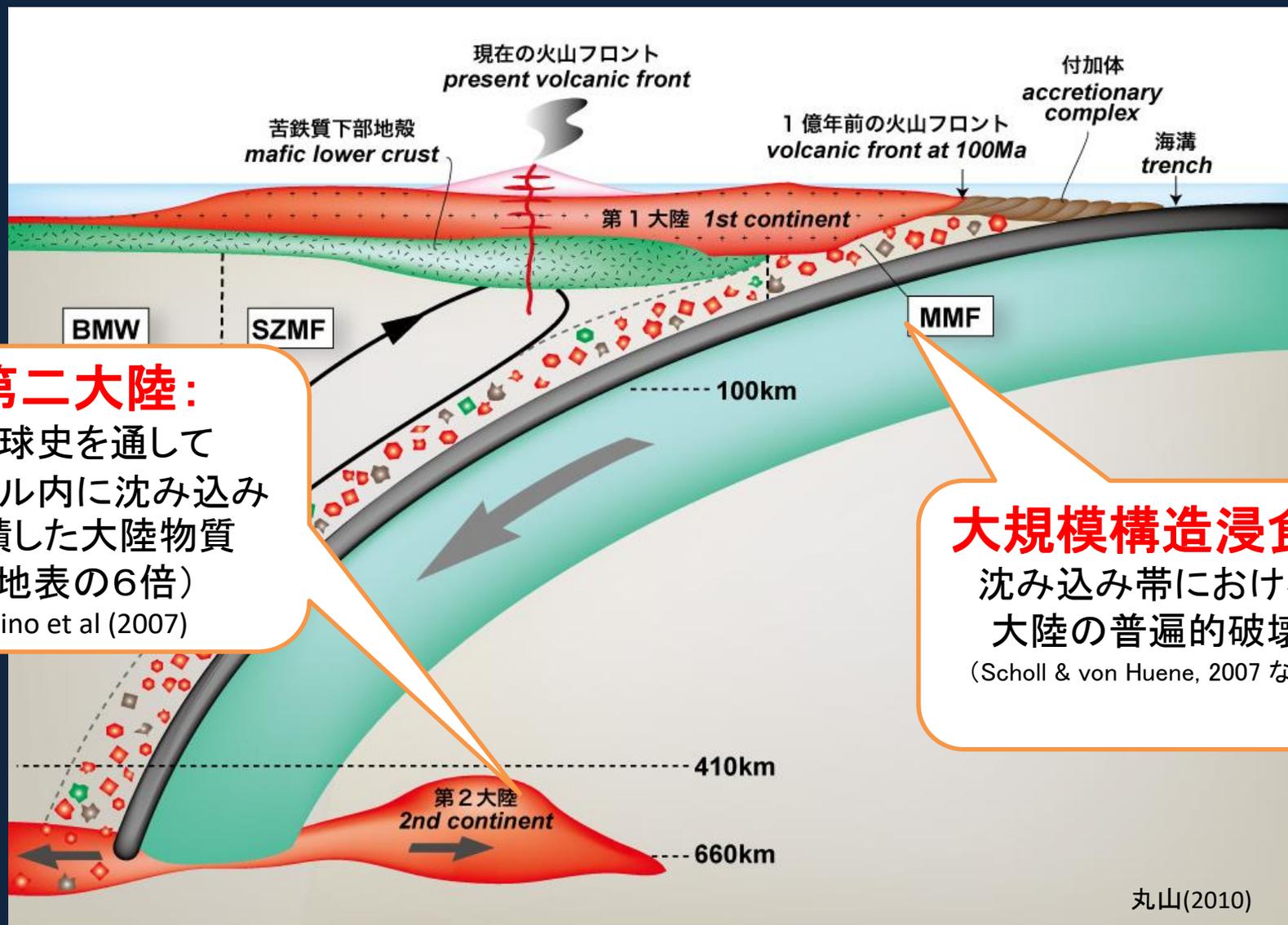


detrital zircon age spectra from sandstones
for 6 time slices; i.e. 2.9, 2.6, 2.3, 1.0 and 0.6 Ga



世界中の教科書に書かれている常識

- ・一度生成した大陸は、~~表層~~に留まる
- ・低密度の大陸は、~~高密度~~のマンテルには沈み込まない



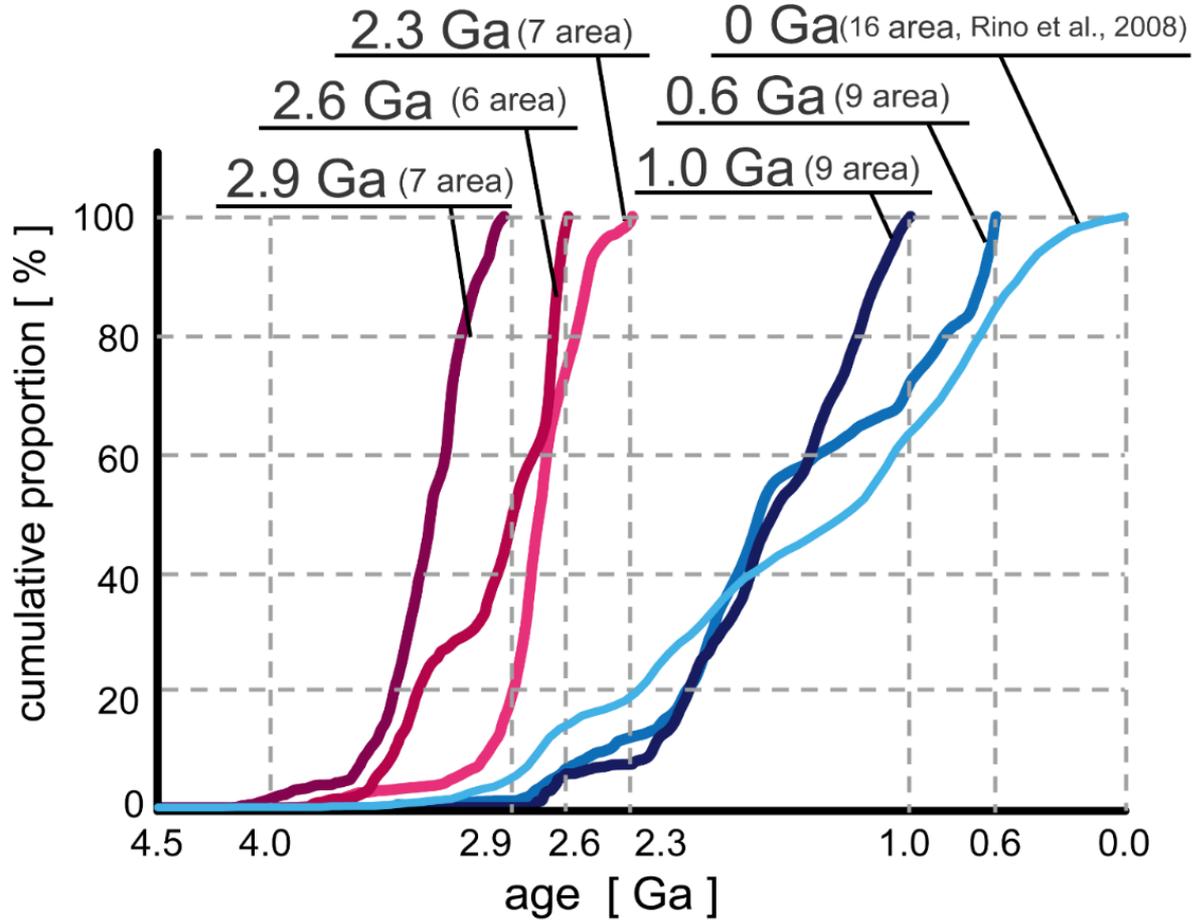
第二大陸:

地球史を通して
マンテル内に沈み込み
蓄積した大陸物質
(地表の6倍)
Rino et al (2007)

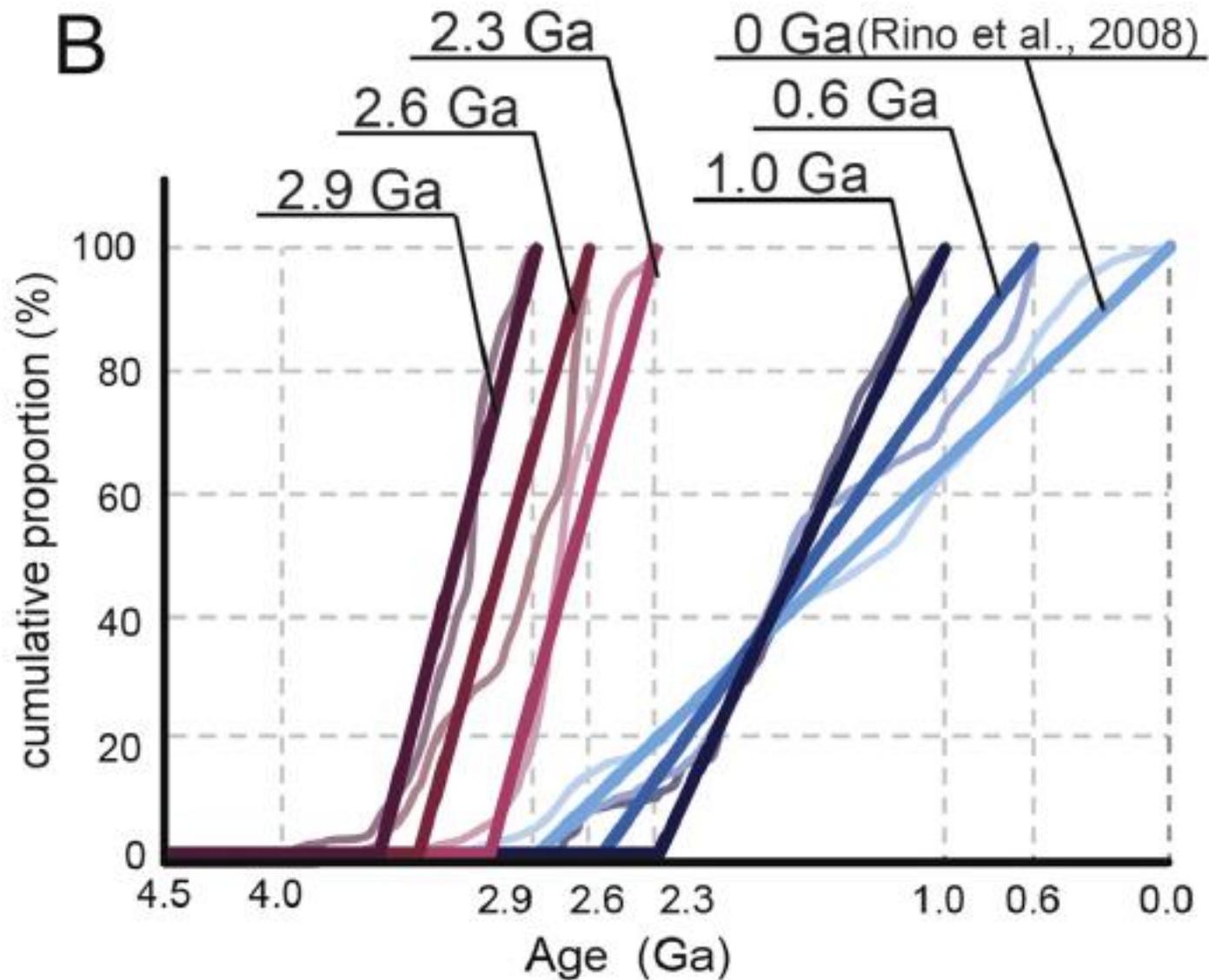
大規模構造浸食:

沈み込み帯における
大陸の普遍的破壊
(Scholl & von Huene, 2007 など)

Clear difference between 2.9-2.3 Ga & 1.0-0 Ga



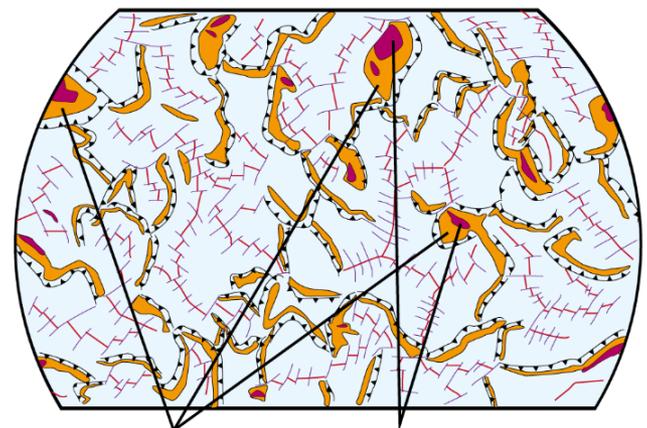
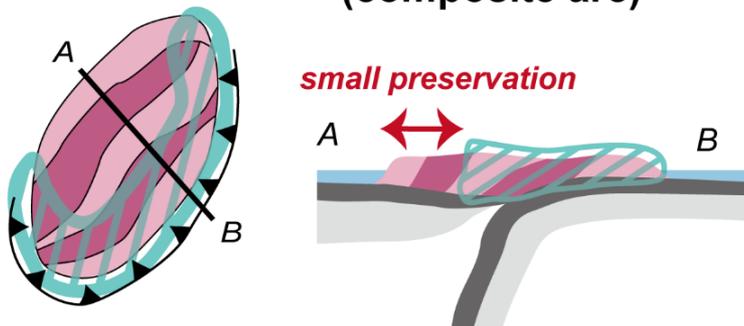
=> Short life of continental crust between 3 and 2 Ga.



• Secular change in size of continents

B. ca. 3.2-1.8 Ga

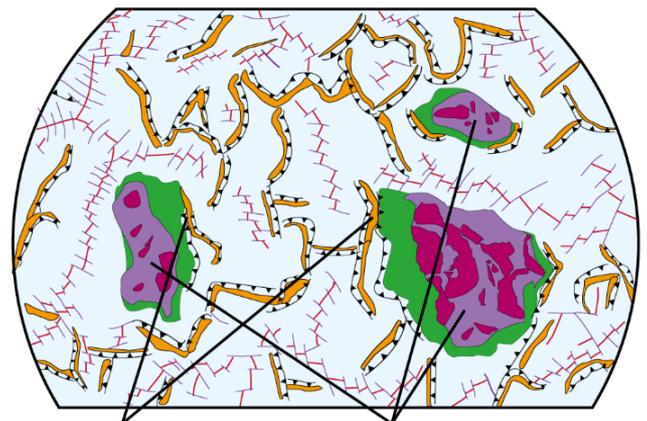
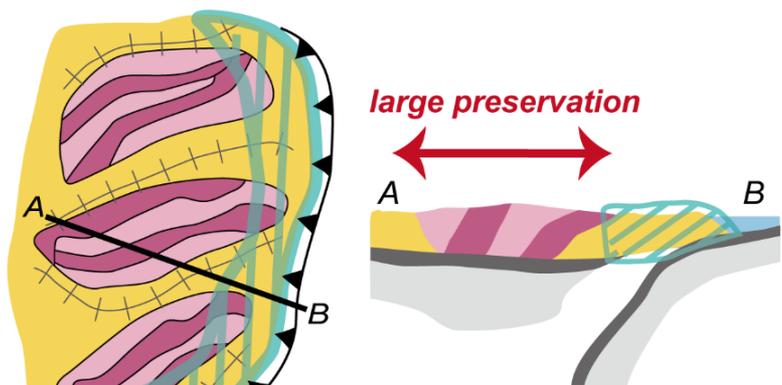
embryonic continent
(composite arc)



embryonic continents preserved old crust

C. ca. 1.8-1.0 Ga

stable large continent

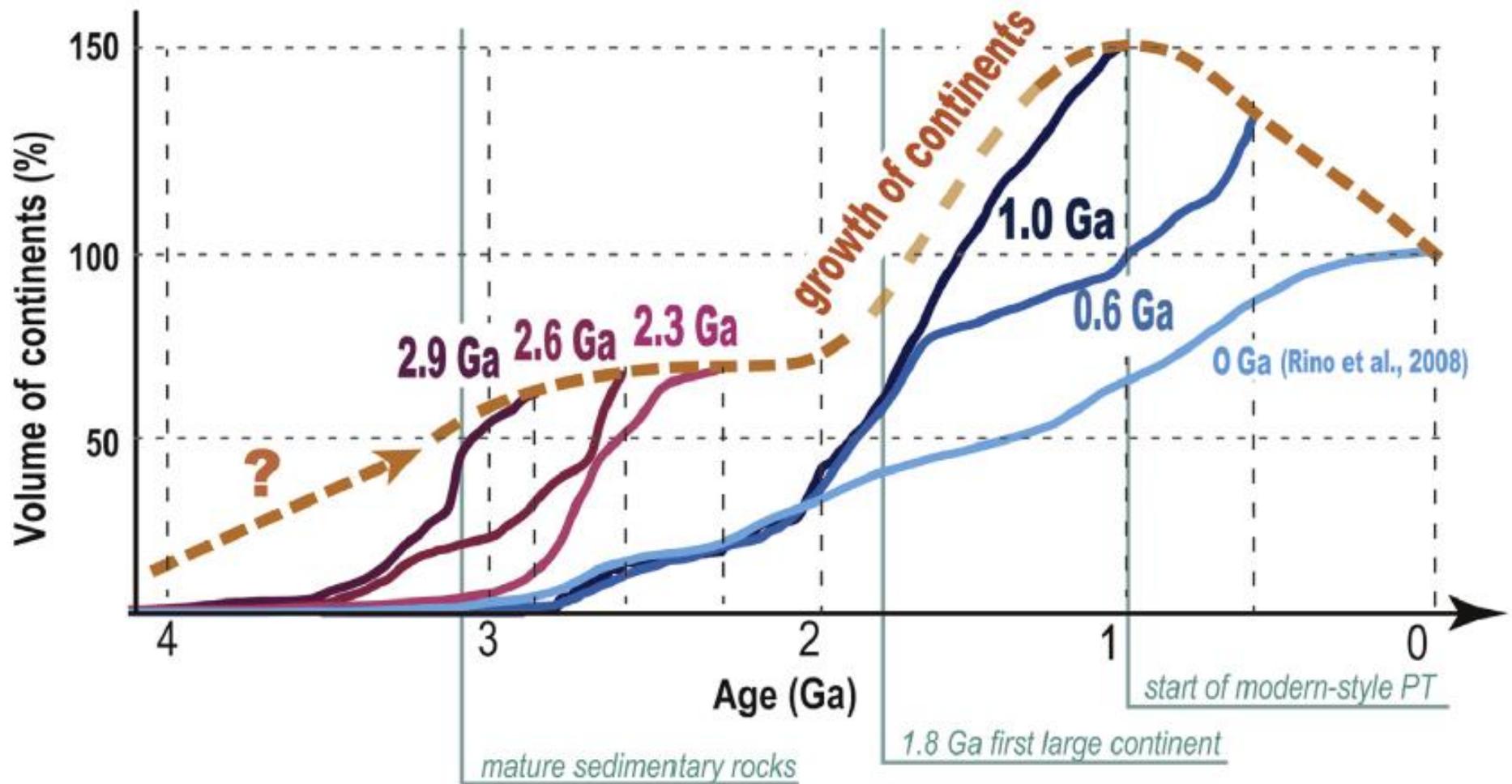


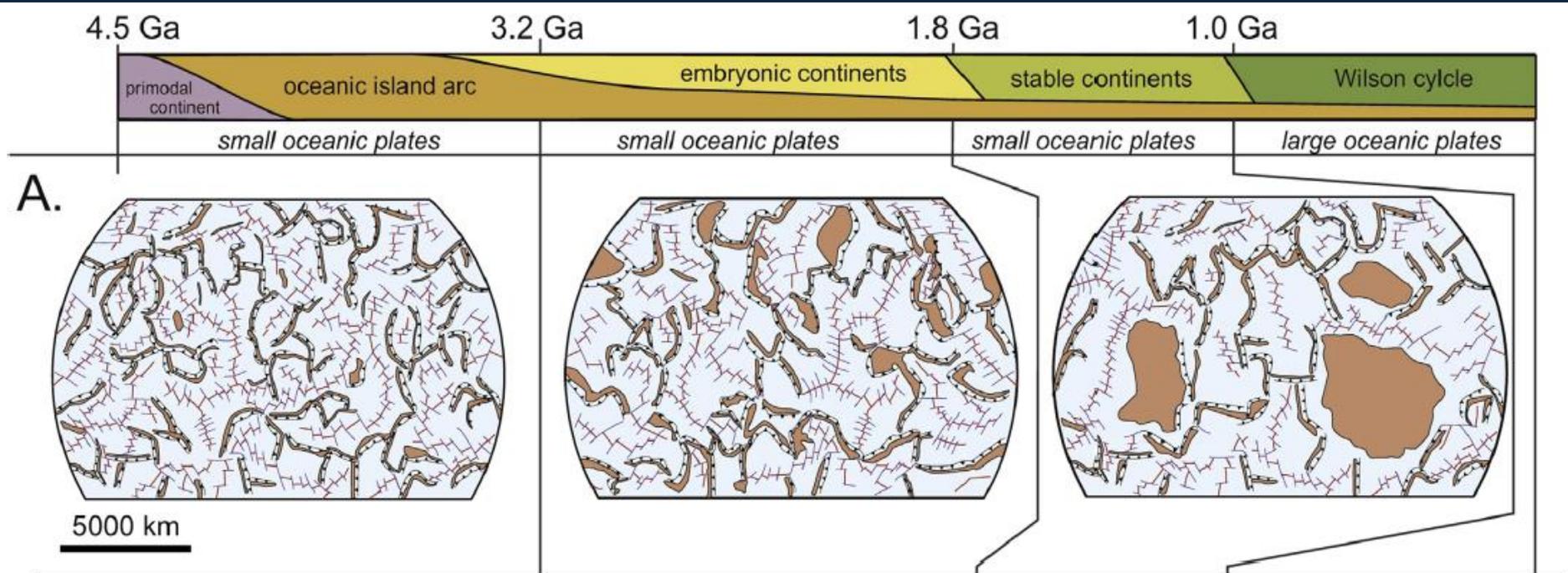
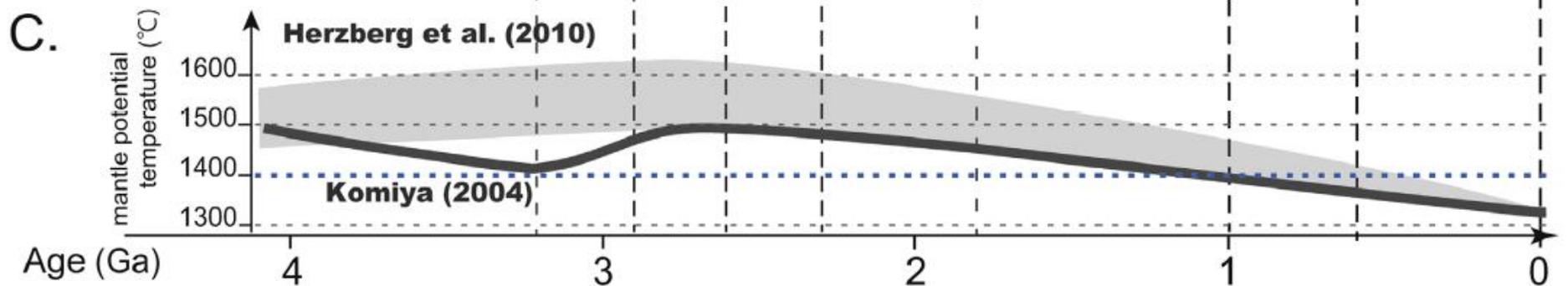
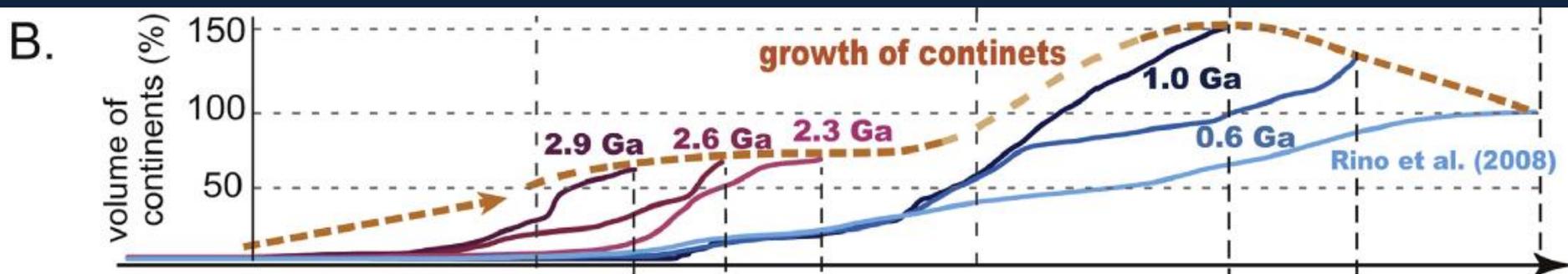
arc accretion stable large continents

 subduction orogen

 trench  mid oceanic ridge

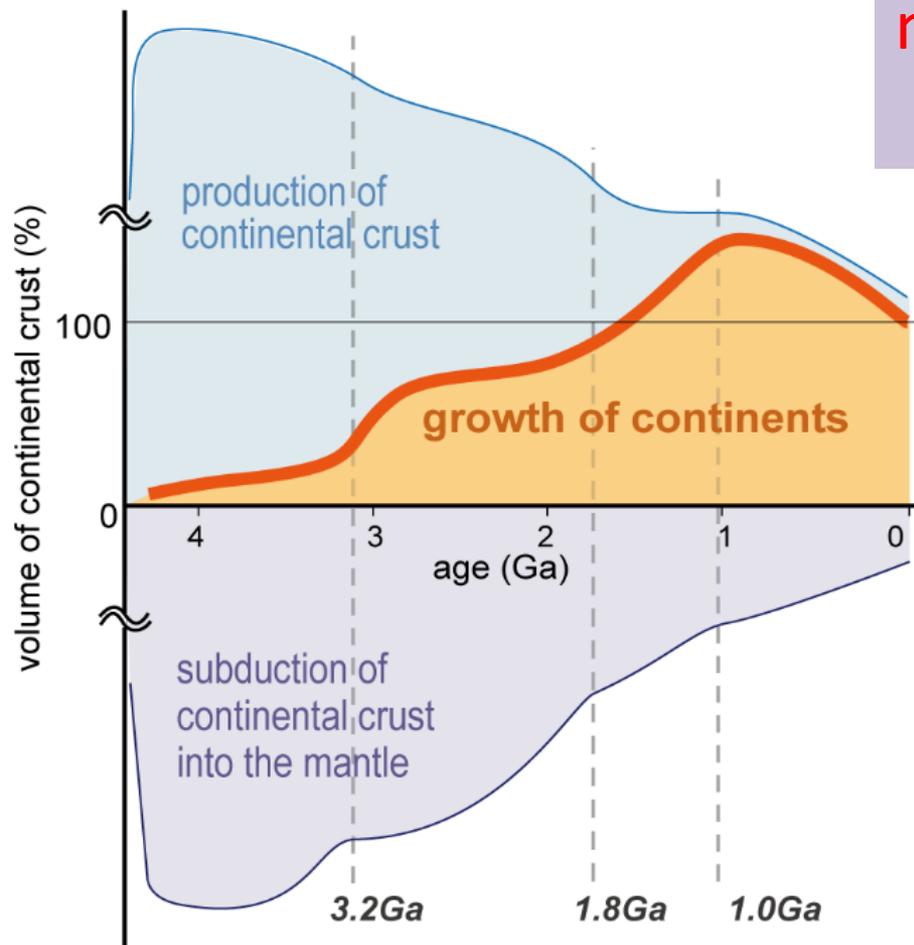
 5000 km



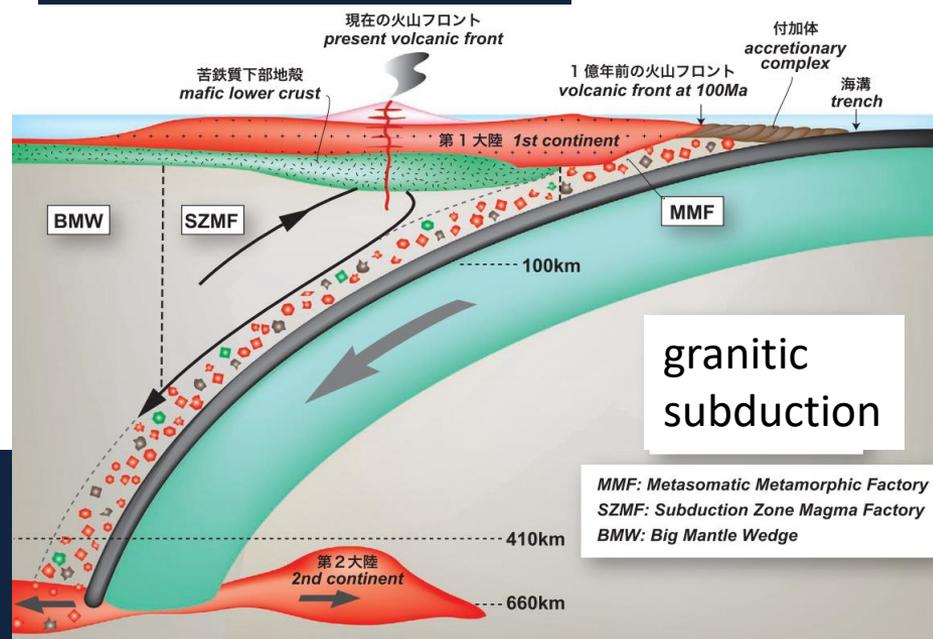


Vast granitic subduction into the mantle in the early Archean & Hadean

much shorter life of continental crust before 3 Ga



Kawai et al. (2013)

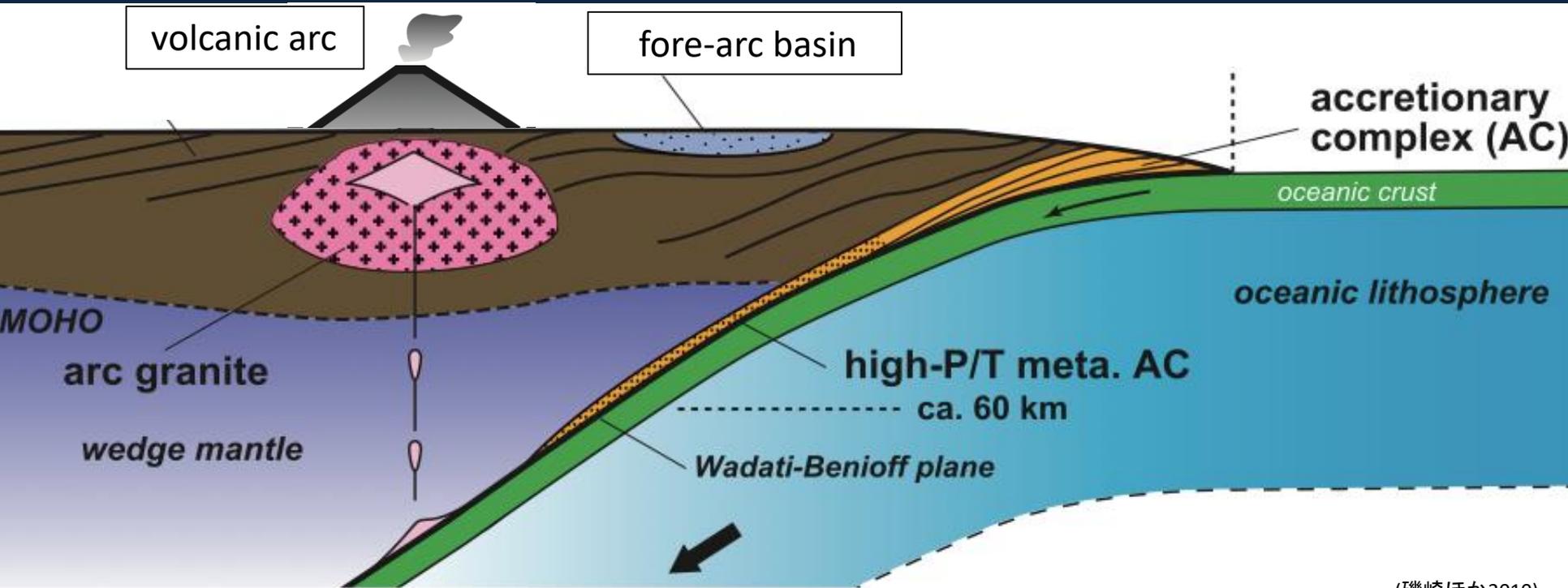


Sawada, Isozaki et al. (2018 in press)

episode 3: Phanerozoic

大陸縁リフトと背弧プルーム

太平洋型造山帯構成要素とその配列 <大陸地殻の成長>

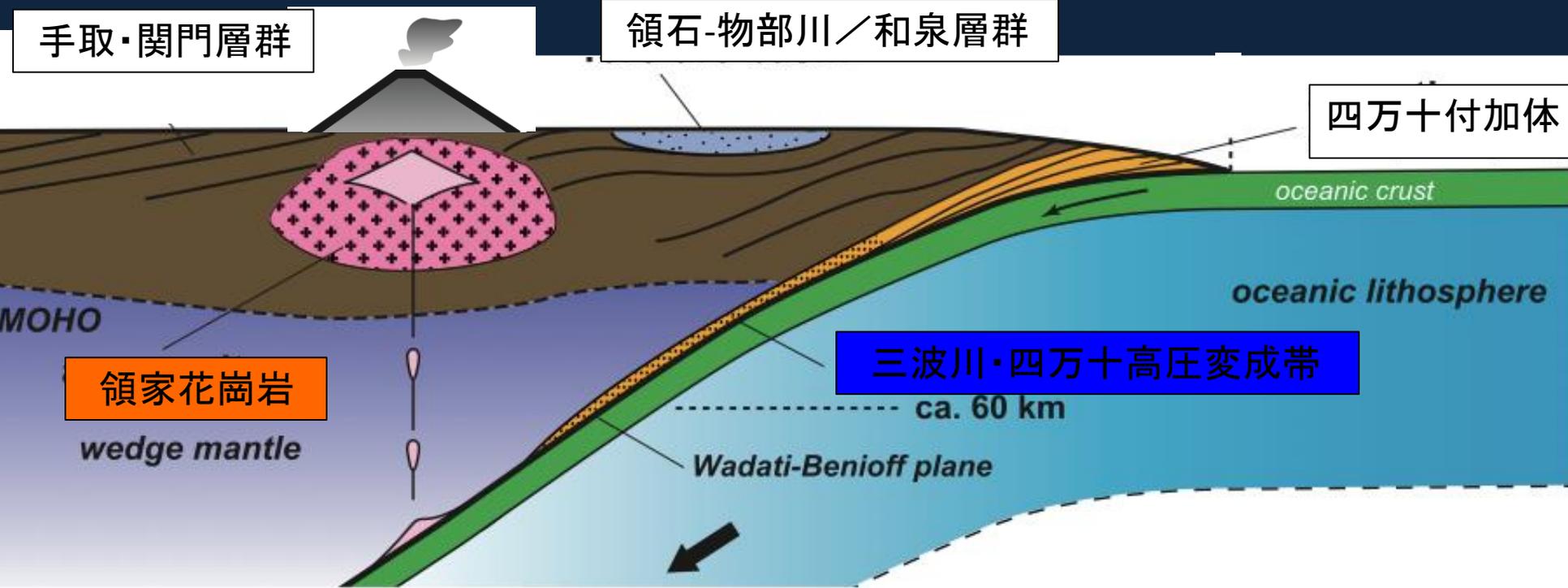


(磯崎ほか2010)

日本列島: 古生代カンブリア紀から現在まで同様の歴史

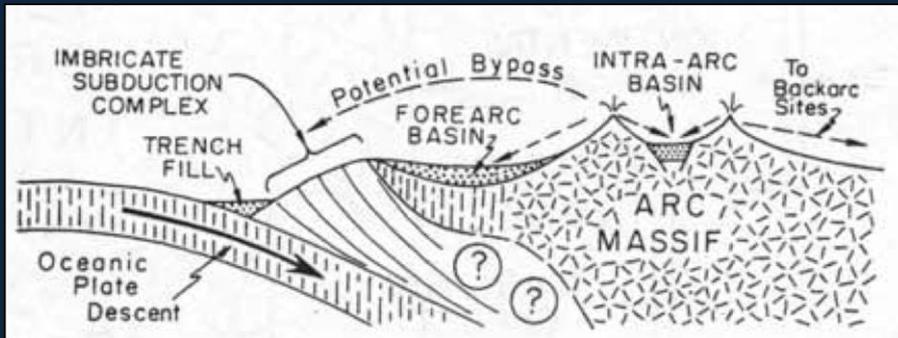
しかし古いものほど断片化・二次的に消失

白亜紀の構成要素は比較的よく残っている



白亜紀日本における地形、表層での物質循環：**碎屑岩**が研究対象

(磯崎ほか2010)



Dickinson & Suczek (1979)

不整合で始まる地層はわかりやすい

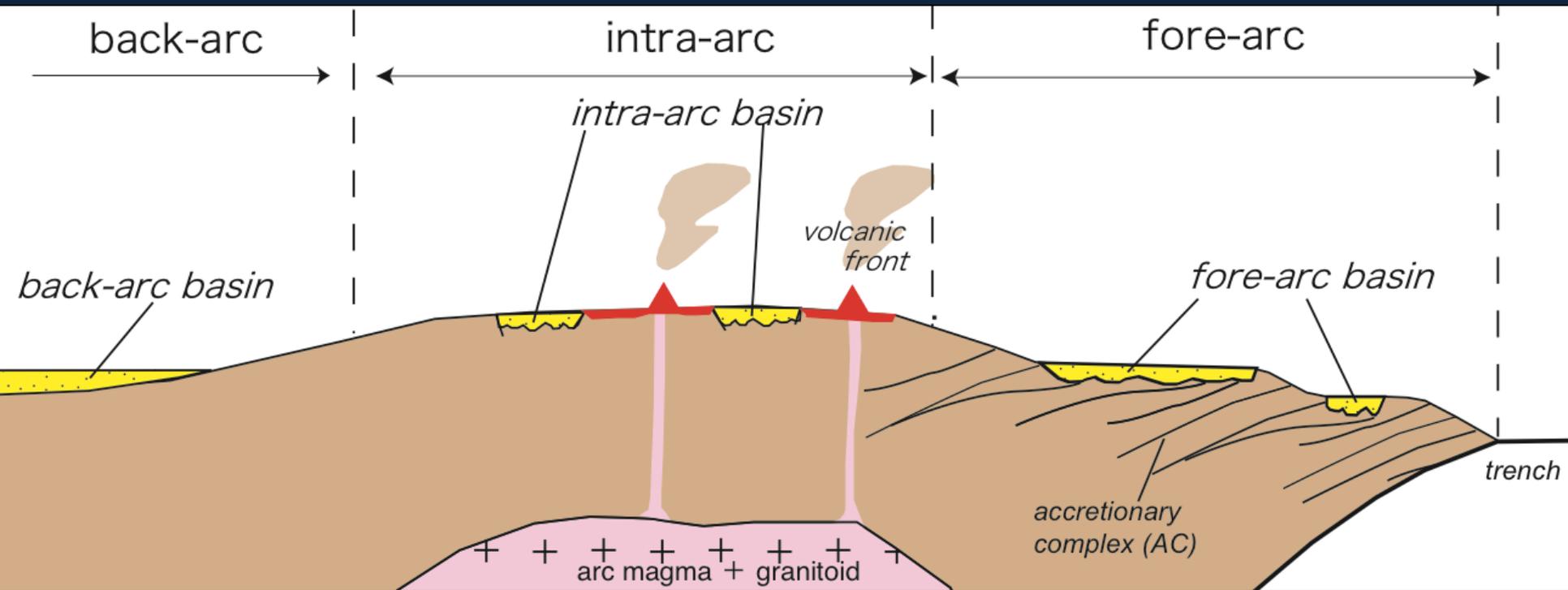
手取／神通

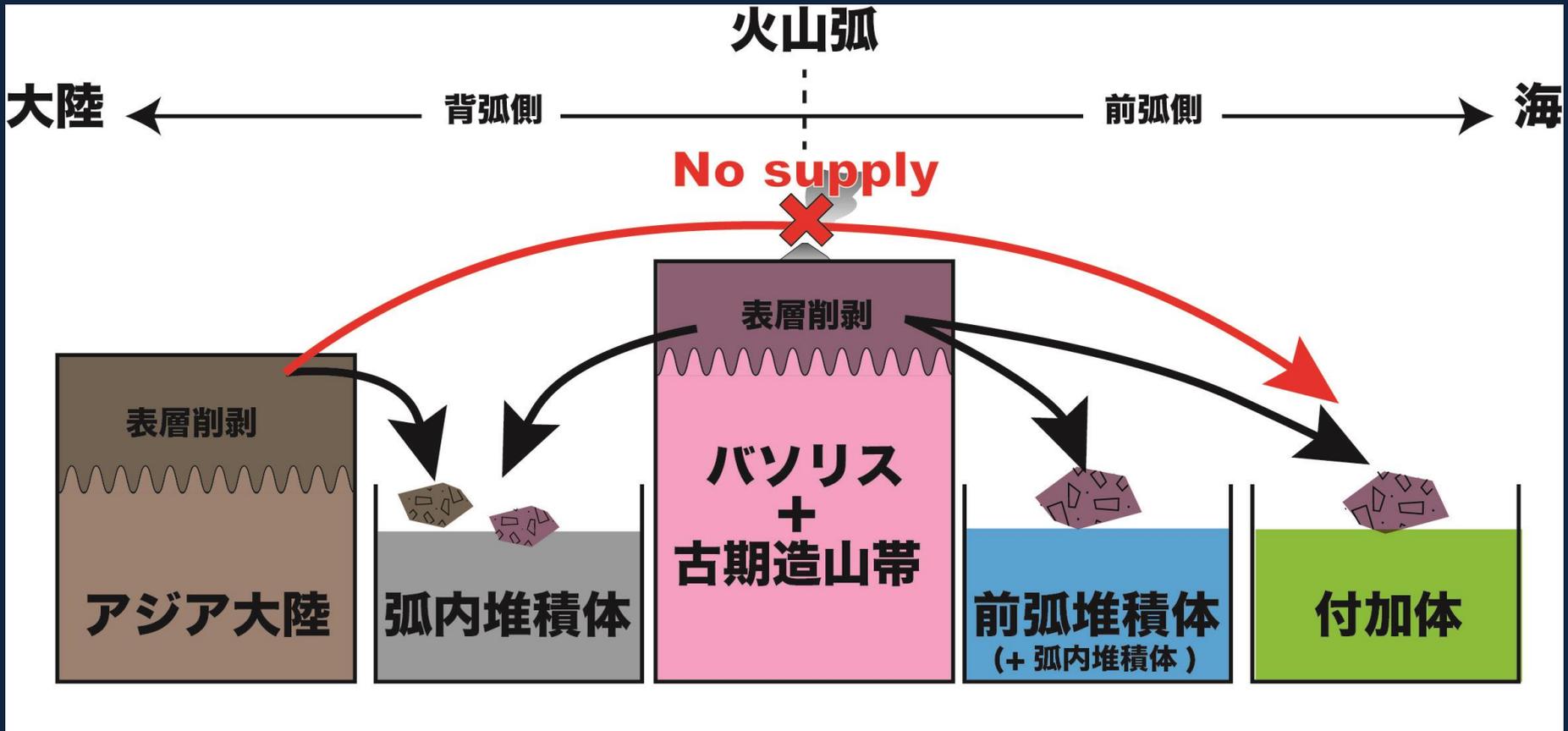
関門／篠山

和泉

物部川

宇和島





先カンブリア時代の粒子

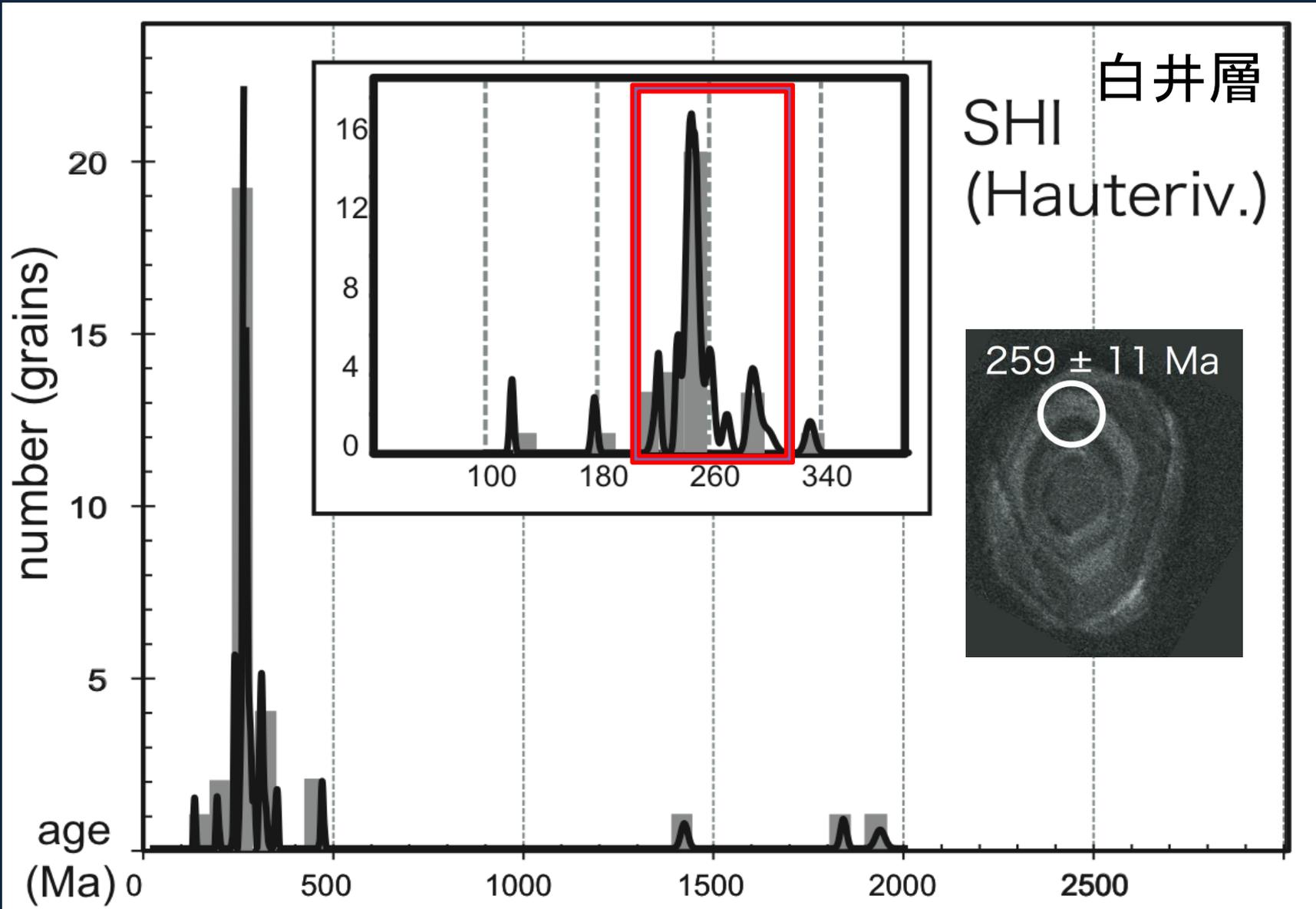
新規花崗岩バソリス帯の隆起 = 巨大なバリア出現
 背弧側からの碎屑物流入ルート遮断

西南日本の白亜系

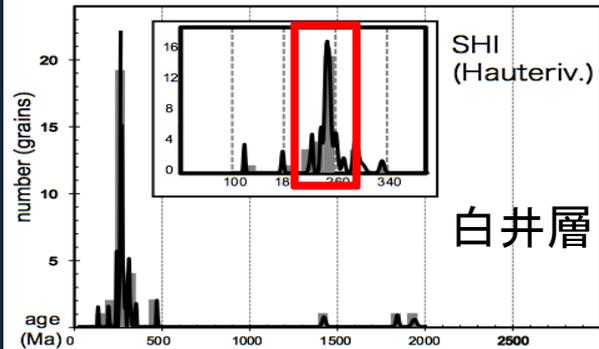
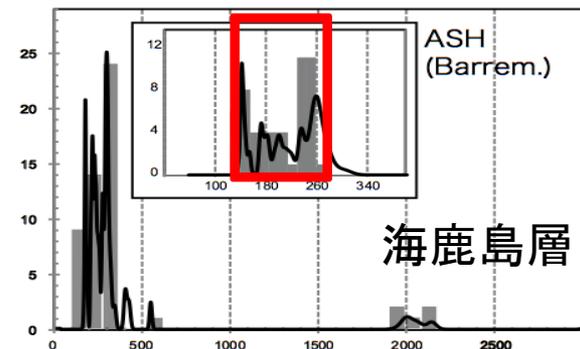
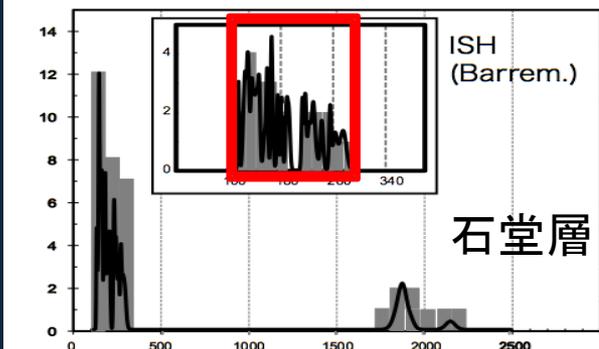
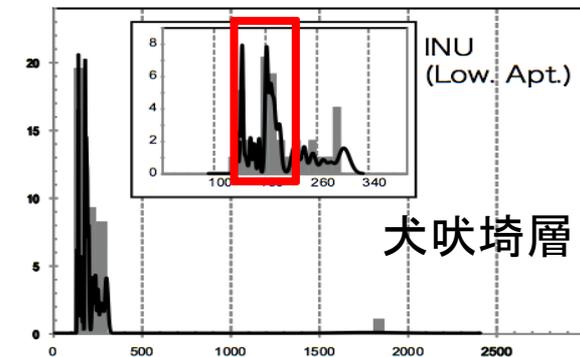
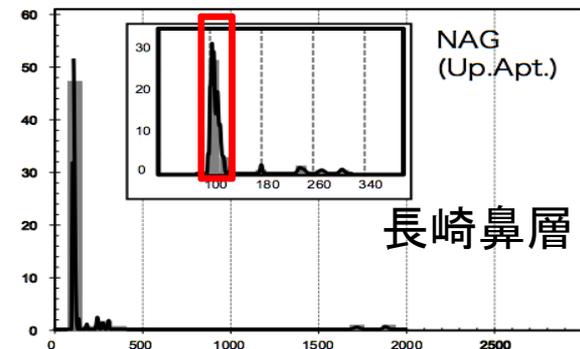
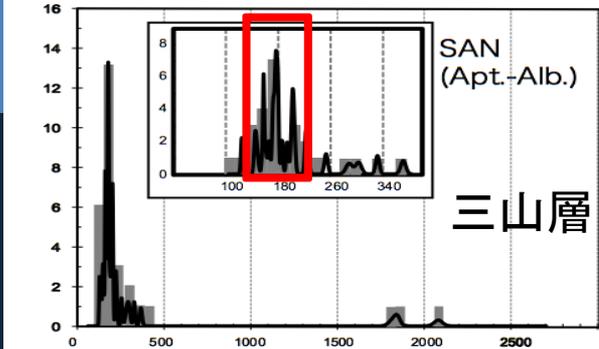


- | | |
|-----------------|------|
| Group 0: 四万十帯 | 海溝 |
| Group 1a: 四万十帯 | 前弧盆地 |
| Group 1b: 秩父帯 | 前弧盆地 |
| Group 1c: 領家帯 | 前弧盆地 |
| Group 2: 秋吉/周防帯 | 弧内盆地 |
| Group 3: 飛驒帯 | 背弧盆地 |
| Group 4: クリッペ | ?? |

碎屑性ジルコンの年代スペクトル： 山中地構帯の下部白亜系 中畑・磯崎ほか(2016a)



スペクトルの層序学的変化

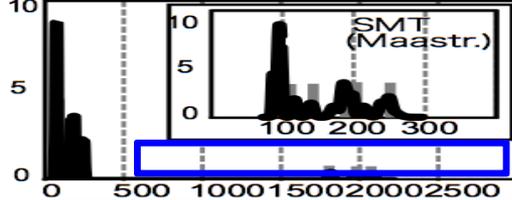


relative probability

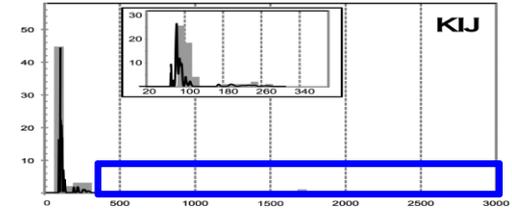
前弧白亜系砂岩にみる
250 Ma 花崗岩の消失

関東地方では、Barremianまでは
広範に露出していたが、
Aptianに消えたように見える。
約 120 Ma

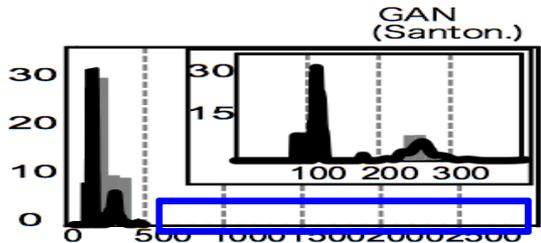
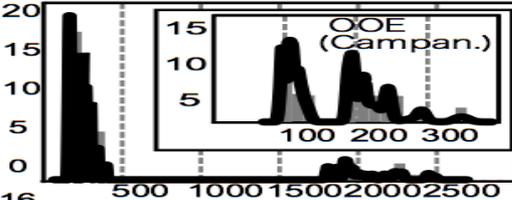
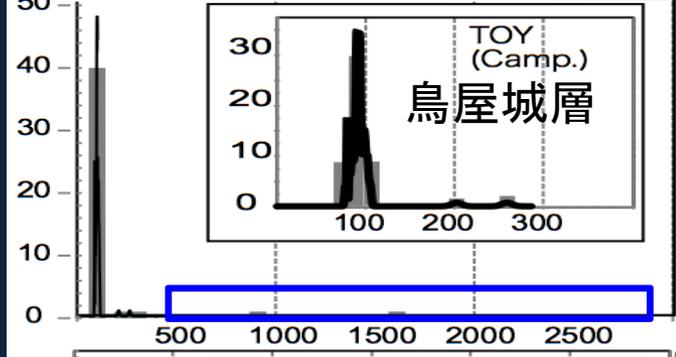
姫浦層群



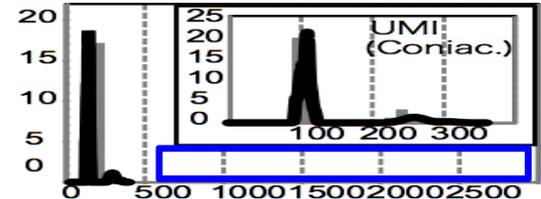
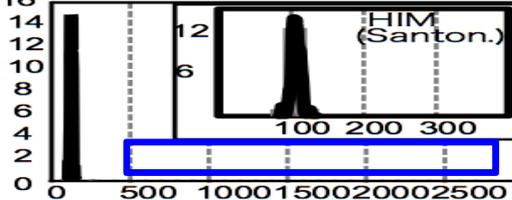
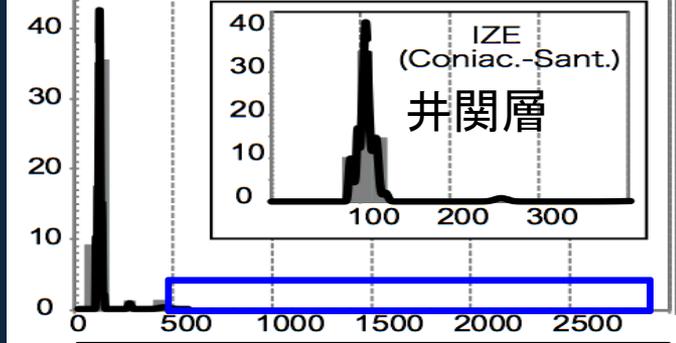
和泉層群



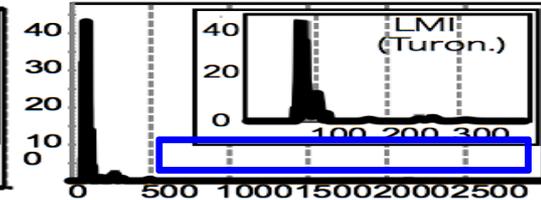
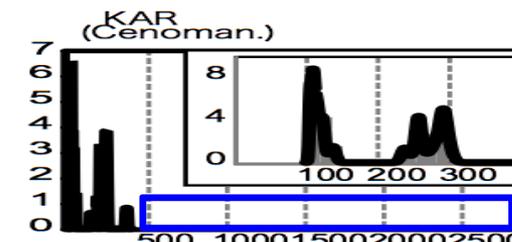
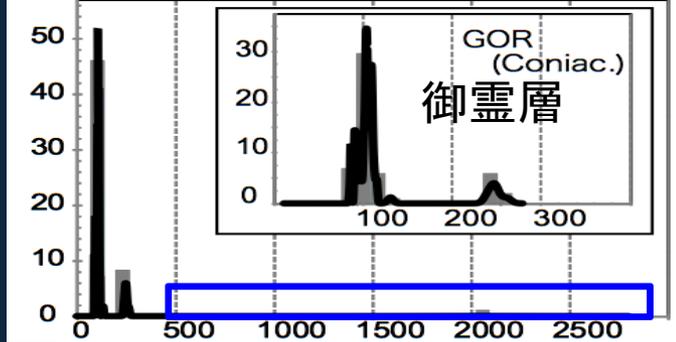
鳥屋城層



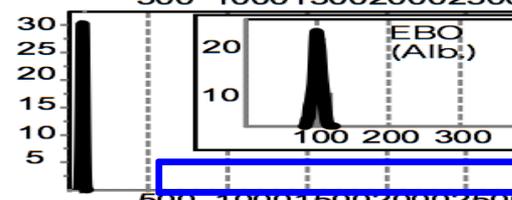
井関層



御霊層



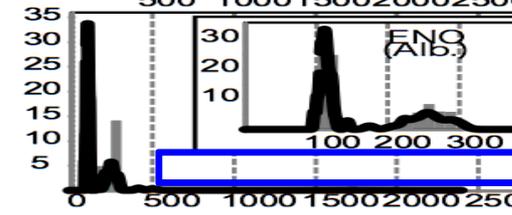
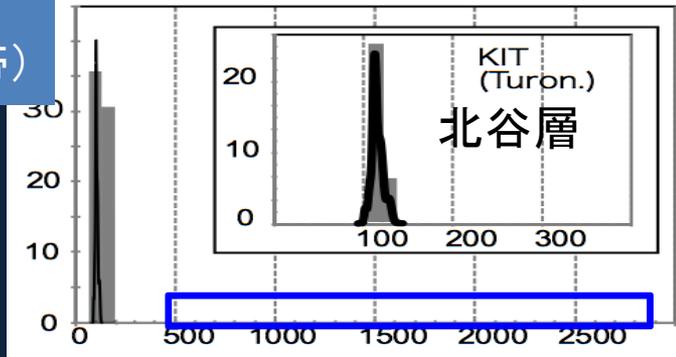
御船層群



有田 (秩父帯)

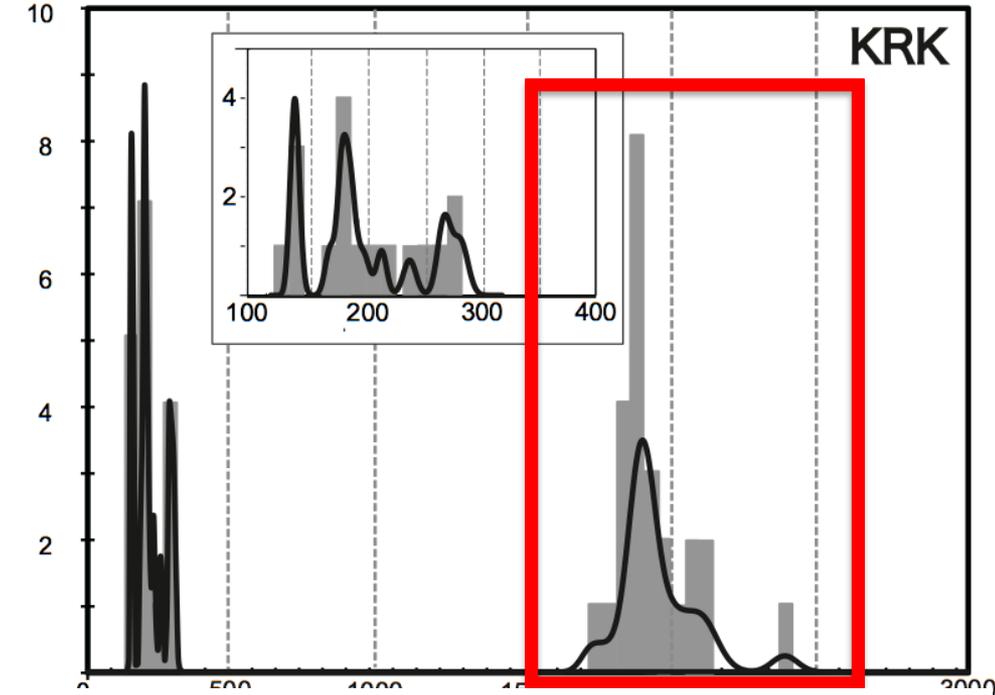
御船/天草 (領家帯)

北谷層



御所浦層群

SNG (Valanginian.)

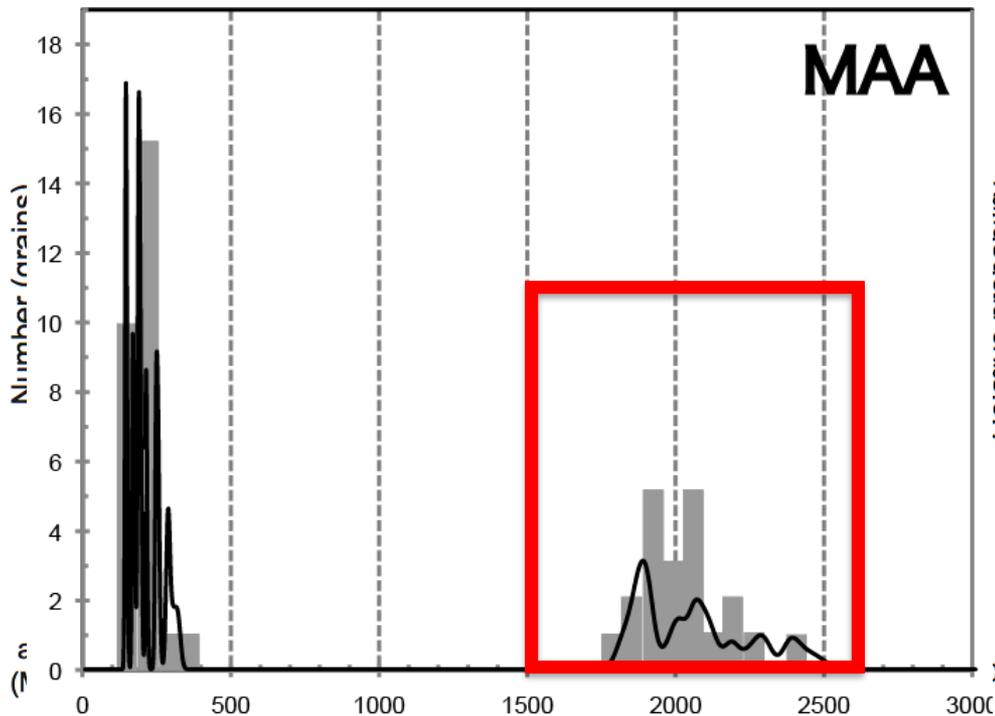


同じ西南日本の白亜系砂岩だが、
異質なパターンが.....

跡倉(群馬)・真穴(愛媛)クリッペ

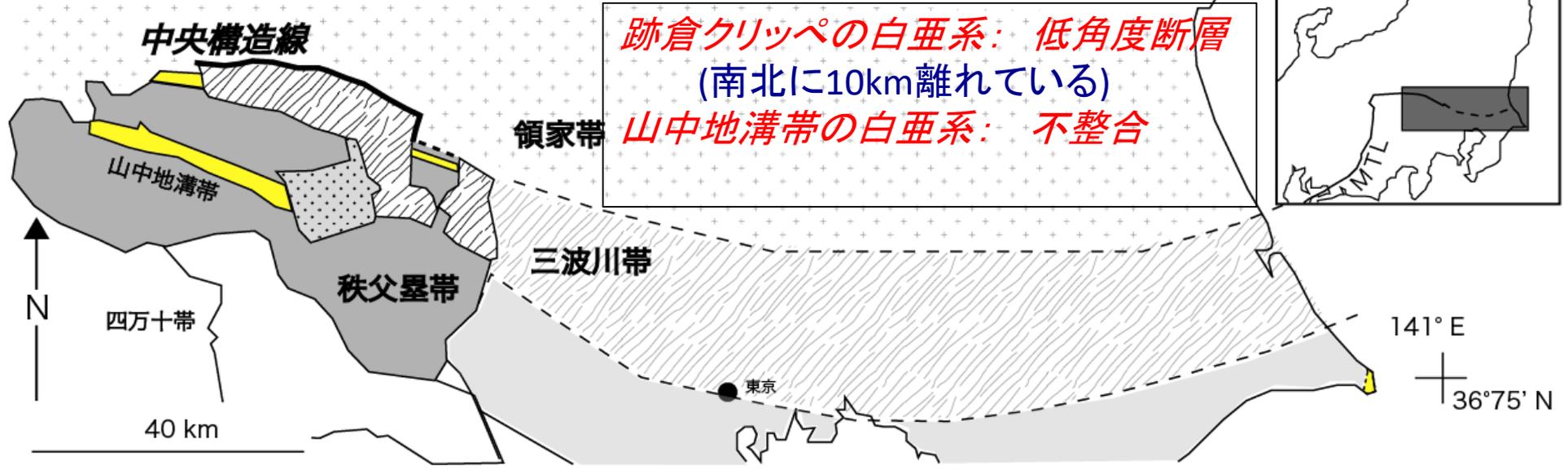
碎屑性ジルコンの年代スペクトル
4年代グループ

- 白亜紀(120-150Ma)
- ジュラ紀(170-200Ma)
- ペルム紀(250-280Ma)
- 原生代前期(1600-2400Ma)



先カンブリア時代粒子が多産
秩父帯／領家帯白亜系と全然違う。

(中畑・磯崎ほか, 2015, 2016b)



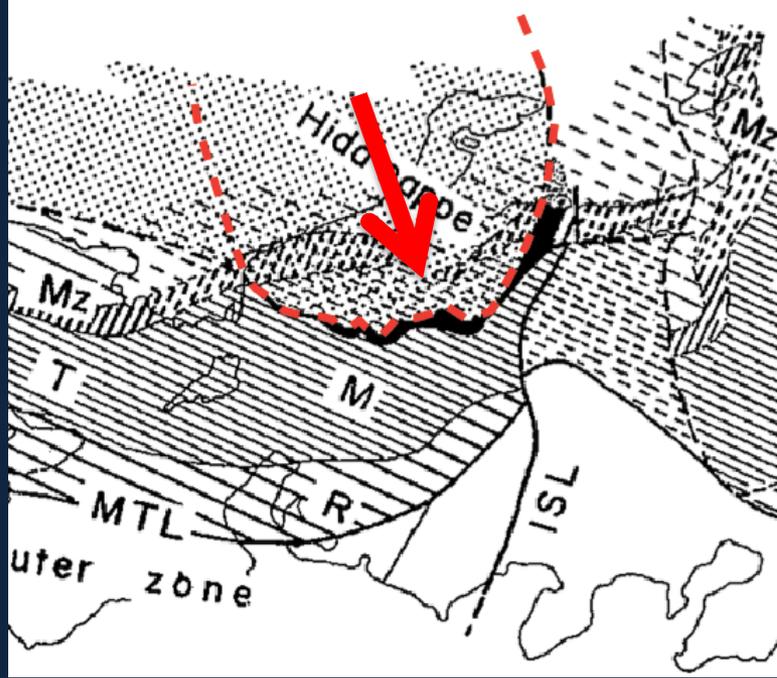
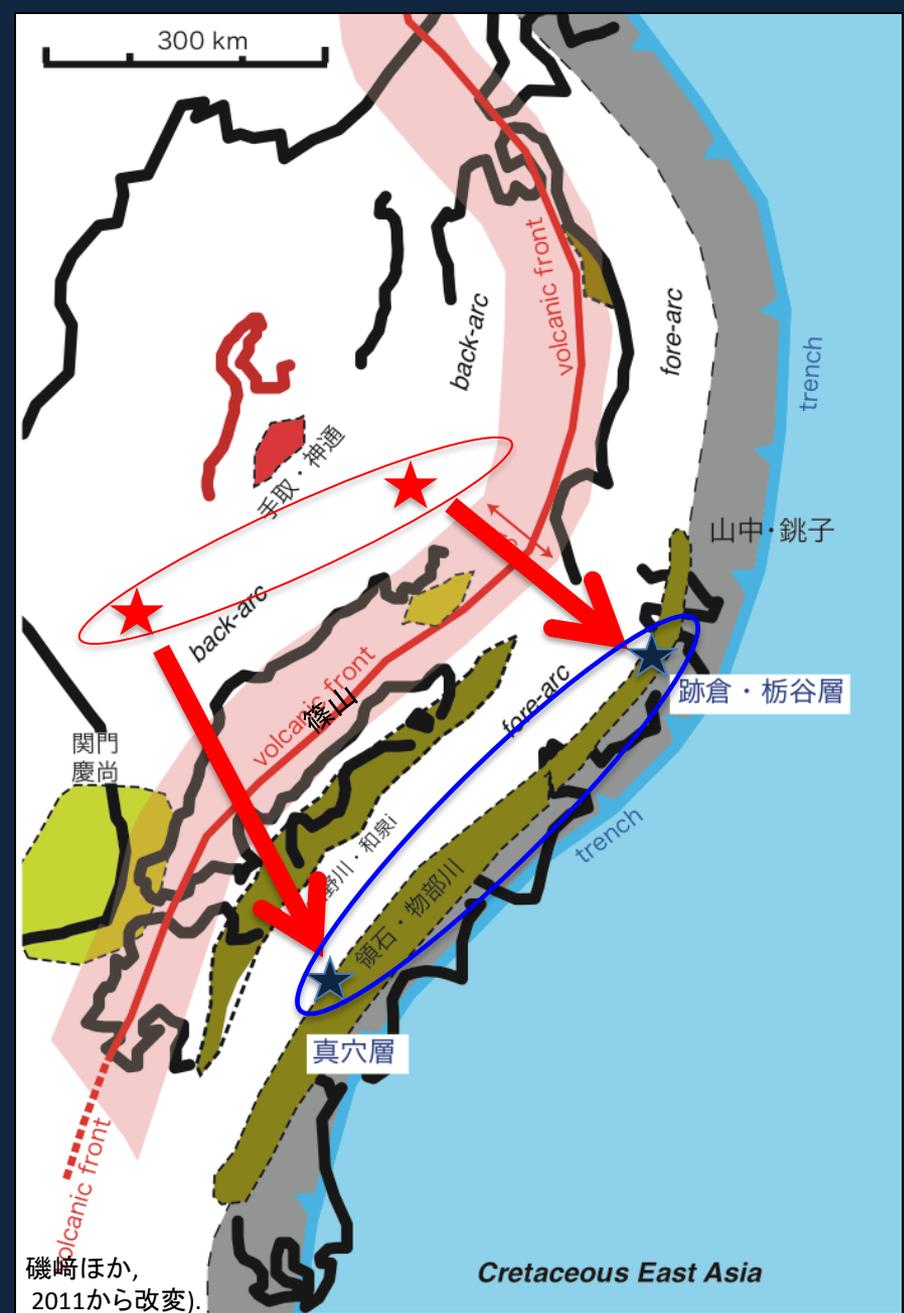
中畑ほか, 2015)



クリッペ下底の断層

白亜系／三波川変成岩

背弧側から前弧域への across-arc 長距離移動



飛騨帯自体が巨大なクリップ (Komatsu, 1990)

弧を横断する200-300 kmの長距離移動

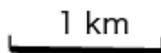
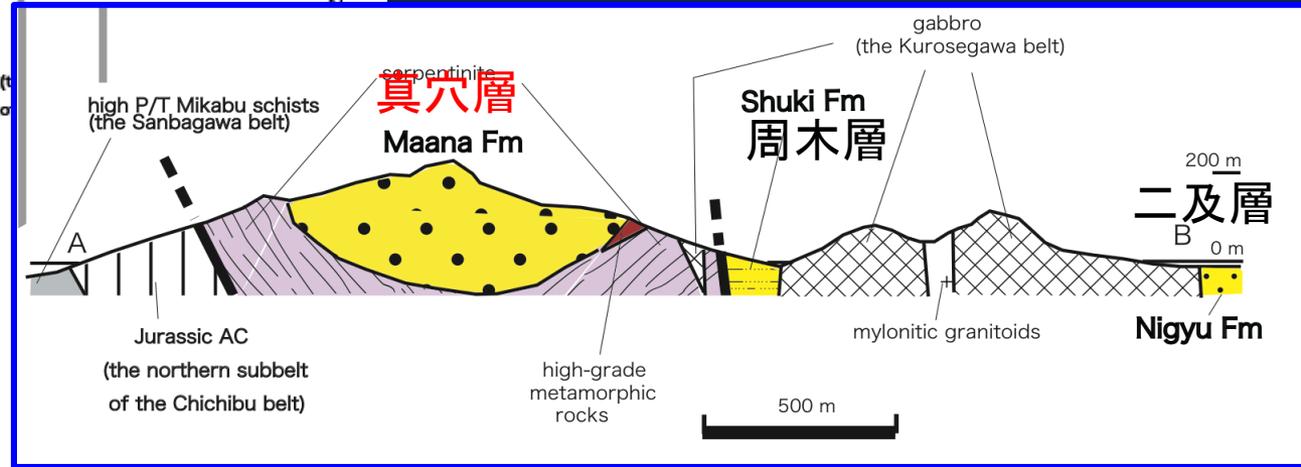
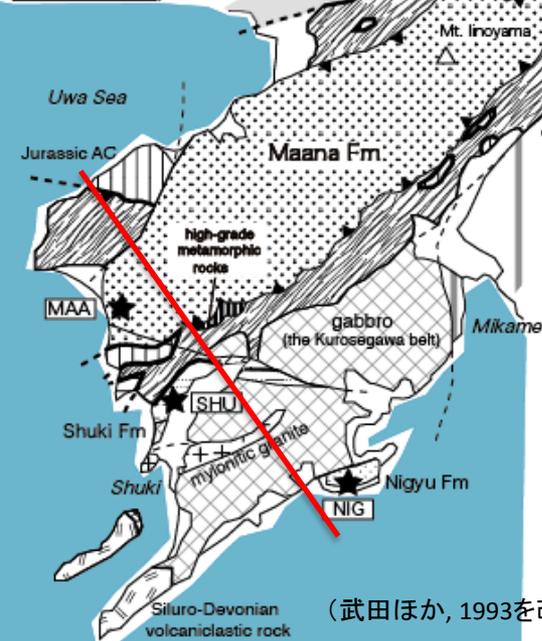
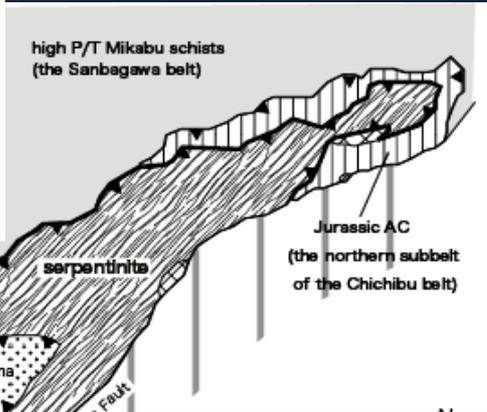
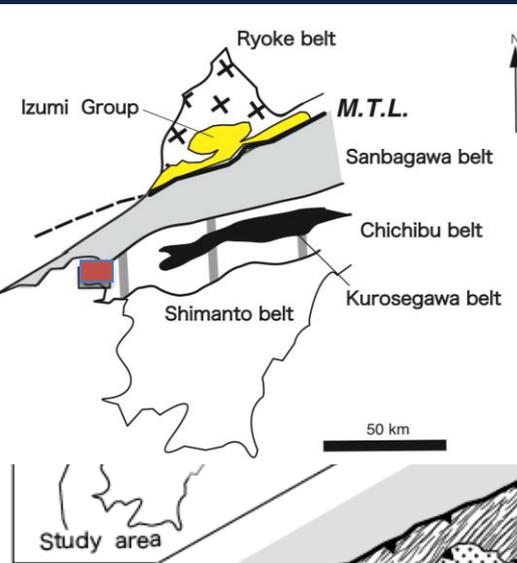
クリップの移動時期: 55~16 Ma
(竹内ほか1990)

日本海形成時の背弧拡大テクトニクス
(リフティング)

愛媛県三瓶地域の浅海成白亜系

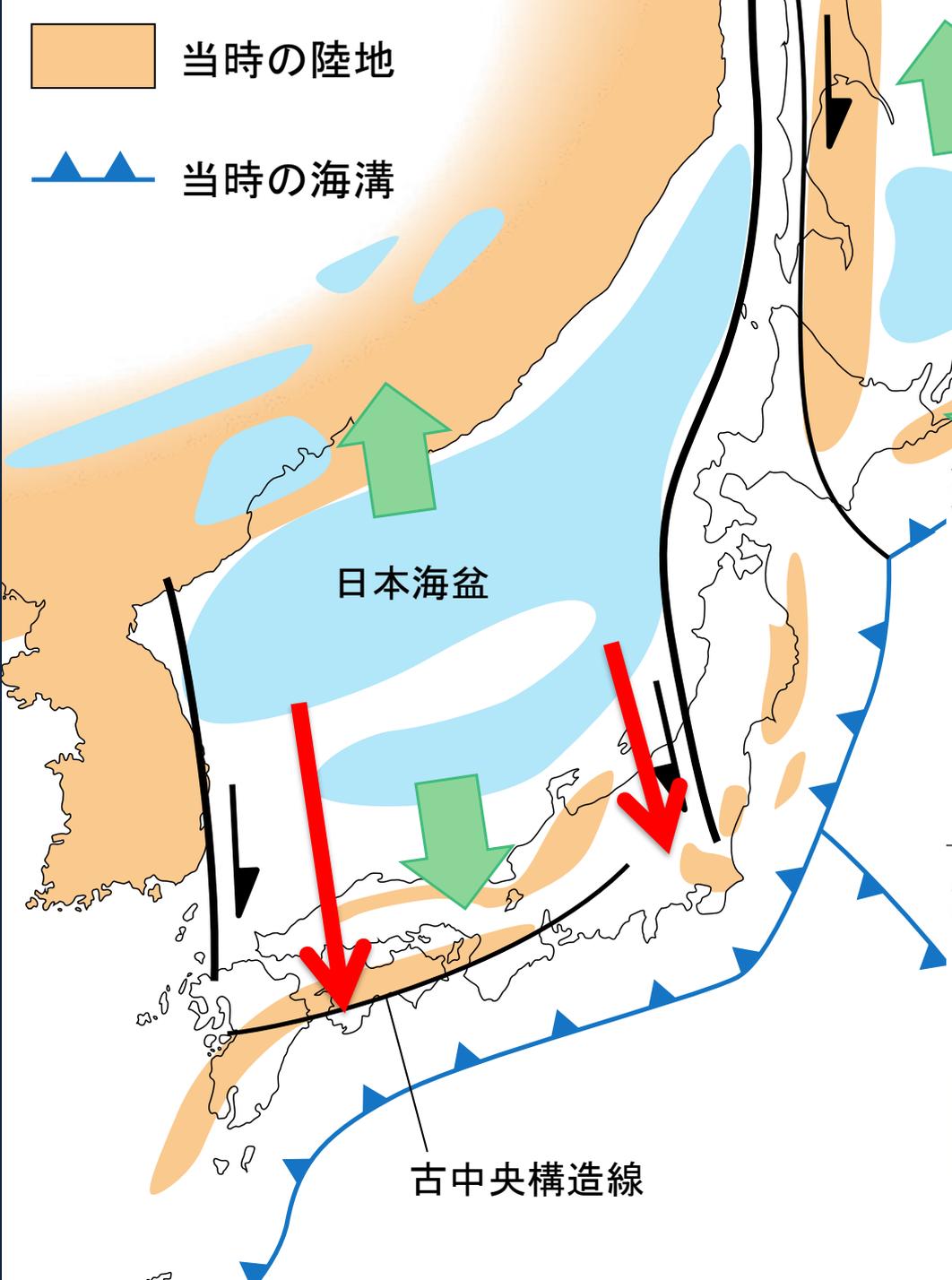
真穴層

浅海成白亜系砂岩 (ジュラ紀～白亜紀)
 異地性のクリッペ: 跡倉クリッペに比較可能
 → 北側の大陸側から来たらしい (武田ほか, 1993)

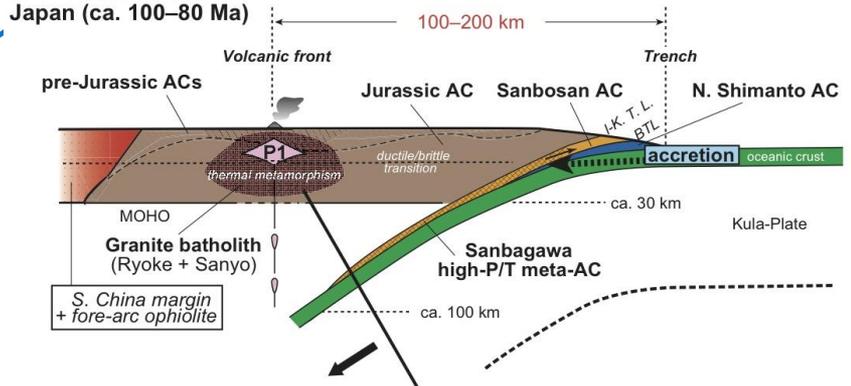


当時の陸地
 当時の海溝

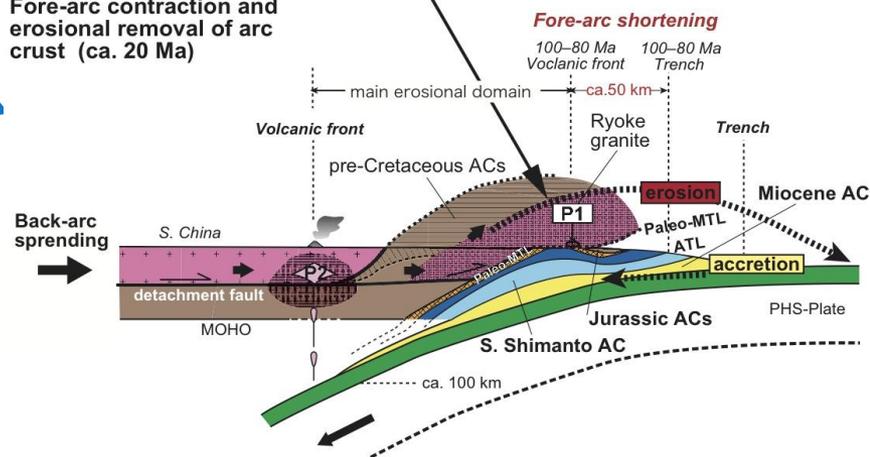
中新世 (25-20 Ma)での 背弧海盆(日本海)拡大

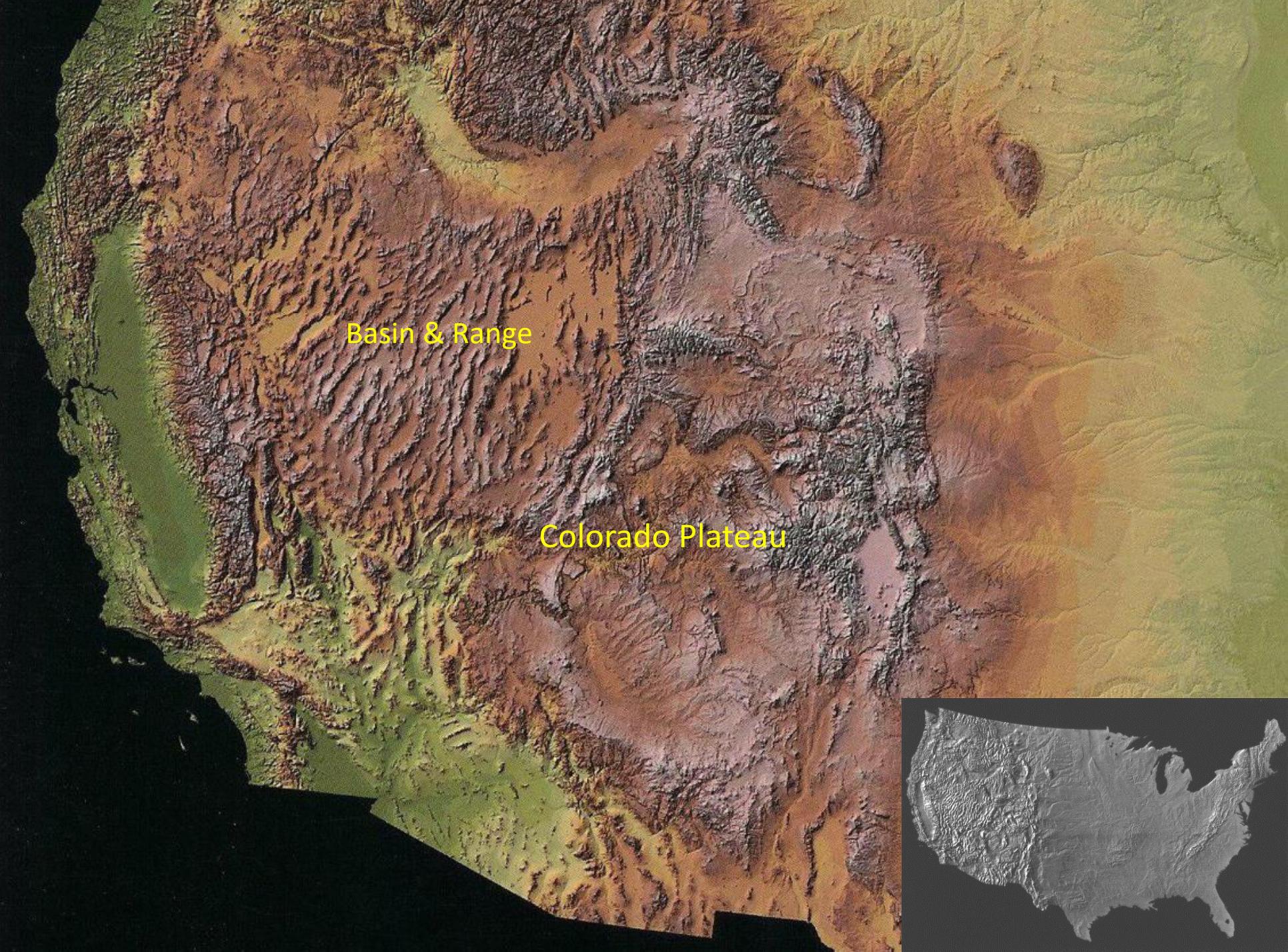


Arc-trench setting of Cretaceous SW Japan (ca. 100-80 Ma)



Fore-arc contraction and erosional removal of arc crust (ca. 20 Ma)

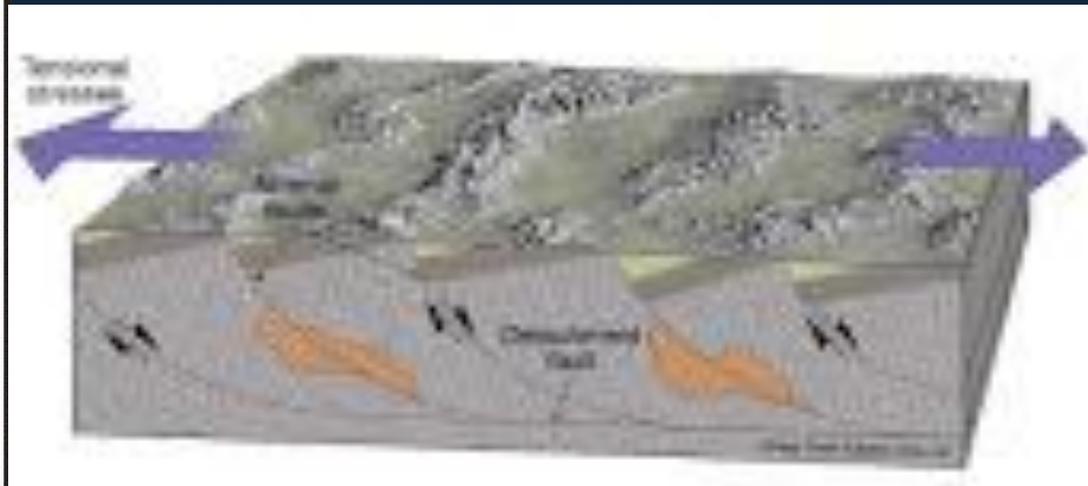
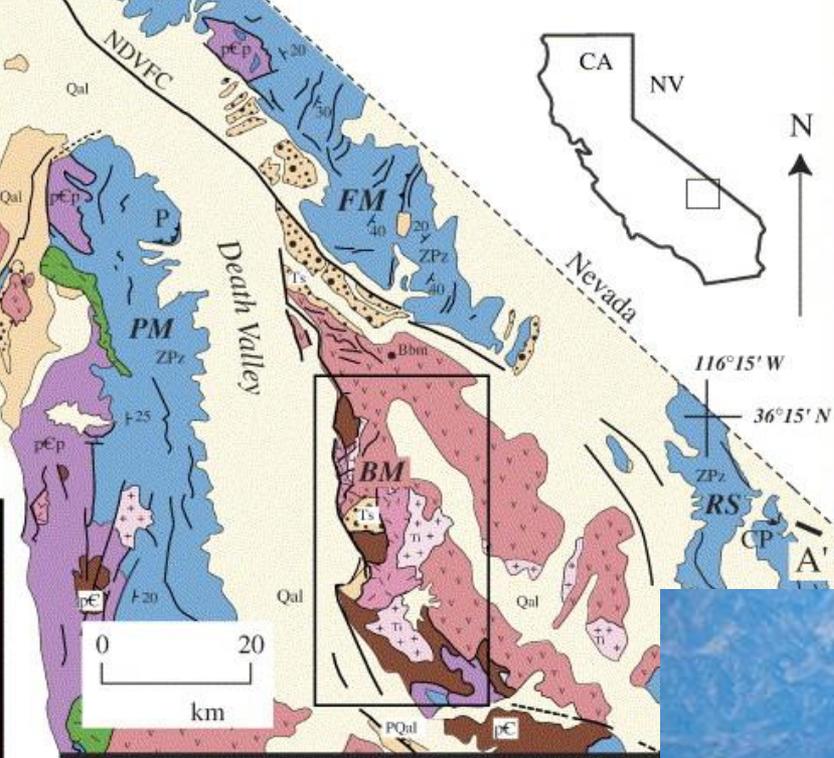


A detailed topographic map of the western United States, showing the Basin & Range province and the Colorado Plateau. The Basin & Range is characterized by a series of north-south trending mountain ranges and valleys, colored in shades of brown and orange. The Colorado Plateau is a large, relatively flat area to the east, colored in shades of yellow and green. The map uses a color gradient to represent elevation, with darker colors indicating higher elevations and lighter colors indicating lower elevations. The coastline of the United States is visible on the left side.

Basin & Range

Colorado Plateau



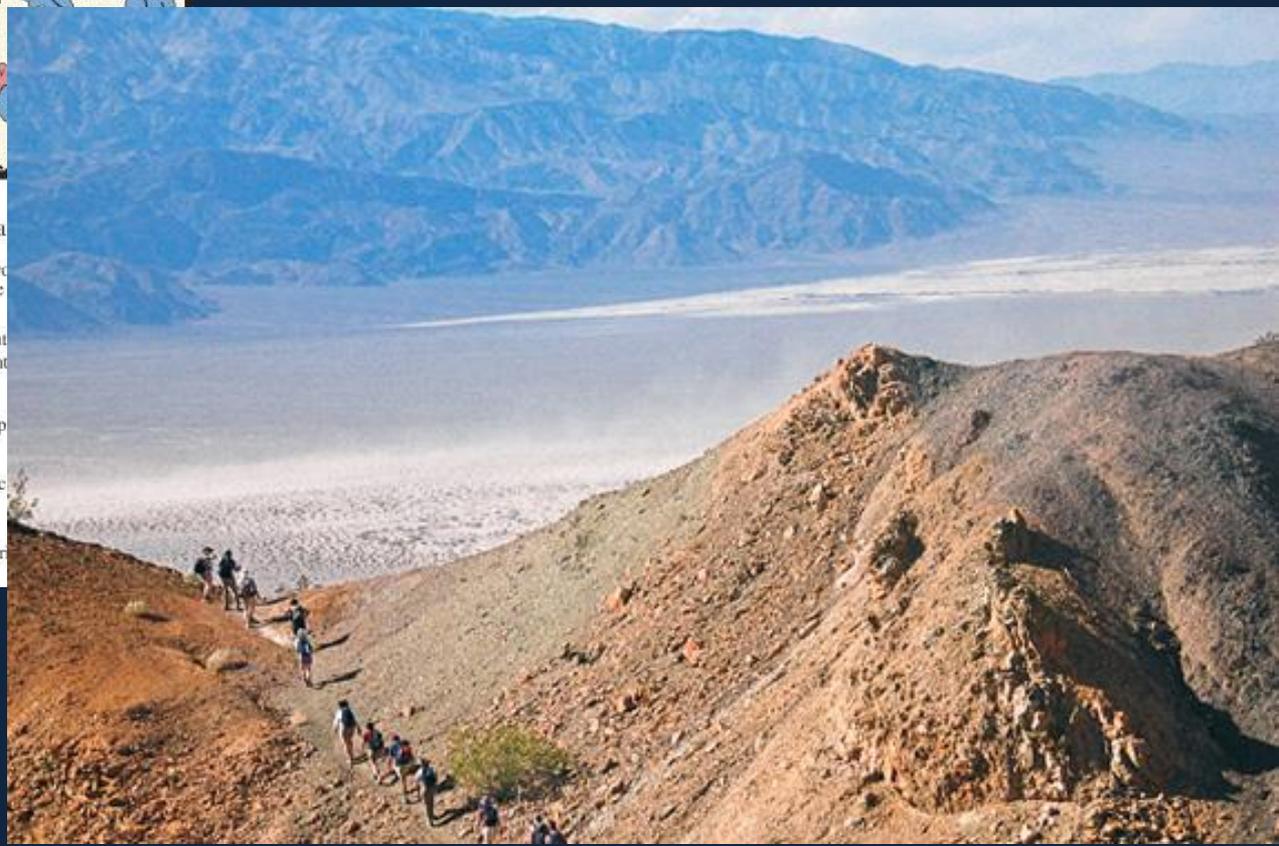


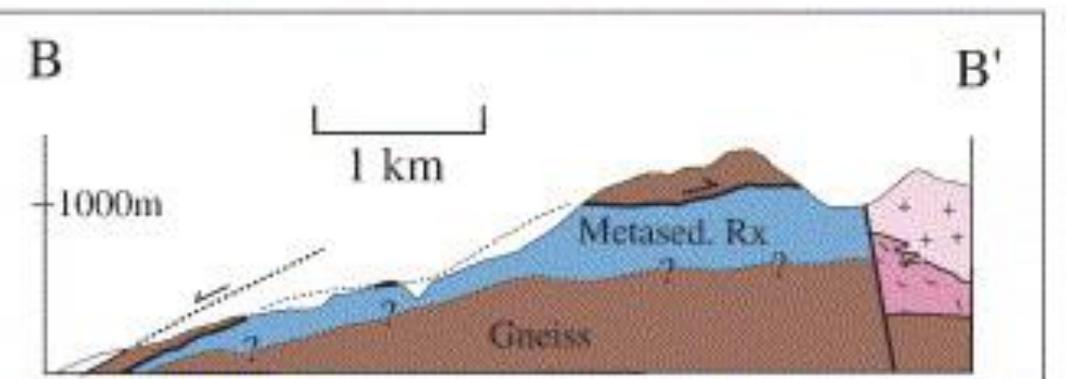
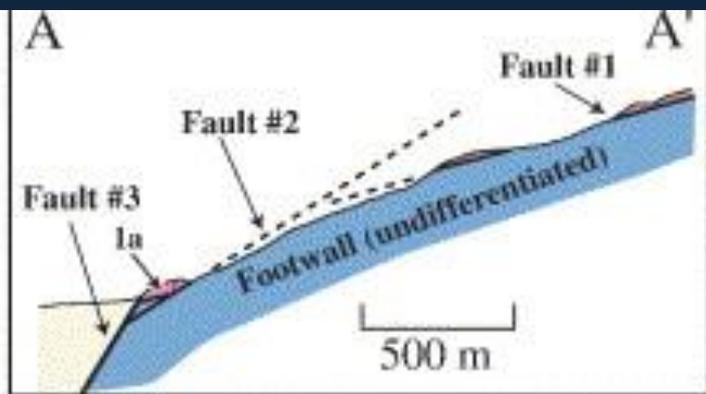
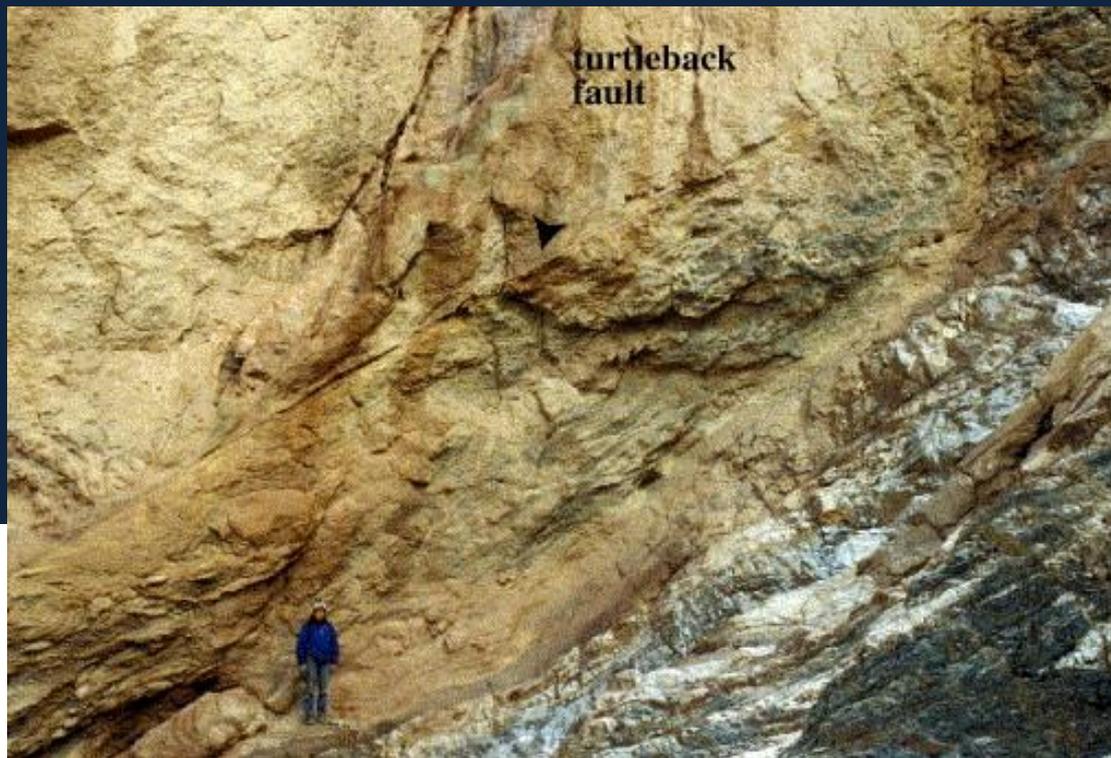
Sediments and Sedimentary Rocks

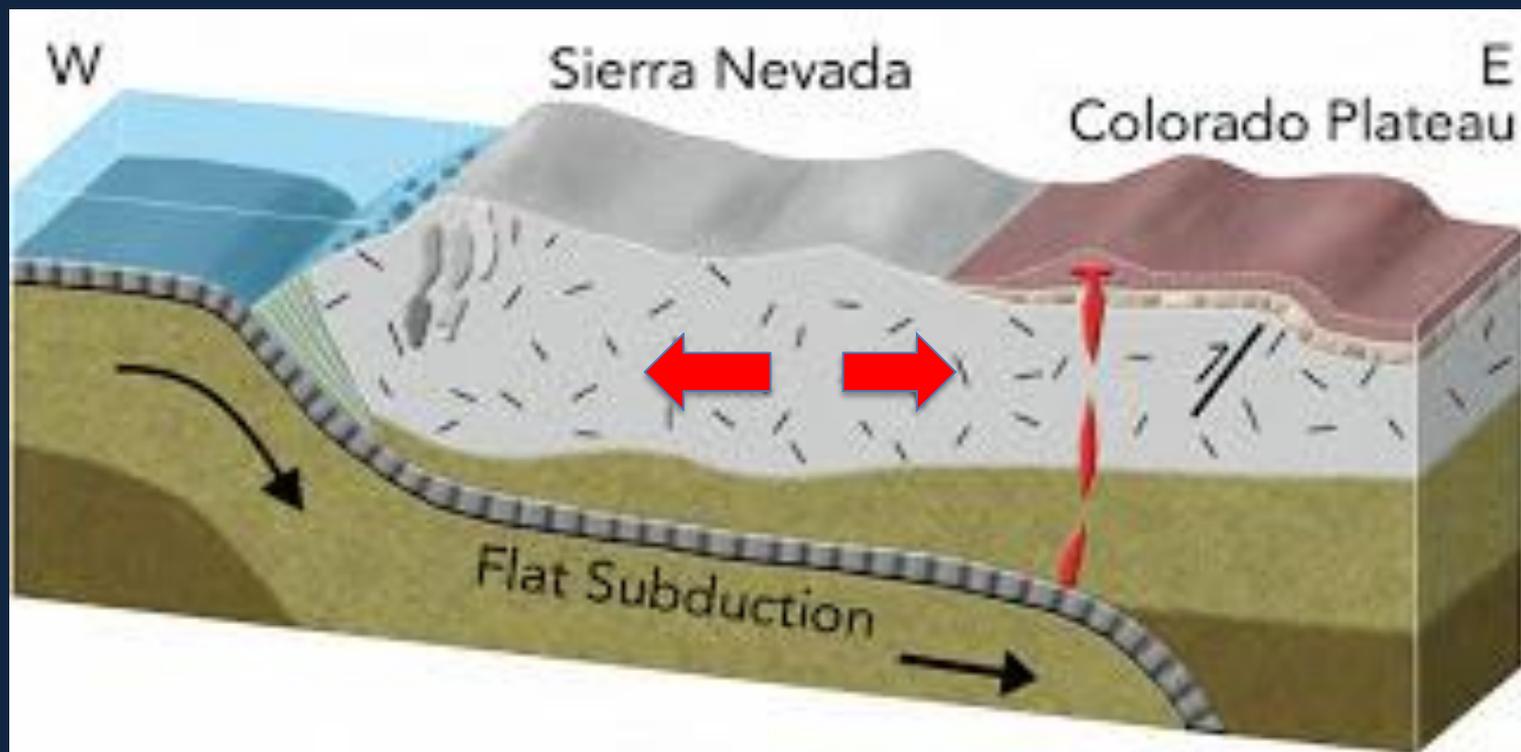
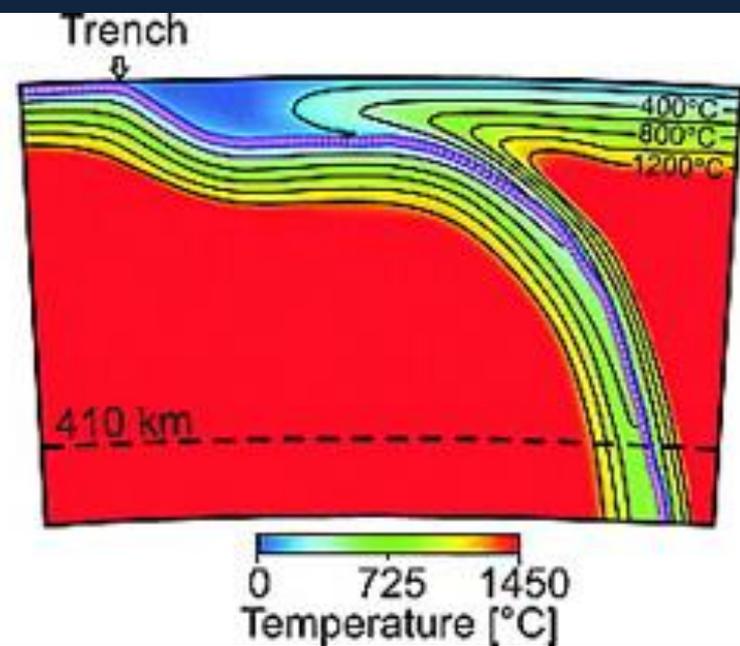
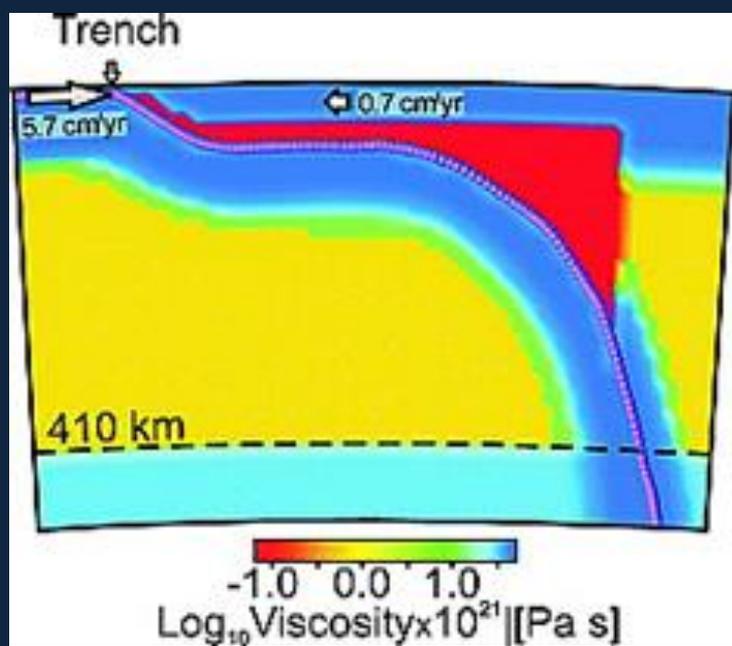
- Qal Quaternary alluvium
- PQal Pliocene-Quaternary deposits
- Ts Tertiary sedimentary rocks
- ZPz Paleozoic and upper Proterozoic sedimentary rocks
- pCp Late Precambrian Pahrump Group

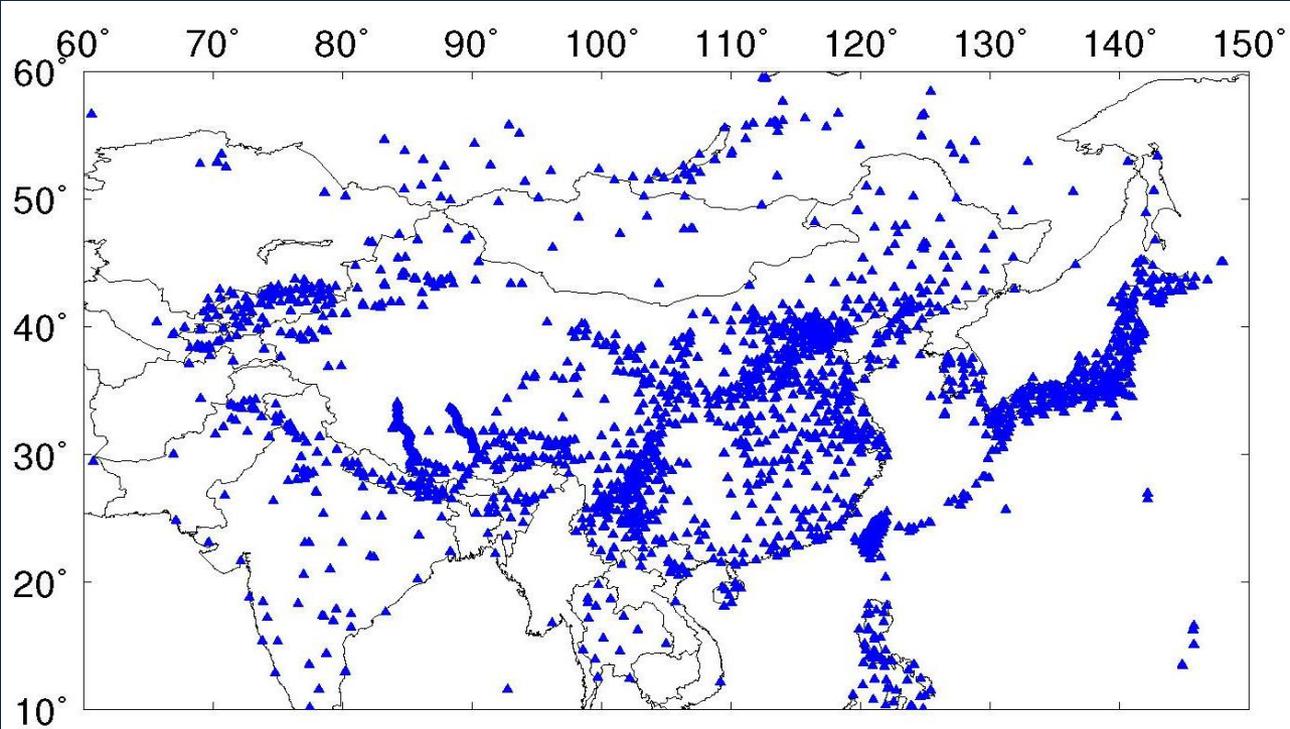
Igneous and meta

- Tv Volcanic rocks mostly late
- Ti Tertiary igneous undifferentiated
- Willow Sp
- Mzi Mesozoic igneous rocks
- pC Precambrian



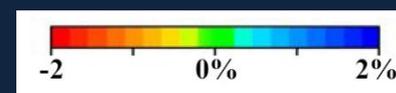
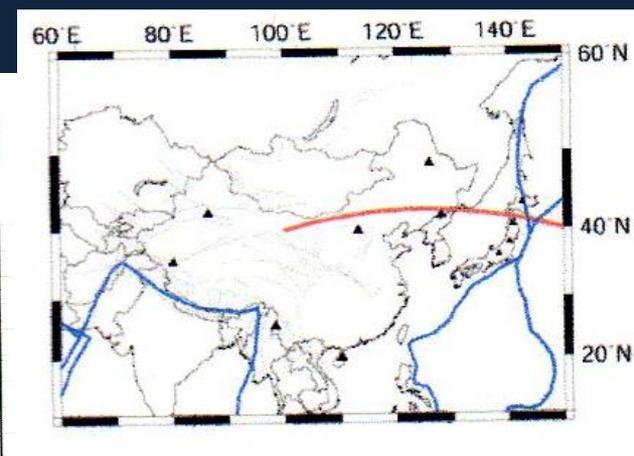
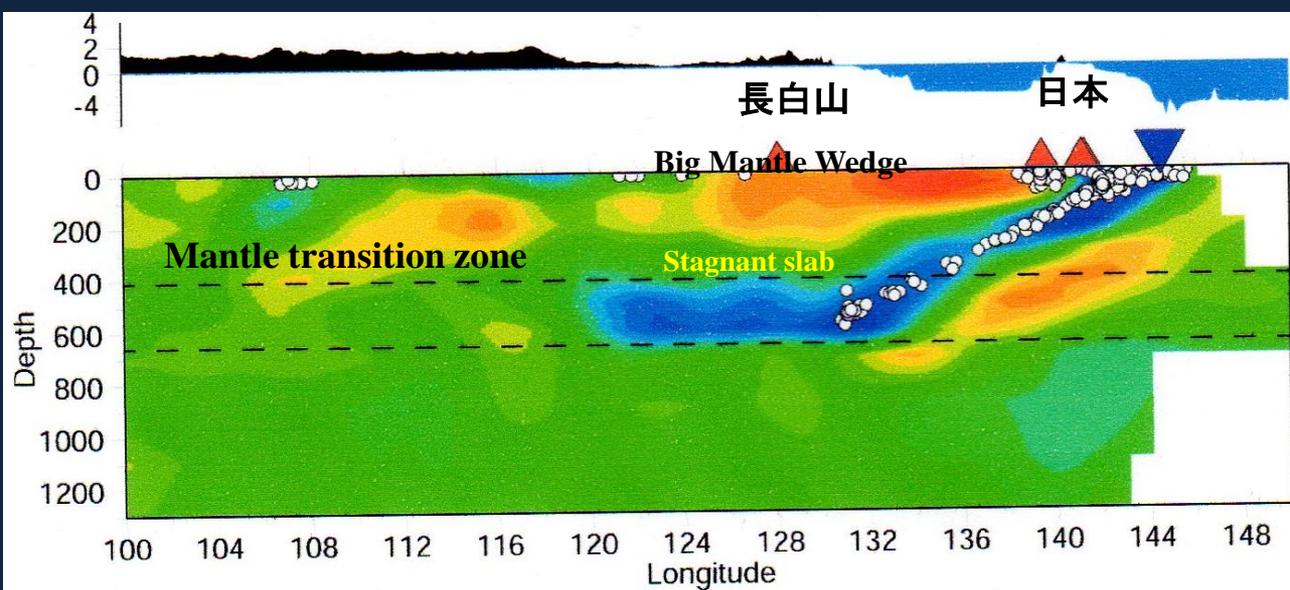






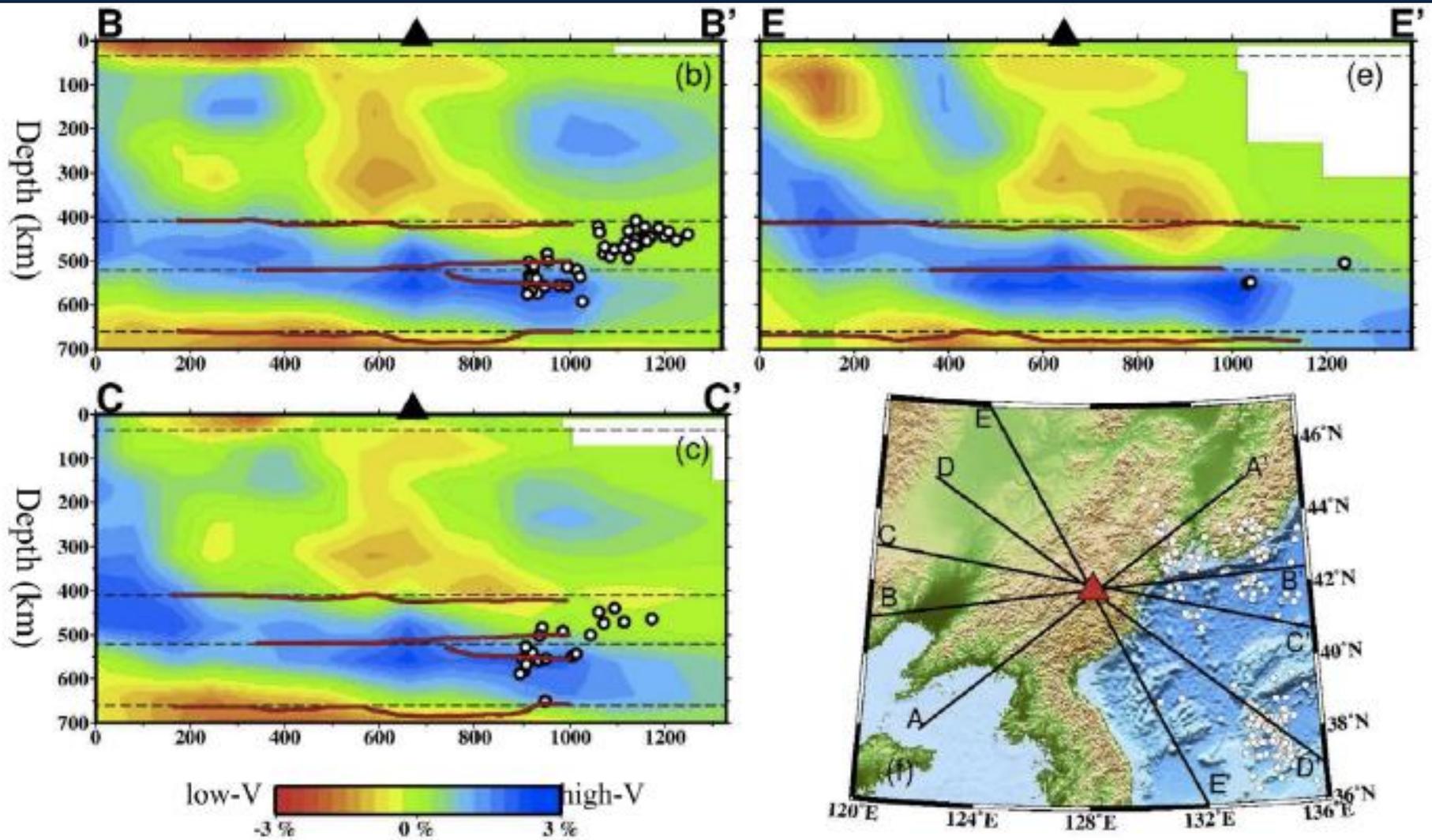
沈み込み帯の火山弧
から離れた地下の熱源

将軍様の古里
長白山

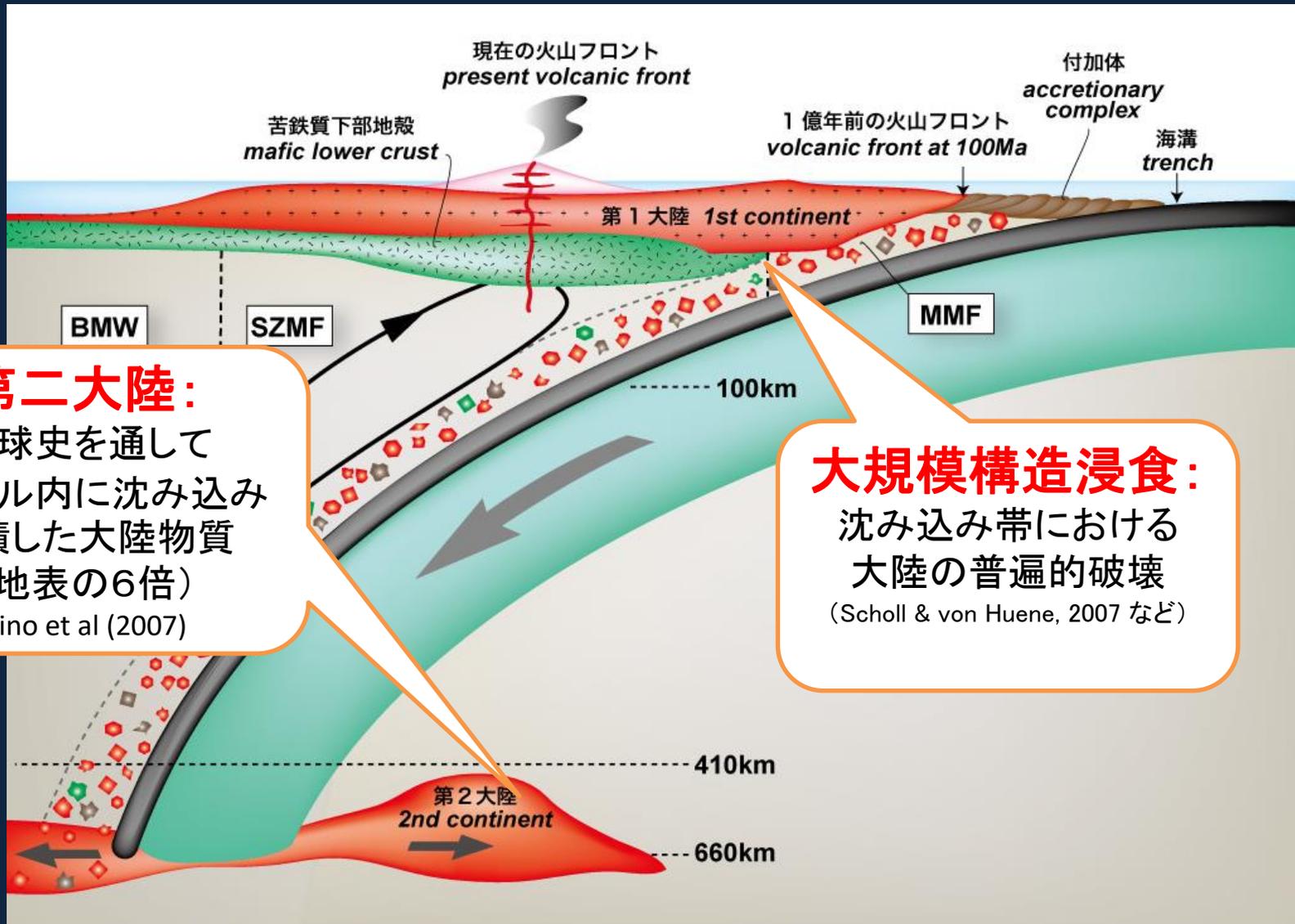


Zhao (2009)

長白山



新たな熱源としての沈み込んだ大陸地殻物質



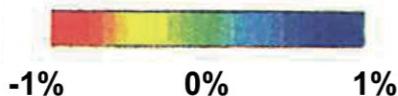
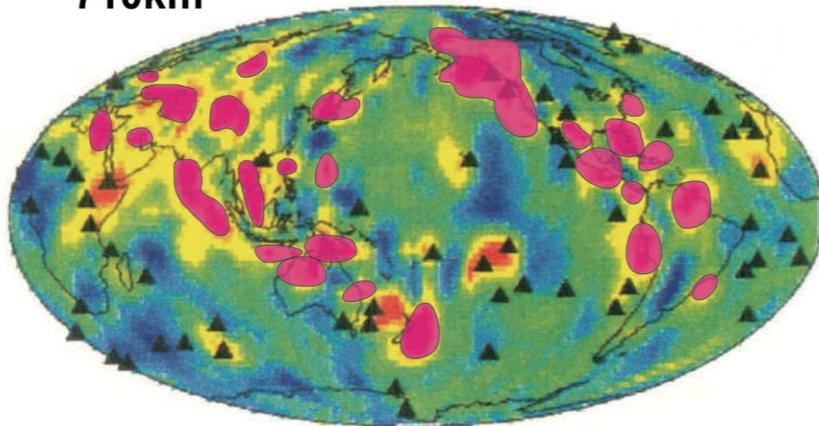
第二大陸:

地球史を通して
マントル内に沈み込み
蓄積した大陸物質
(地表の6倍)
Rino et al (2007)

大規模構造浸食:

沈み込み帯における
大陸の普遍的破壊
(Scholl & von Huene, 2007 など)

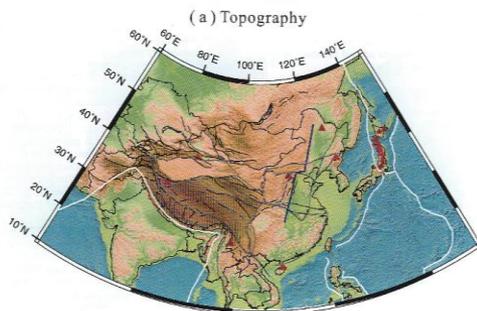
710km



26 second continents

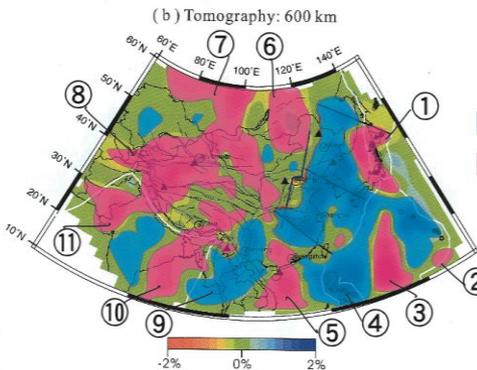
沈み込んだ花崗岩の行方 (第2大陸)

西太平洋下に沈み込み帯が集中しているため中国大陸の下には沈み込んだ花崗岩が大量に存在しており、固体地球的に重要な領域



Sub-continents

- ① Japan
- ② S. Mariana
- ③ Palece vela
- ④ Taiwan
- ⑤ Indo-China
- ⑥ Siberia
- ⑦ Kazakhstan
- ⑧ Greater India
- ⑨ Tibet
- ⑩ Bengal
- ⑪ Decan



■ slabs
■ TTG continents

第2大陸の分布の予想図

結論

どの時代の地球についても
ジルコン年代学は重要で、面白い！

zircono-phobiaにならず、zircono-phileになろう！