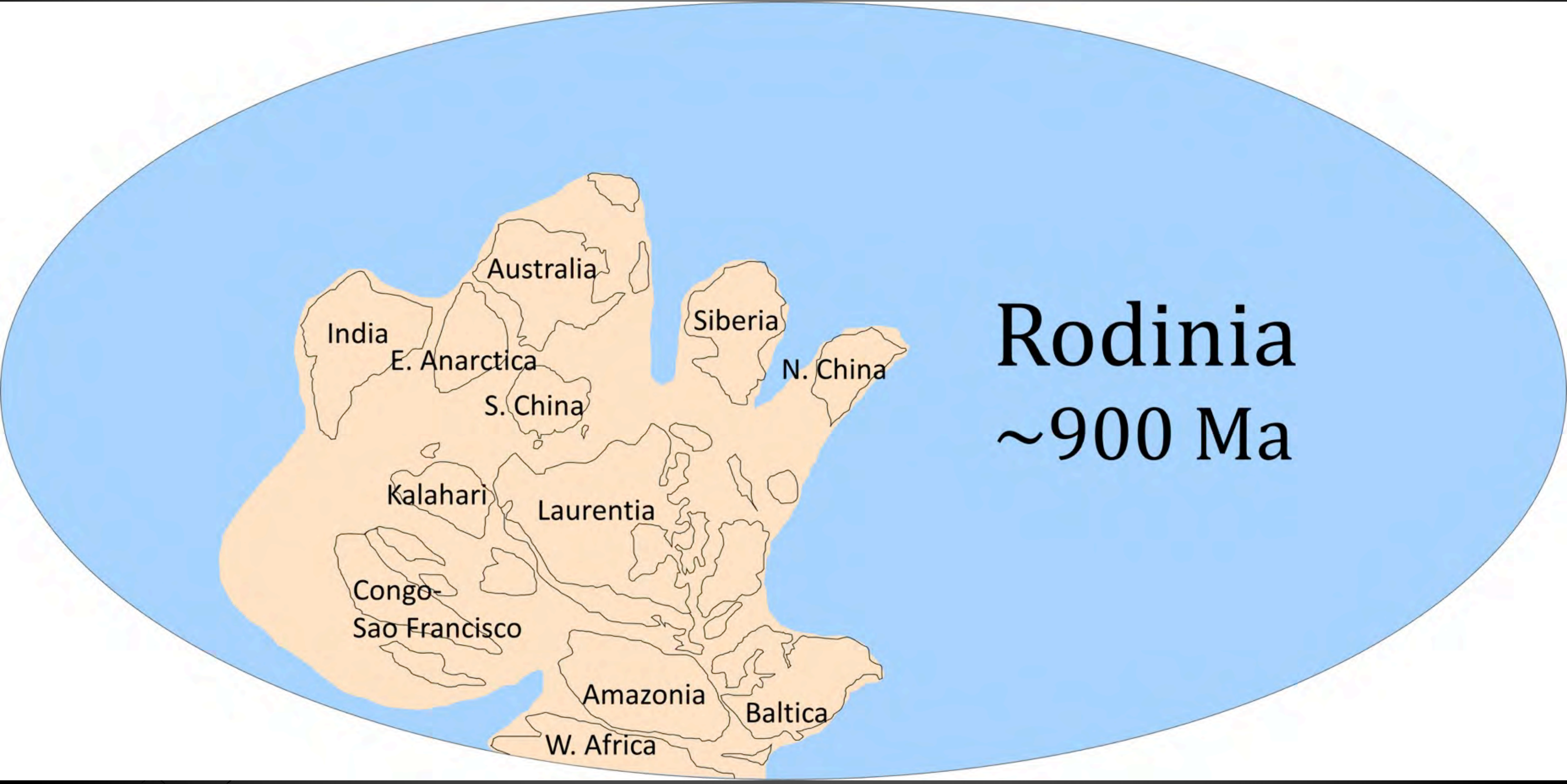
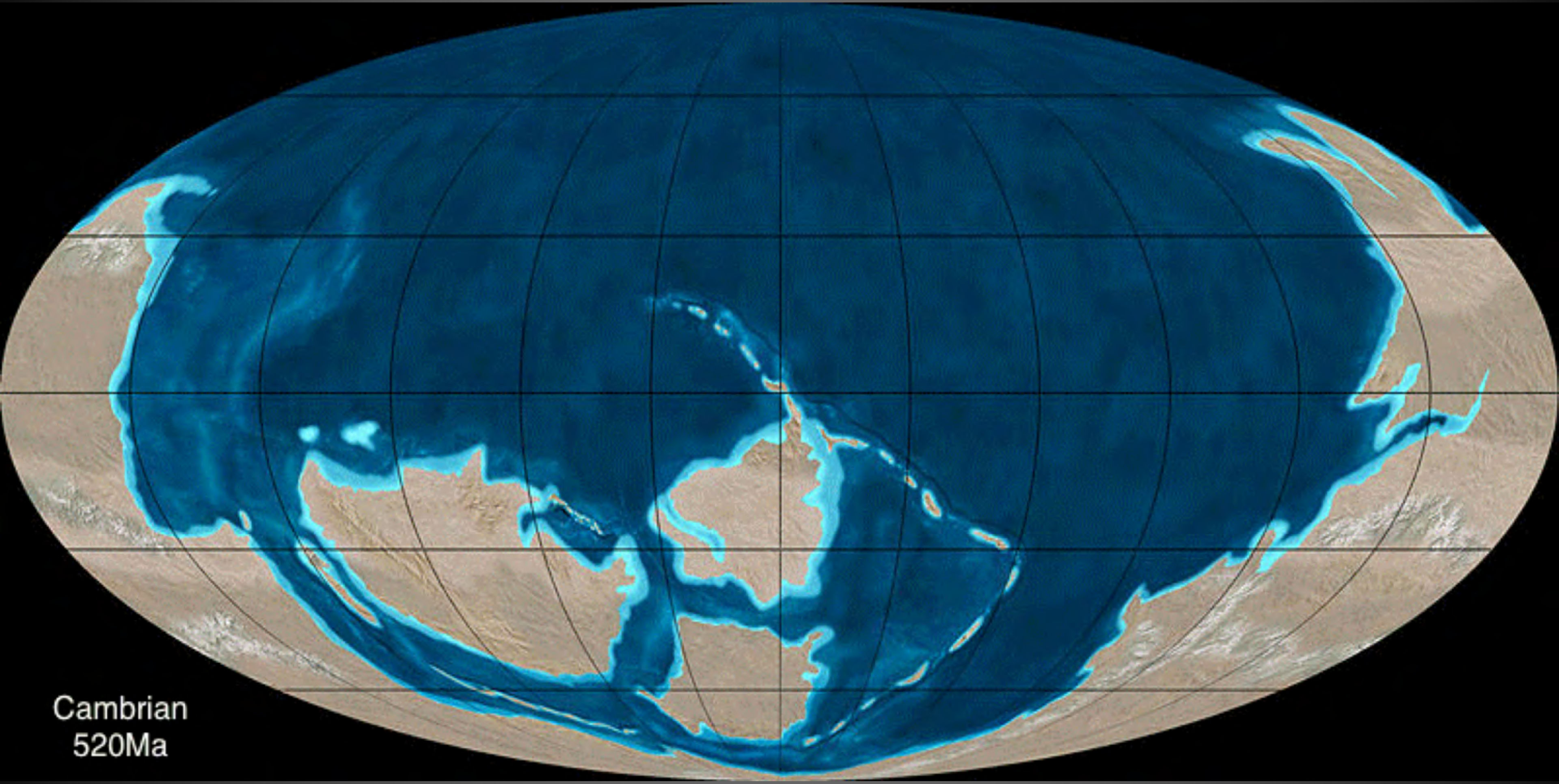
What's up with Rodinia?

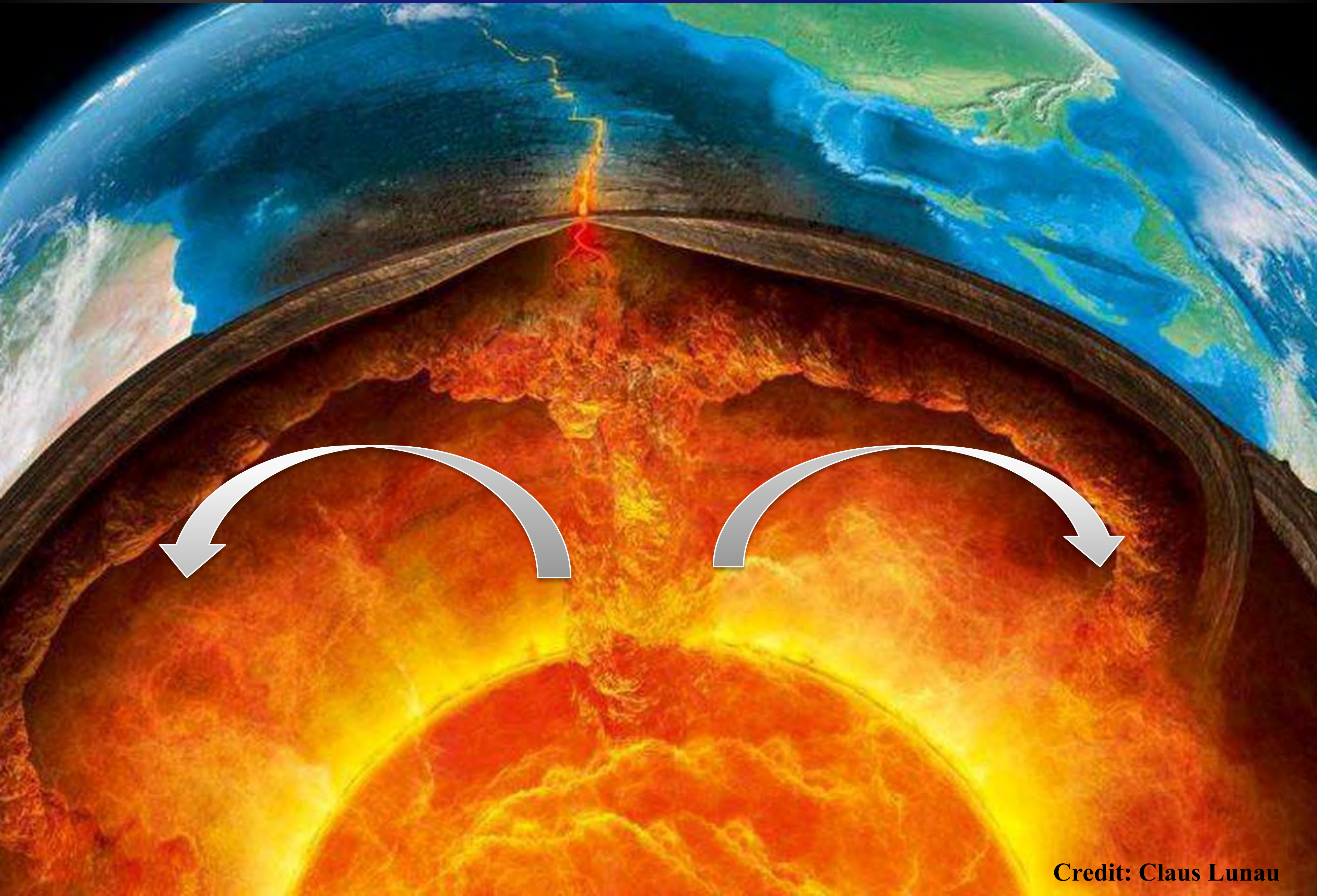
Chao Liu, Simone Runyon, Andrew Knoll, Robert Hazen



The Supercontinent Cycle

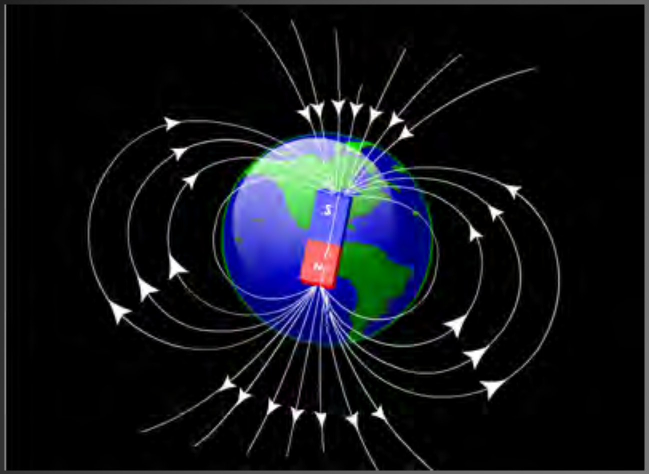


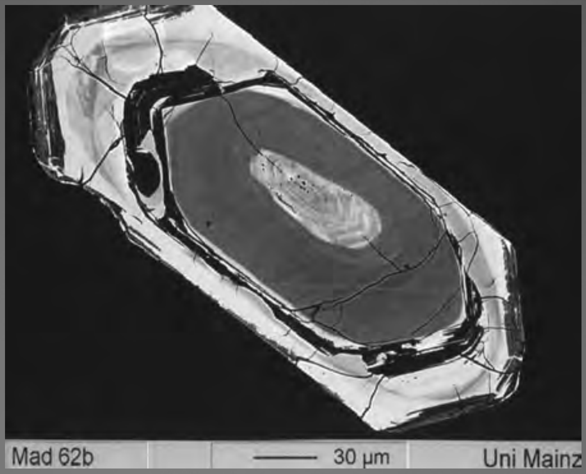
Why? Plate Tectonics

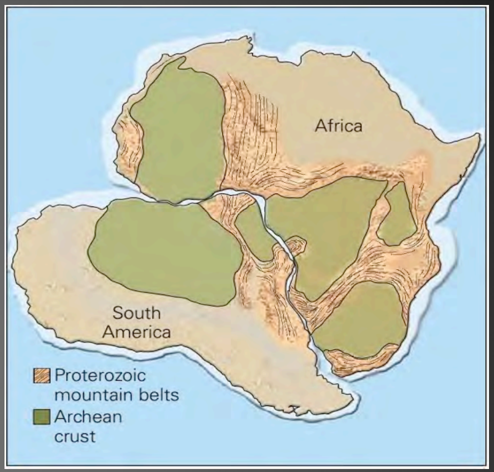


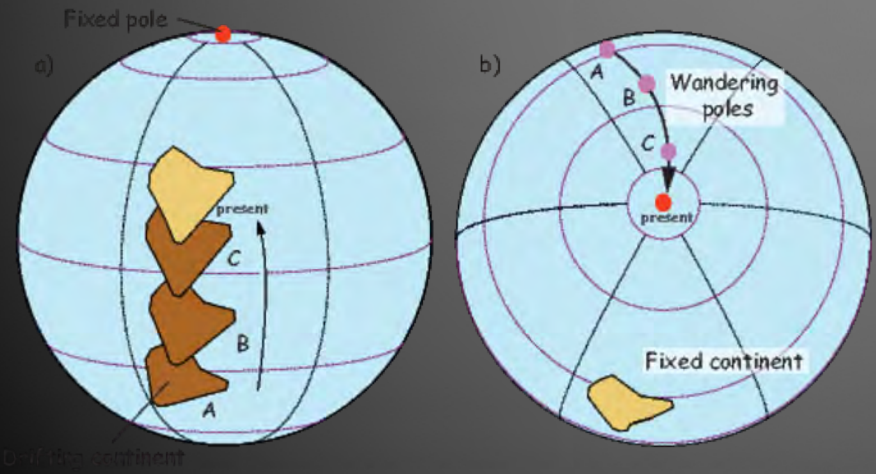
Credit: Claus Lunau

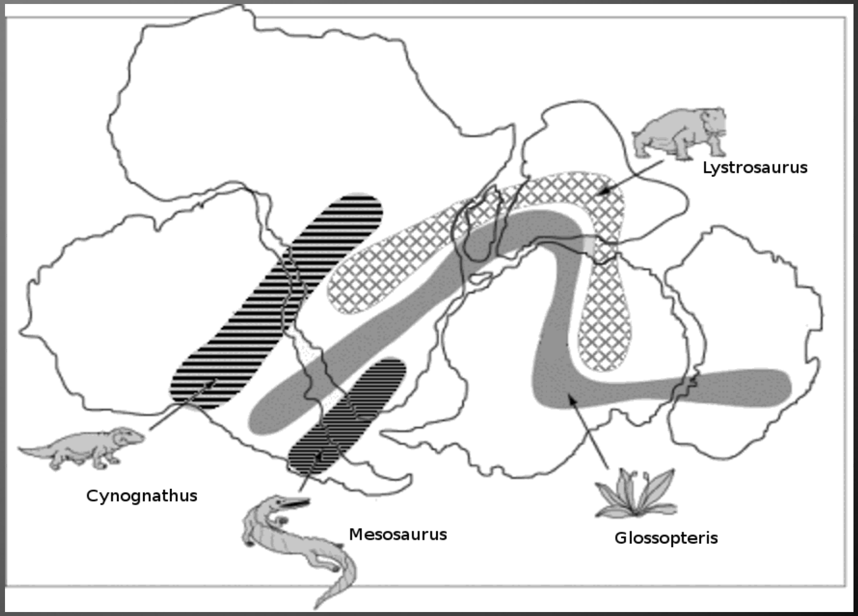
Evidence: Paleomag, Geochron, Fossils

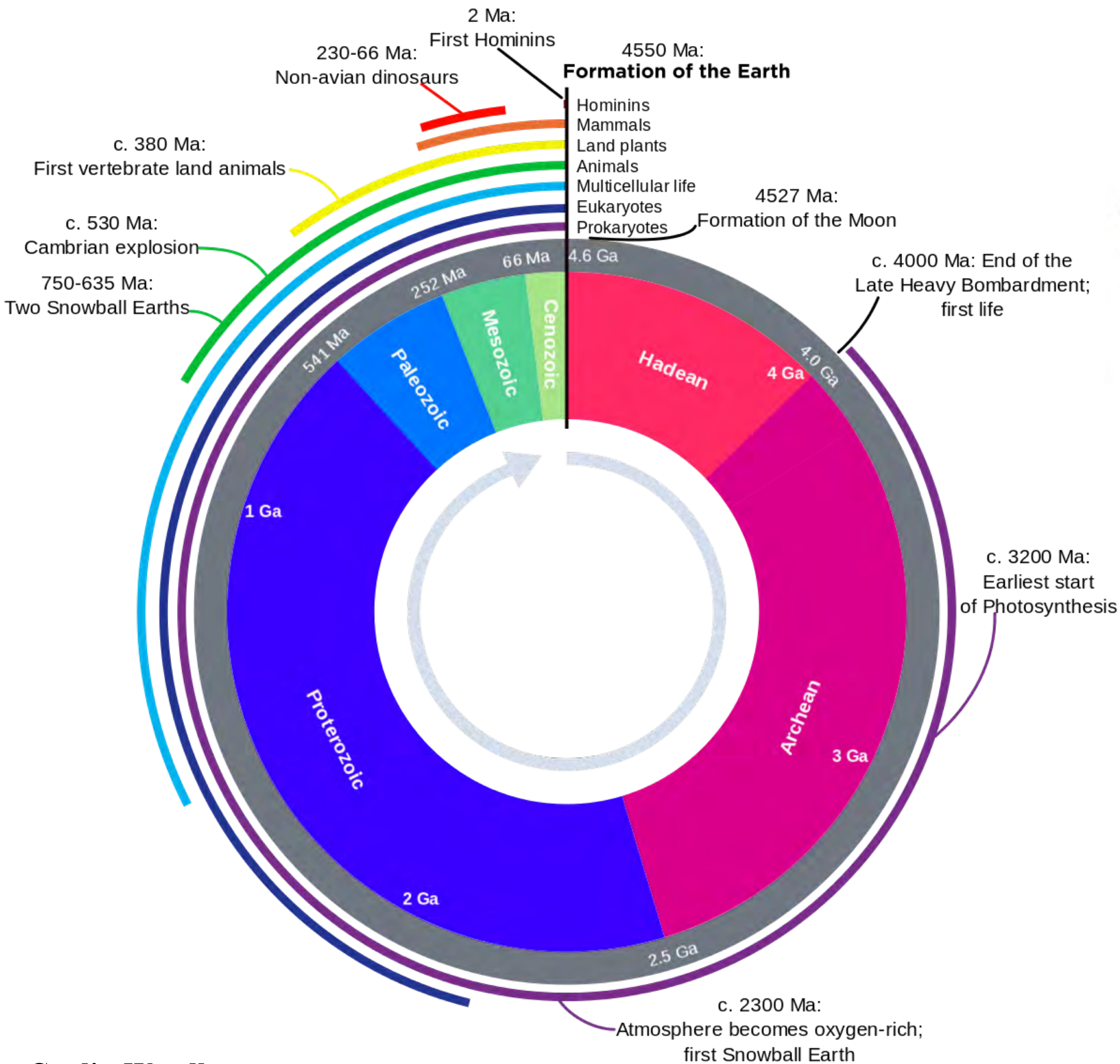




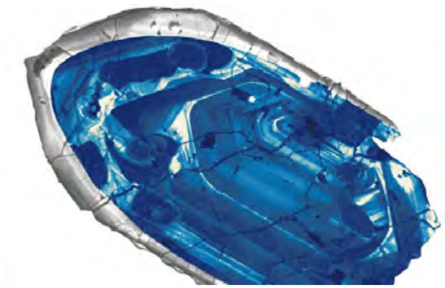








Geochron



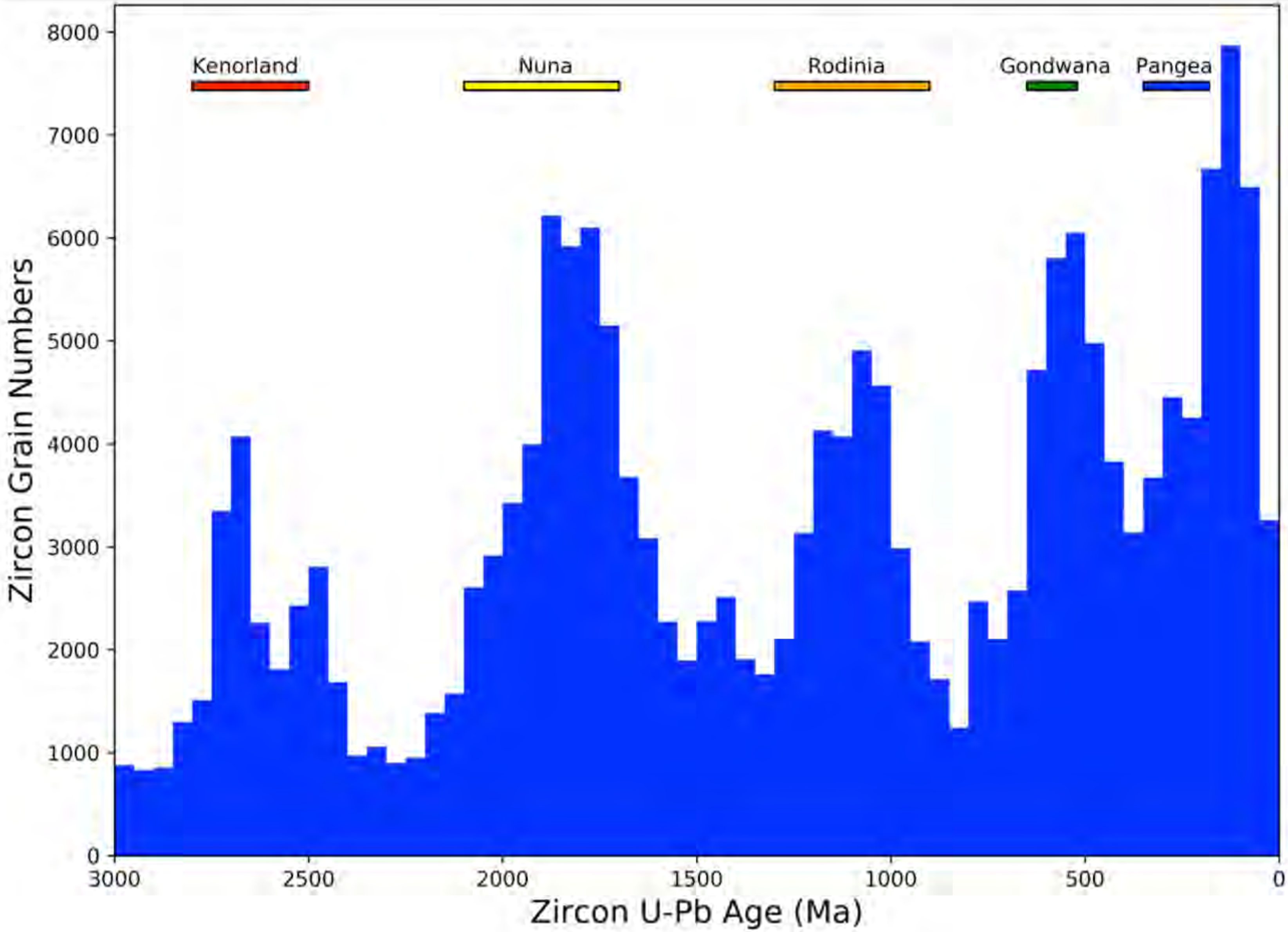
Valley et al., 2014

Paleomag

Fossils

Credit: Woudloper

All supercontinents show zircon pulses.

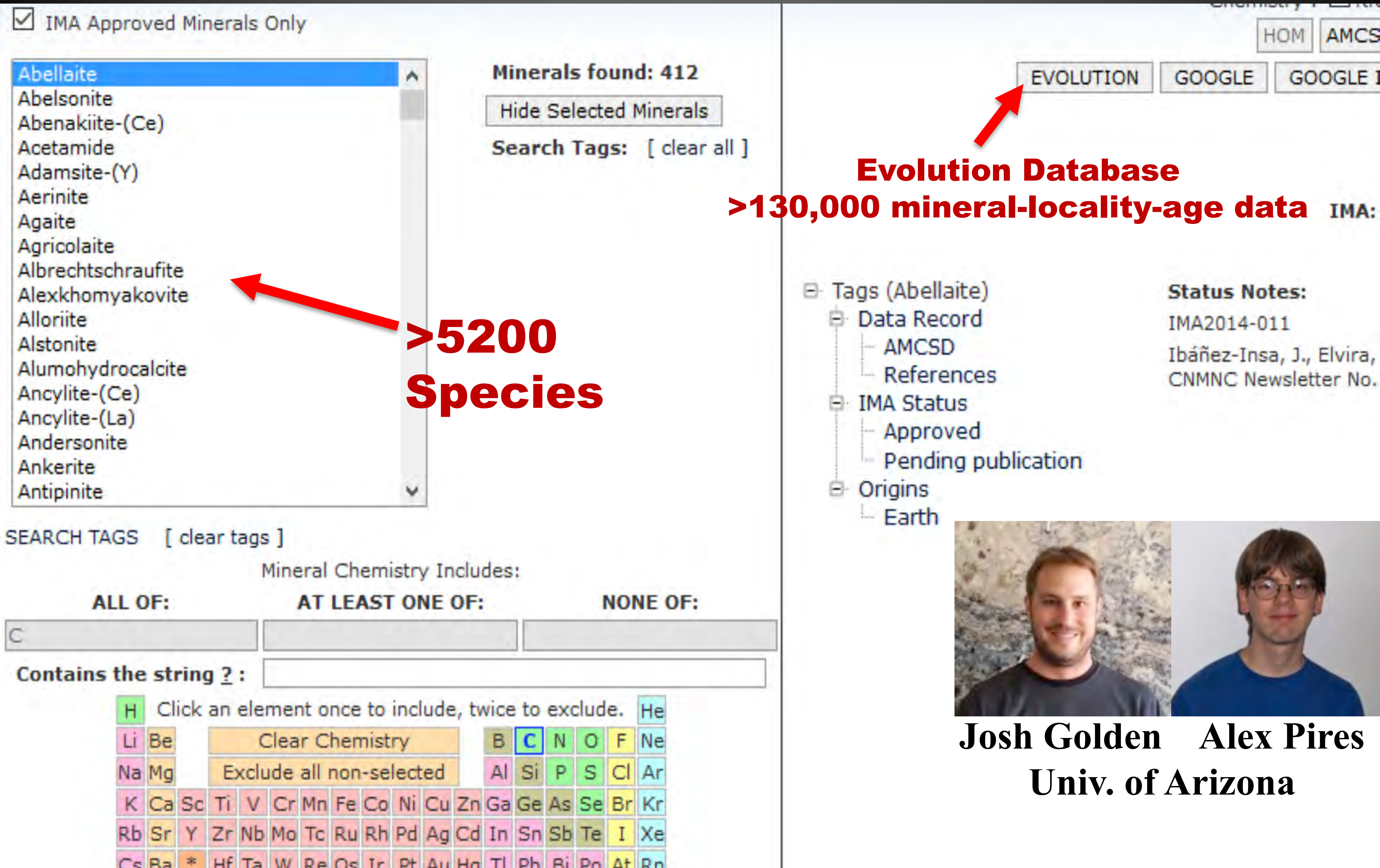


After Voice (2011)

How about other minerals?

>5200 mineral species

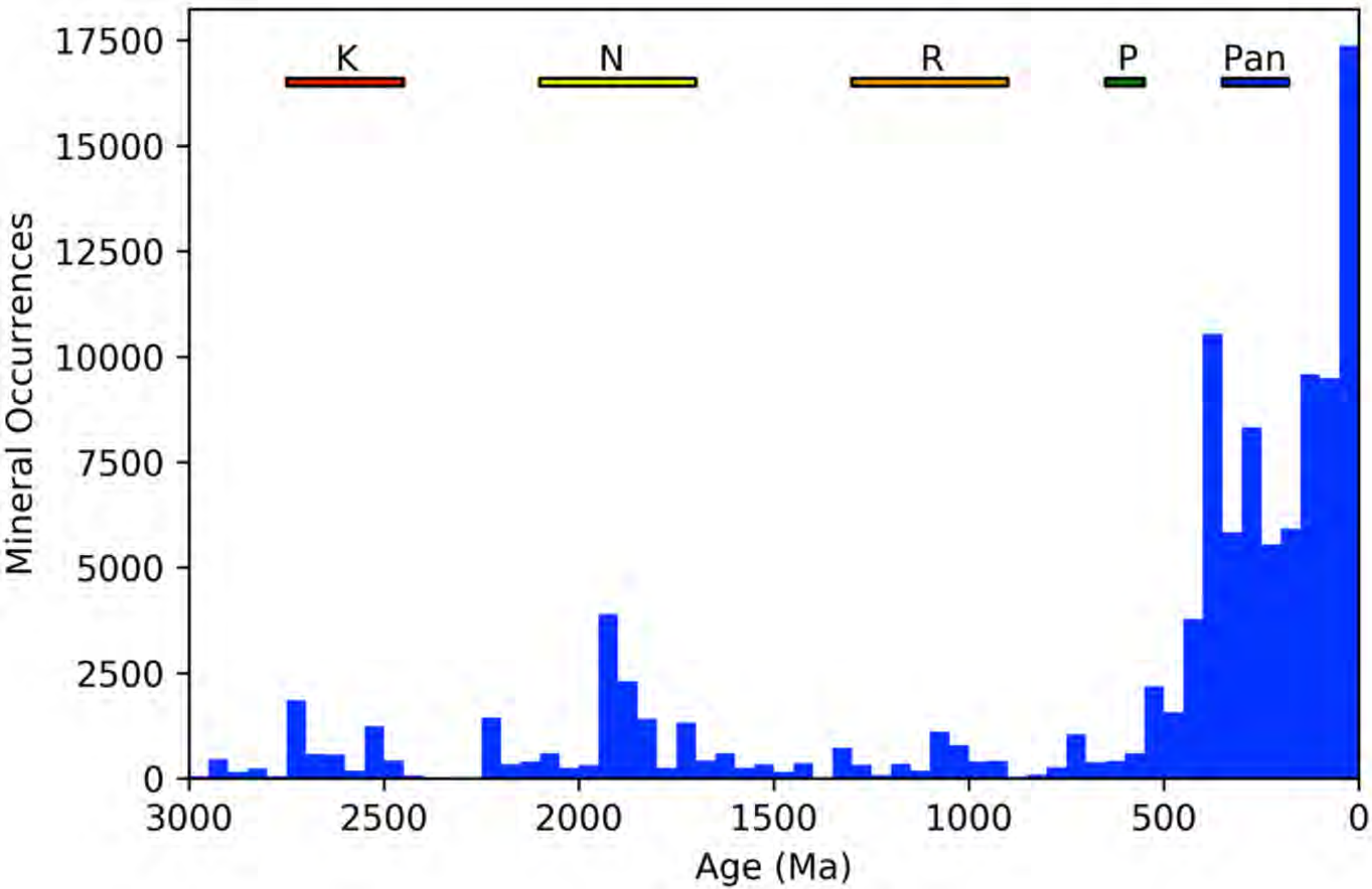
rruff.info/ima



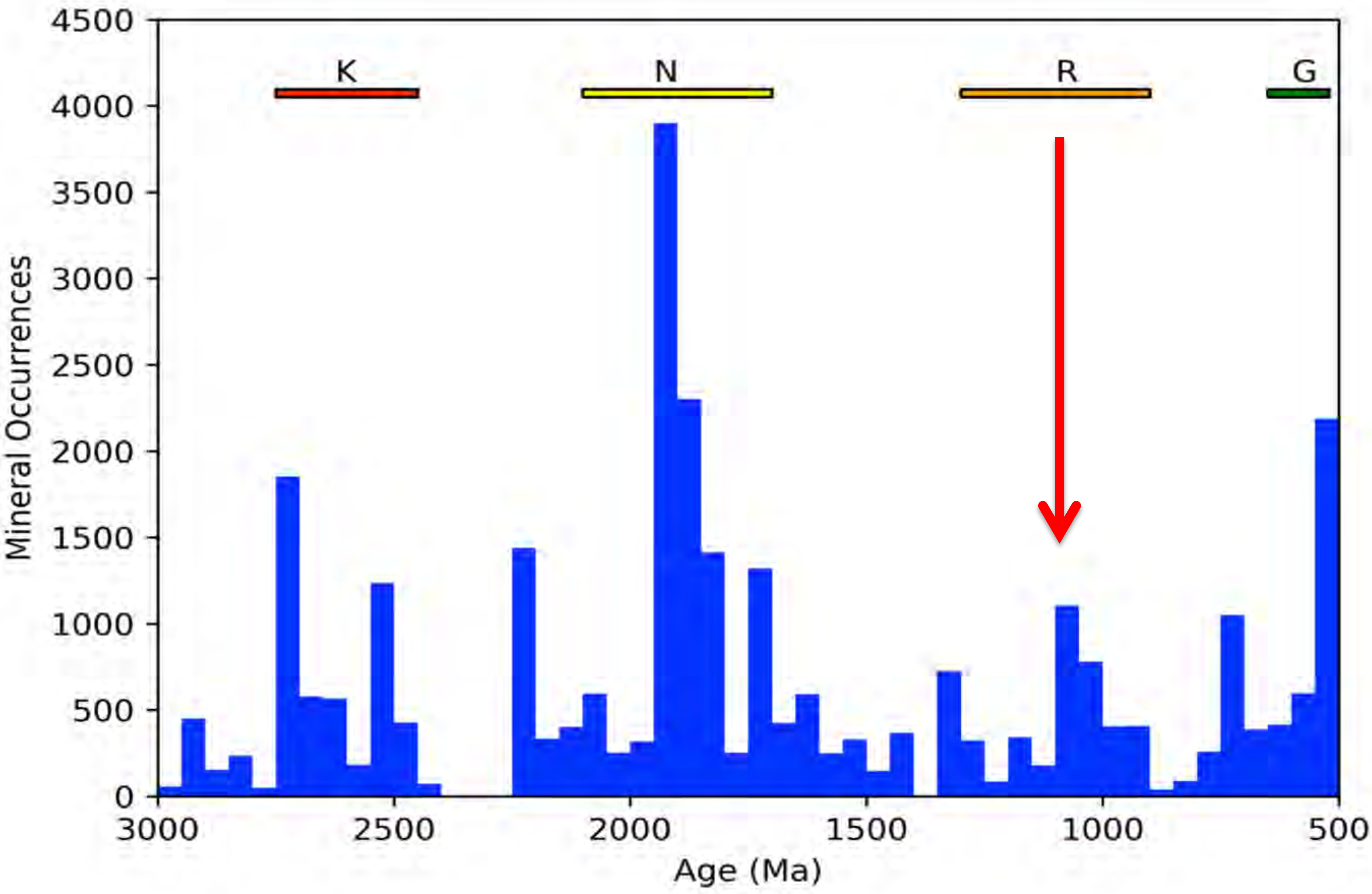
Josh Golden **Alex Pires**

Univ. of Arizona

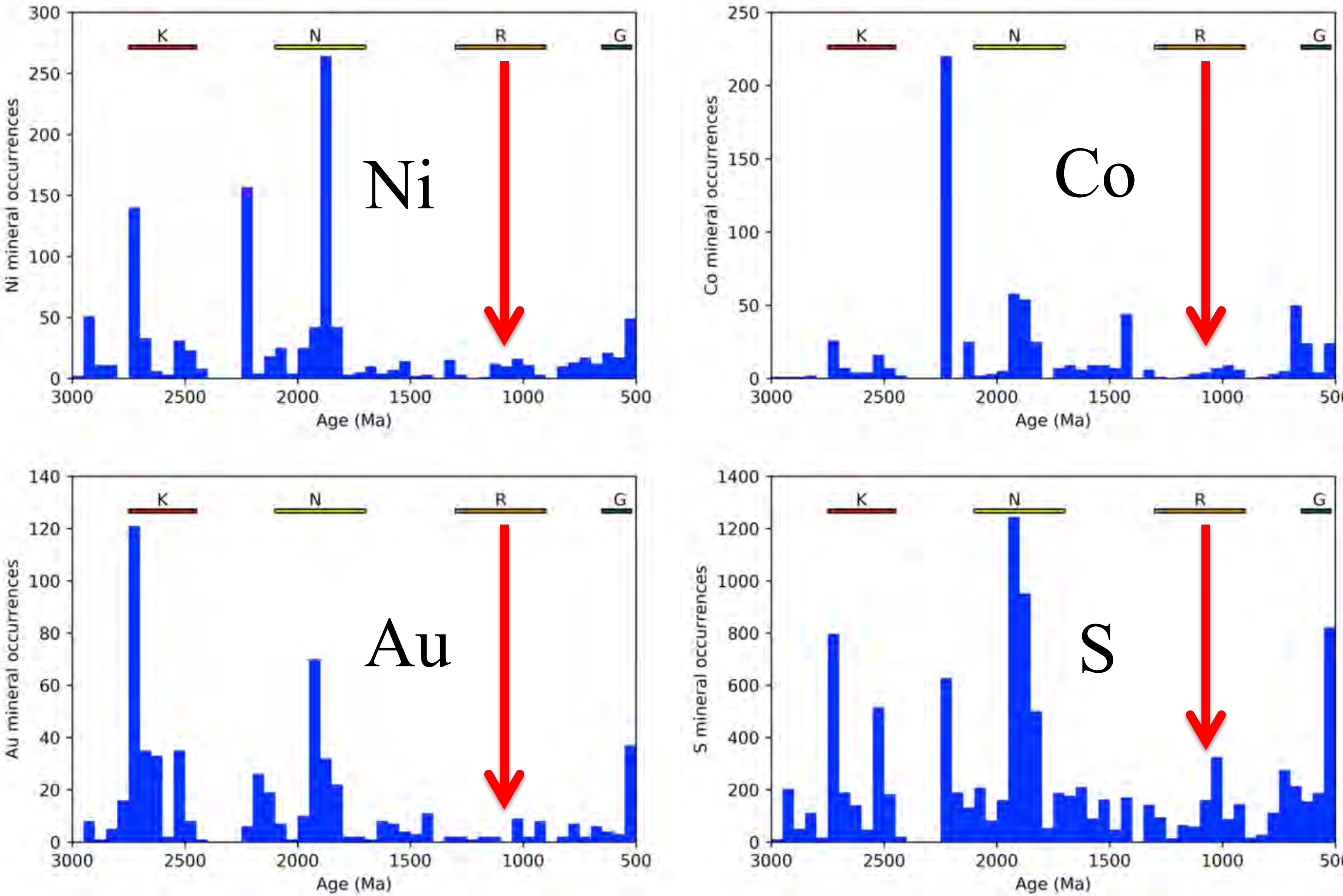
High-T Minerals through Deep Time



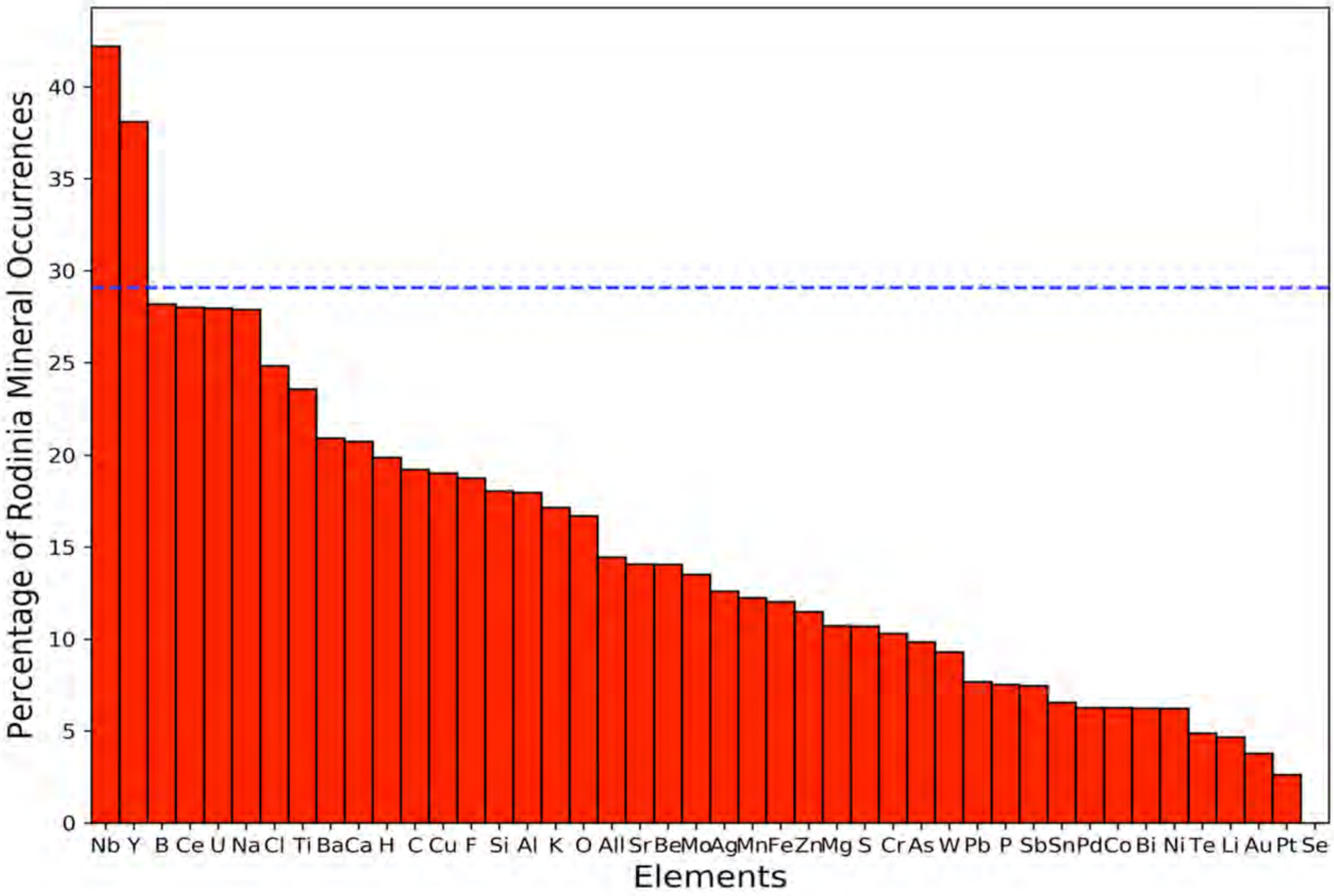
Less mineralization during Rodinian assembly



Less mineralization during Rodinian assembly



Not all species...



Questions

1. Why is the formation of high-T Nb and Y minerals as pronounced as, or even more prominent than zircons during Rodinia assembly?

2. Why are many other high-T minerals, especially Ni, Co, PGE minerals, much less abundant during Rodinia assembly?

Coupling geochemical and mineral databases!

EarthChem.org

EarthChem IEDA

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single-point access to geochemical databases

data synthesis
PetDB, NAVDAT, SedDB, and other topical data collections

data compliance
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- Data Templates
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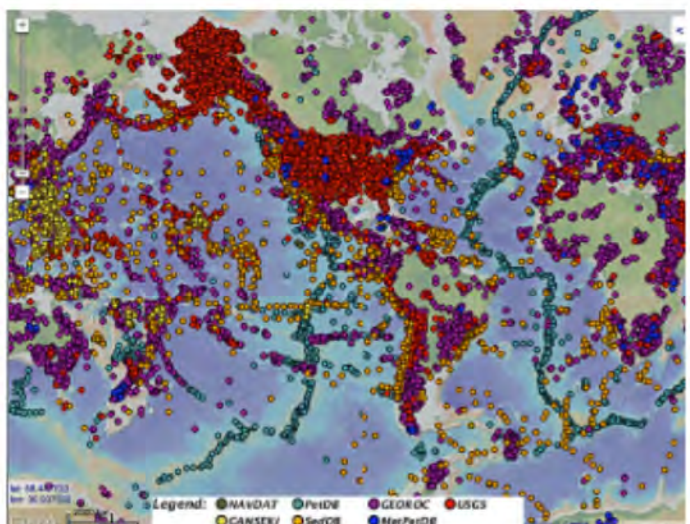
EarthChem Portal Home

Search seamlessly across multiple databases

The EarthChem Portal offers a "one-stop-shop" for geochemistry data of the solid earth with access to complete data from multiple data systems. The portal returns integrated search results from the federated databases PetDB, SedDB, GEOROC, NavDat, USGS, and GANSEKI. The portal features mapping and visualization tools.

Click on the link to access the EarthChem Portal data collection:

Search EarthChem Portal



EarthChem Portal sample locations, color coded by database.

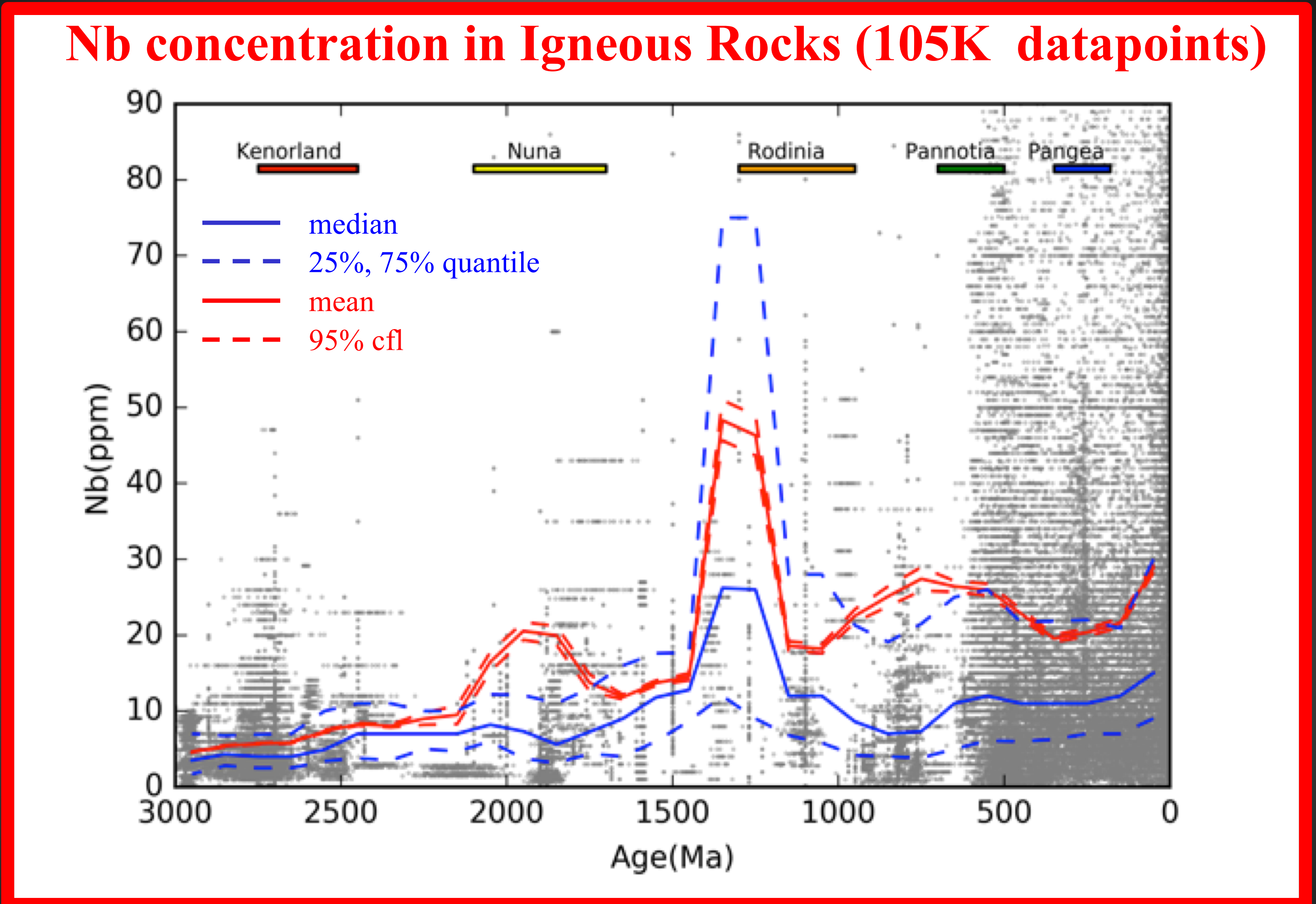
Kerstin Lehnert

Analysis of Earthchem Data

1. Bootstrap resampling is prerequisite to minimize spatial and temporal sampling bias (Keller and Schoene, 2012).

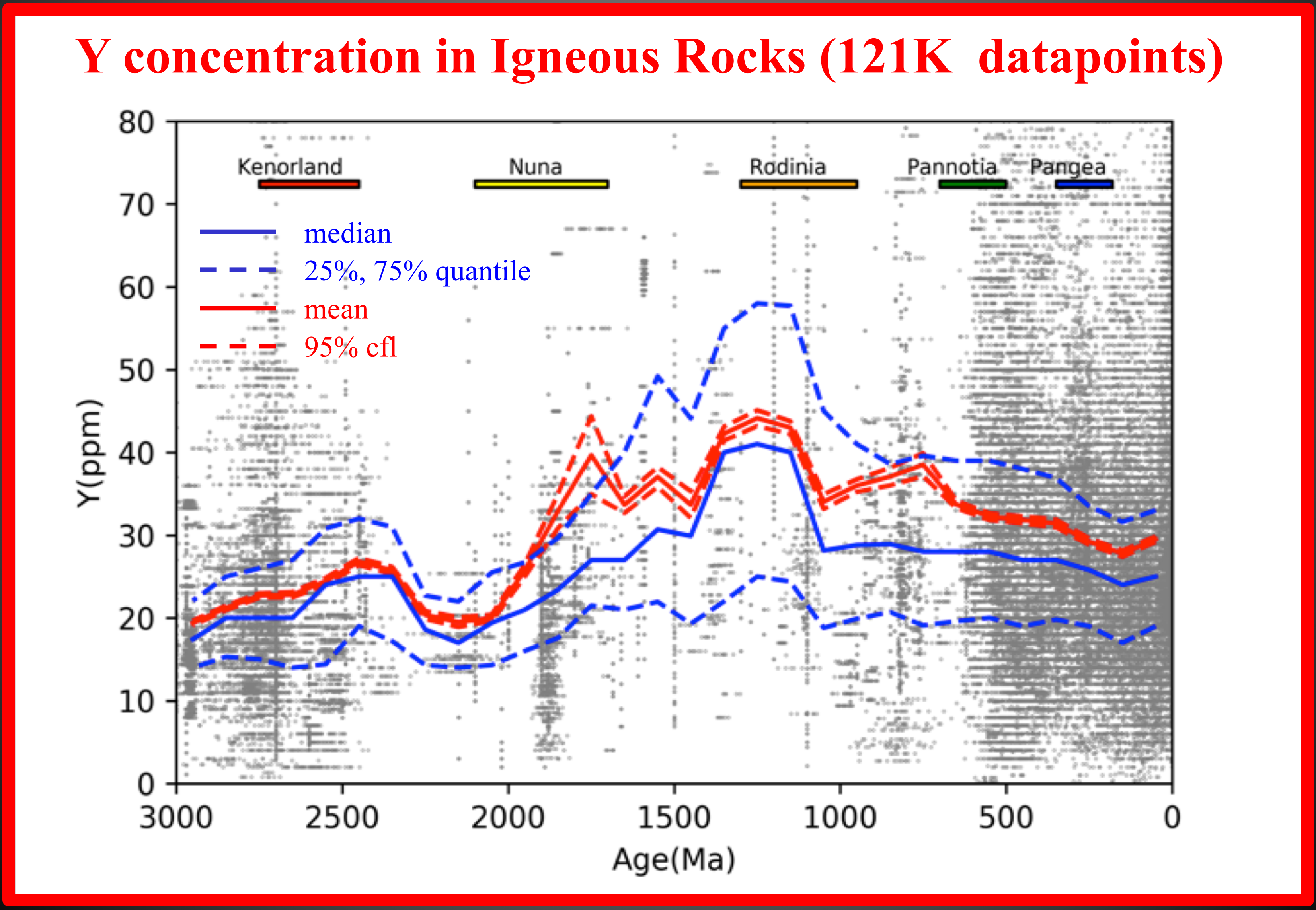
$$W_i \propto 1 \Big/ \sum_{j=1}^{n} \left(\frac{1}{1+((z_i - z_j)/a)^2} + \frac{1}{1+((t_i - t_j)/b)^2} \right)$$

2. The resampled data were analyzed for mean, 95% confidence intervals of the mean, median, 25% and 75% quantile intervals with a bin size of 200 Myrs at a 100 Myrs frequency.

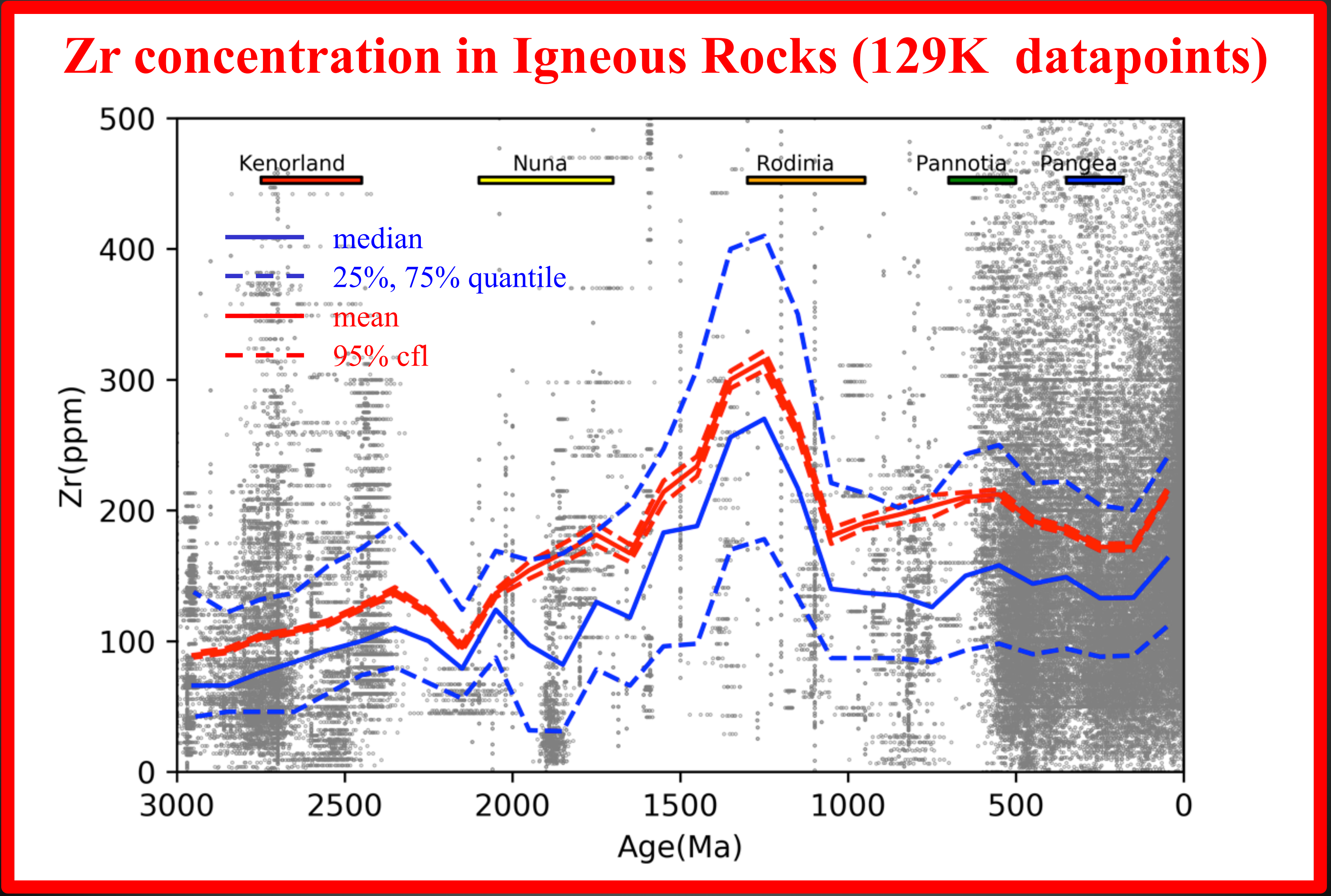


The period of Rodinia assembly displays the highest average niobium content in Earth history.

Igneous rocks formed during and immediately before Rodinia assembly exhibit highest global average yttrium concentrations in the last 3 Ga.



Highest global average zirconium concentrations in the last 3 Ga.

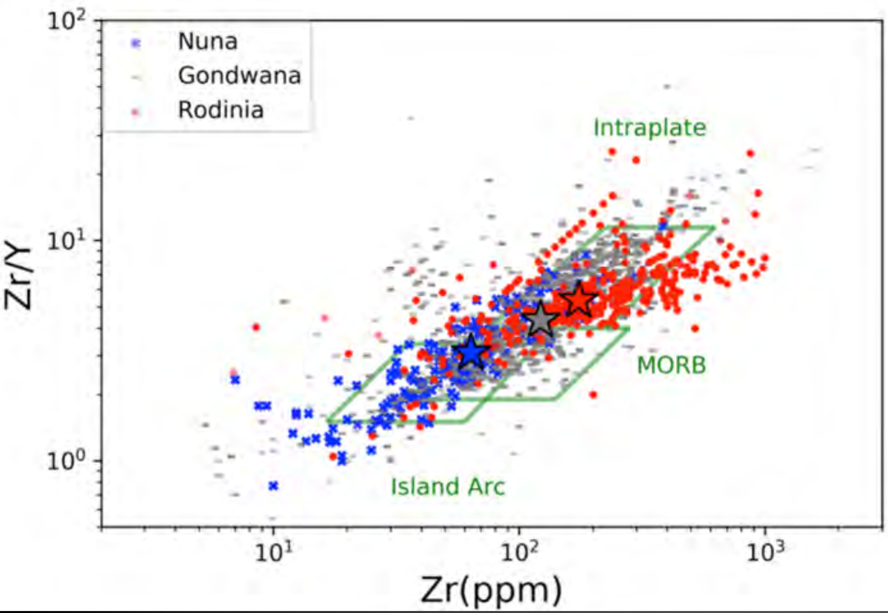


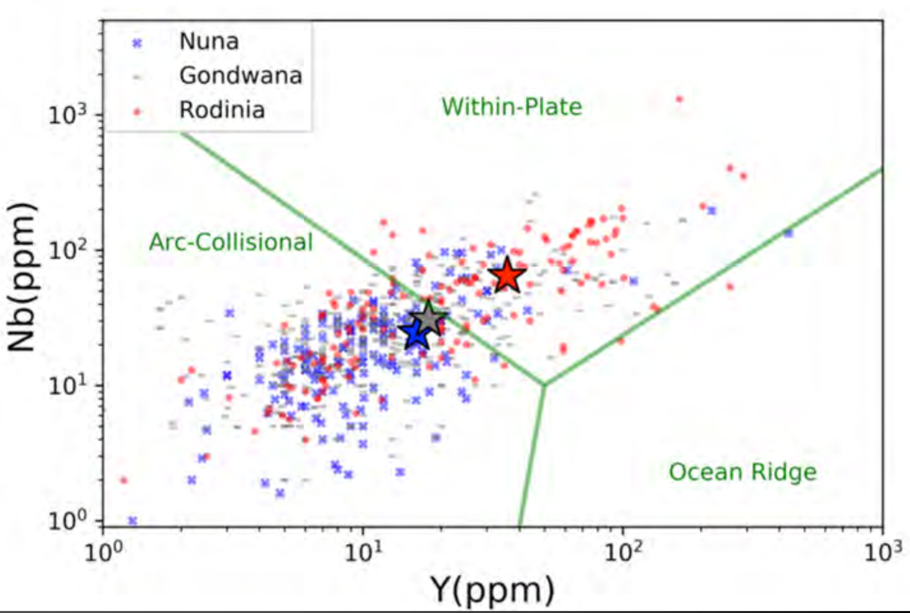
Nb, Y, Zr are enriched in igneous rocks, either mafic or felsic, formed during Rodinian assembly compared with other supercontinents.

t>0; p<<0.1

	All		Mafic		Felsic	
Zr	t statistic	p value	t statistic	p value	t statistic	p value
Rodinia-Kenorland	54.86	0	52.01	0	13.2	3.07E-35
Rodinia-Nuna	24.63	1.10E-128	25.9	1.51E-137	5.15	3.60E-07
Rodinia-Pannotia	2.12	0.03	7.38	3.02E-13	2.42	0.02
Rodinia-Pangea	26.47	1.67E-149	23.16	1.86E-113	6.81	1.77E-11
Nb						
Rodinia-Kenorland	46.08	0	22.58	2.72E-101	19.74	6.15E-66
Rodinia-Nuna	14.36	3.37E-46	8.03	1.51E-15	4.16	3.51E-05
Rodinia-Pannotia	4.33	1.52E-05	0.13	0.48	3.88	0.0001
Rodinia-Pangea	15.24	7.11E-52	2.05	0.04	1.7	0.09
Y						
Rodinia-Kenorland	44.02	0	40.3	5.25E-304	23.38	1.91E-96
Rodinia-Nuna	19.59	1.76E-83	24.49	1.57E-123	6.99	5.24E-12
Rodinia-Pannotia	13.35	2.59E-40	10.62	5.03E-25	9.83	8.69E-22
Rodinia-Pangea	24.1	6.43E-125	25.07	1.07E-132	7.65	3.49E-14

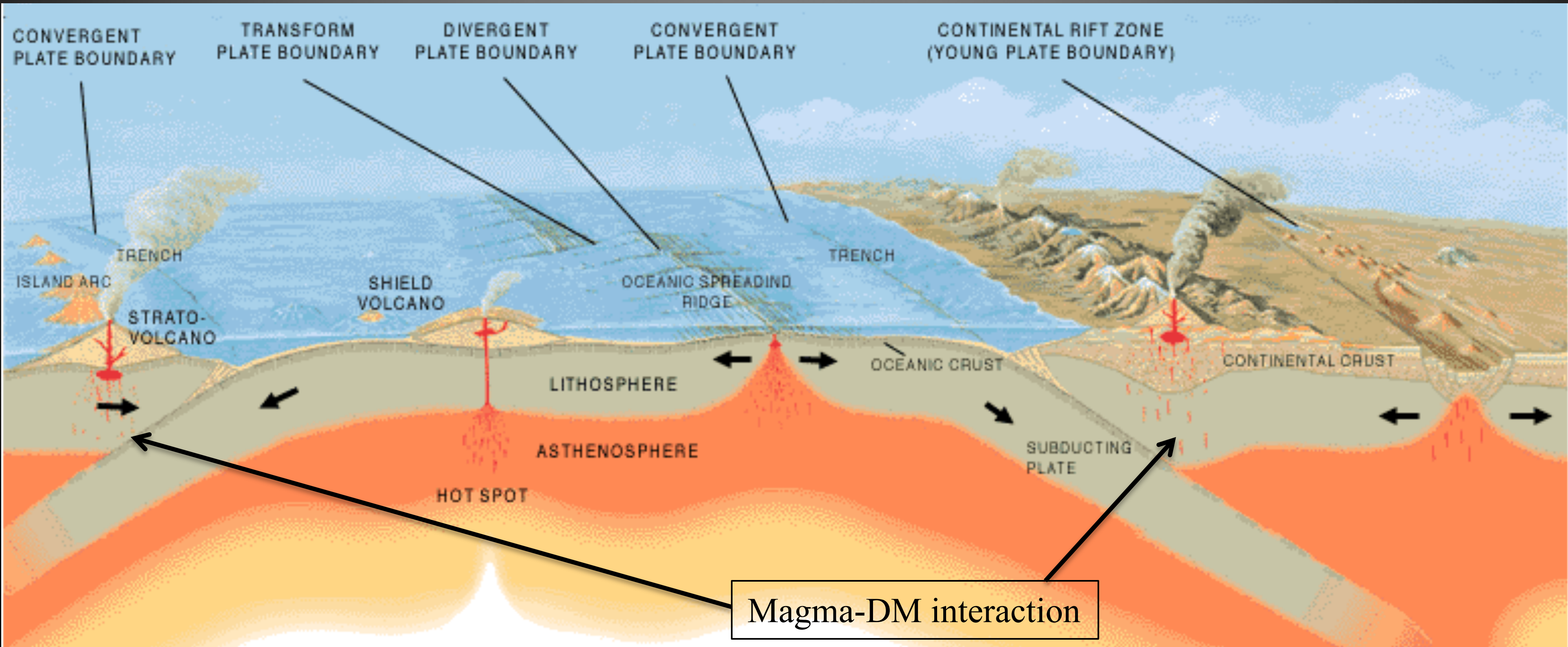
Tectonic discrimination of both mafic and felsic rocks indicates prevalence of 'within-plate' magmatism during Rodinian assembly, instead of arc-collisional magmatism for other supercontinents (Pearce and Norry, 1979; Pearce et al., 1984).





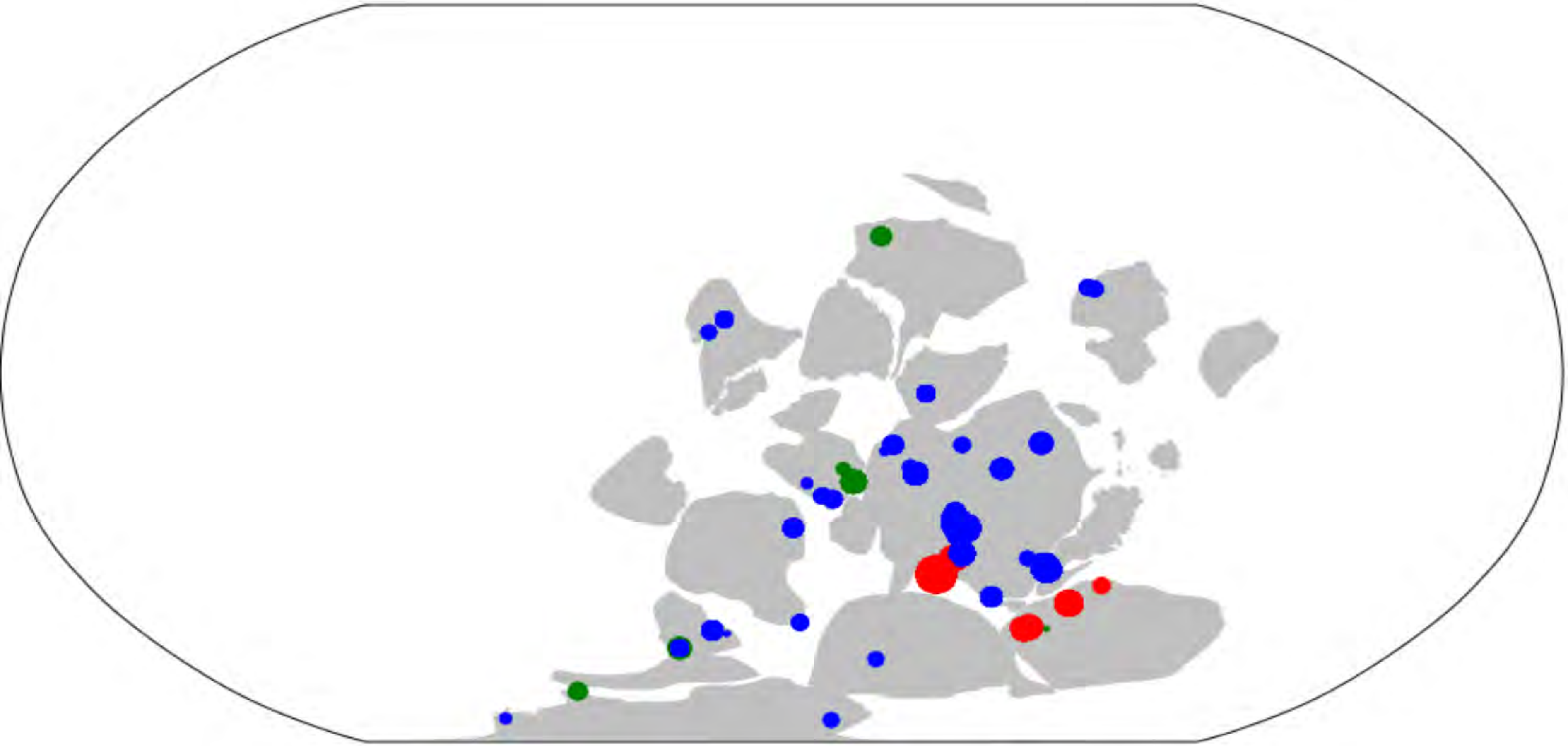
Intra-plate magmatism: Petrologic significance

Their source magmas did not interact with depleted mantle, thus are enriched in Nb/Y/Zr.



Keleman et al., (1990); Woodhead et al., (1993)

Extensional Tectonic Settings



Blue: Intraplate; Red: Orogenic Extension

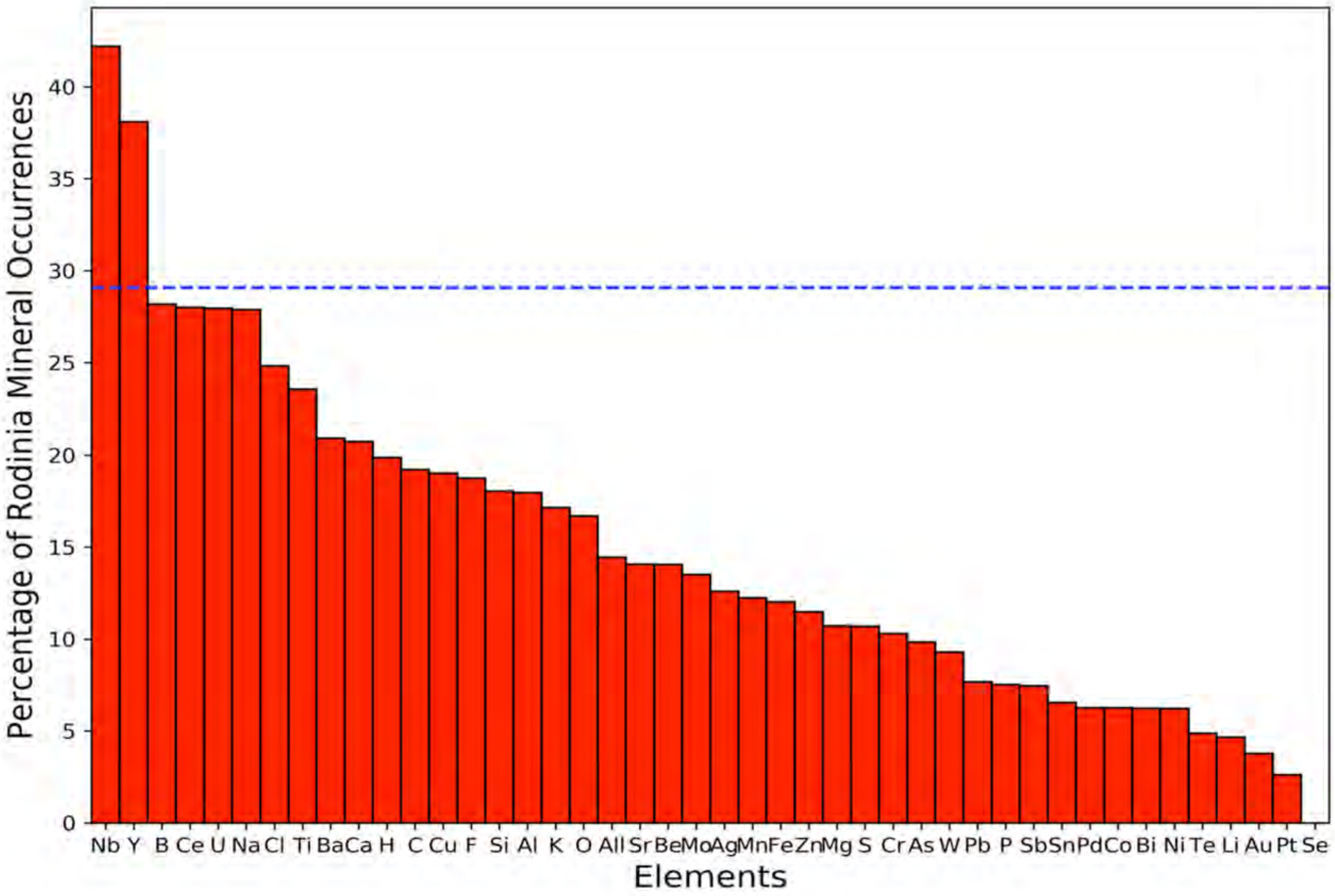
Intra-plate magmatism

Widespread massif anorthosite, A-type granite and NYF (Nb, Y, F rich)-type pegmatite.

NYF-type pegmatites are extremely enriched in Nb/Y (thousands of ppm), leading to the crystallization of rare Nb/Y minerals and the observed Rodinian peaks.

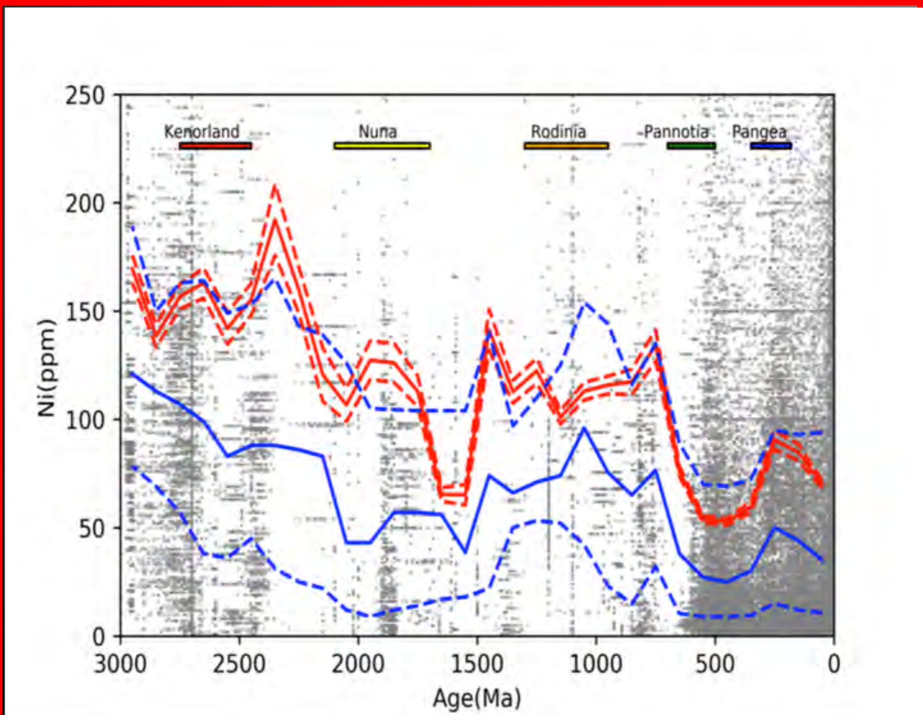
Columbite, Samarskite-(Y), Uranpyrochlore from White Cap pegmatite, Colorado

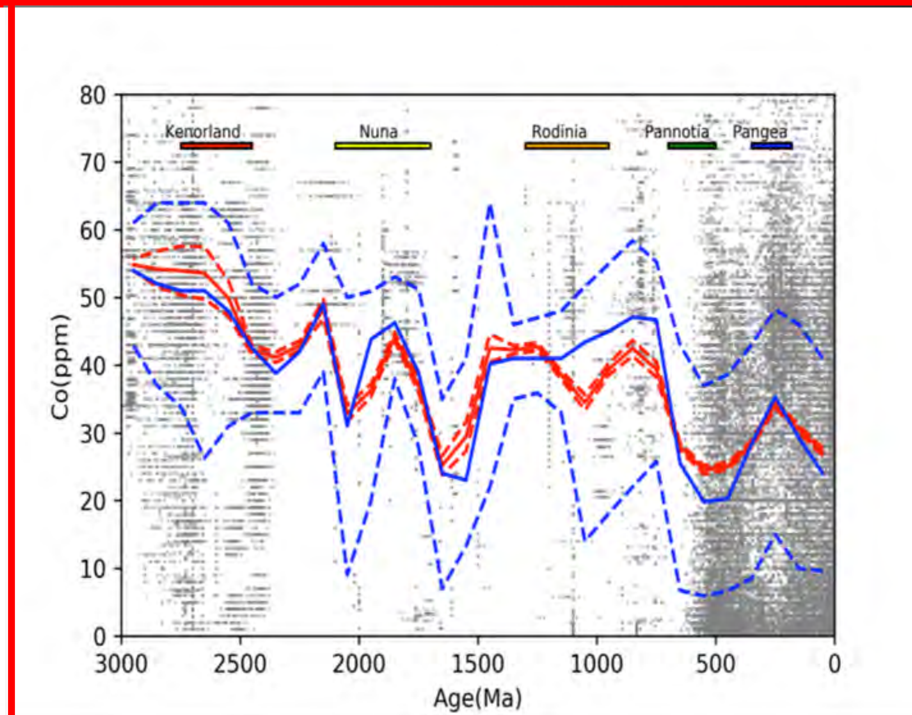
The other end of the spectrum



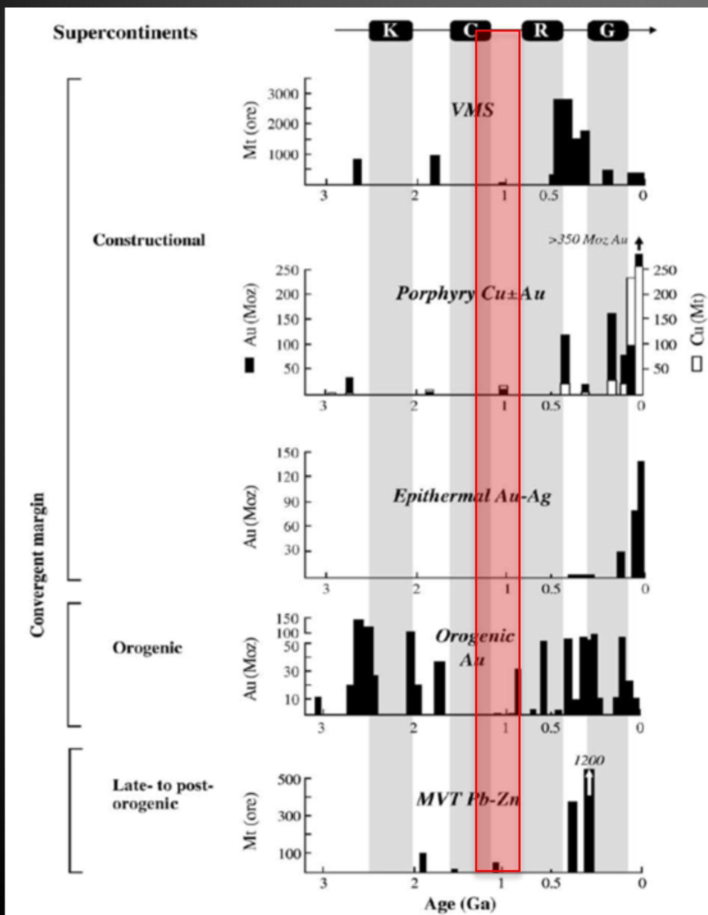
The concentrations of Ni, Co, Au, PGE, and many other elements in igneous rocks exhibit no anomalies during Rodinian assembly. Implying that:

- The unique tectonic setting or environment inhibited formation of these minerals (Generational);
- These minerals formed but are not preserved (Preservational).

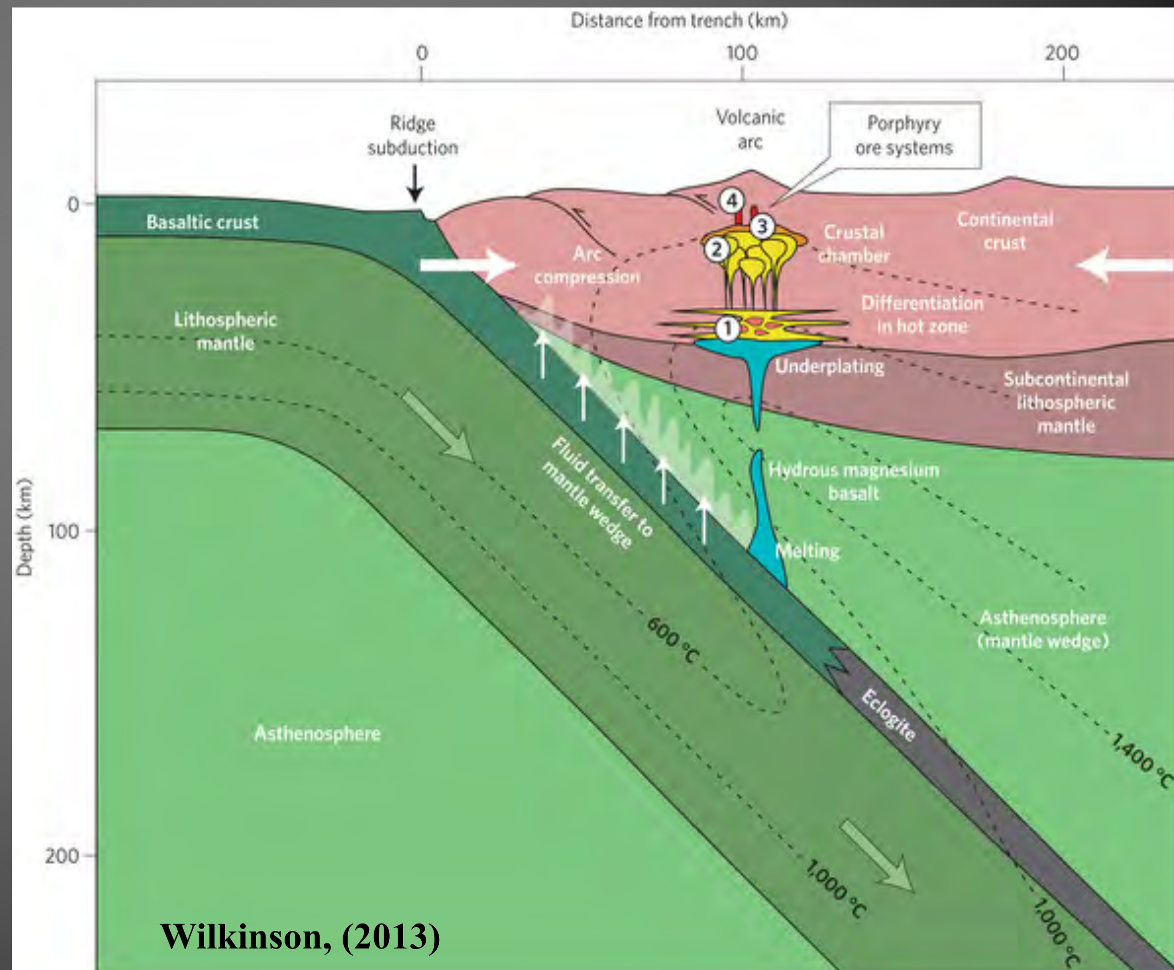




- **Mineral depletion is consistent with scarcity of convergent-margin ore deposits (e.g., VMS, Porphyry, Orogenic Au)**



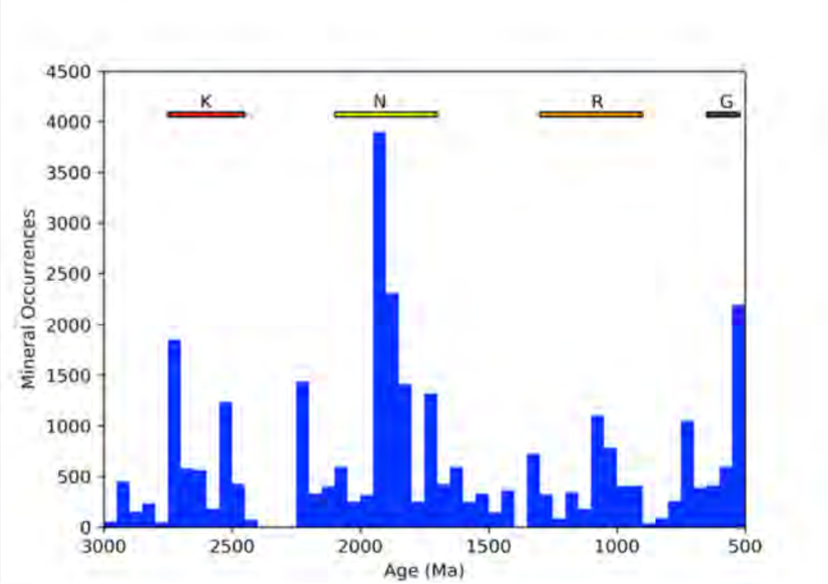
Bierlein et al., (2009)

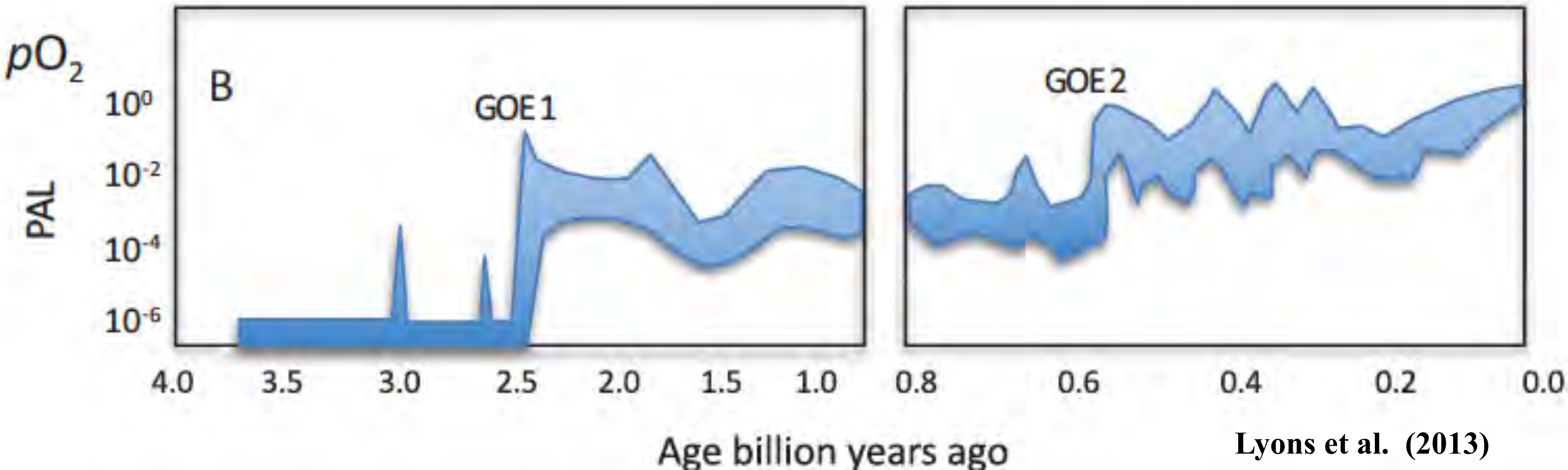


Wilkinson, (2013)

Generational: high f_{O2}?

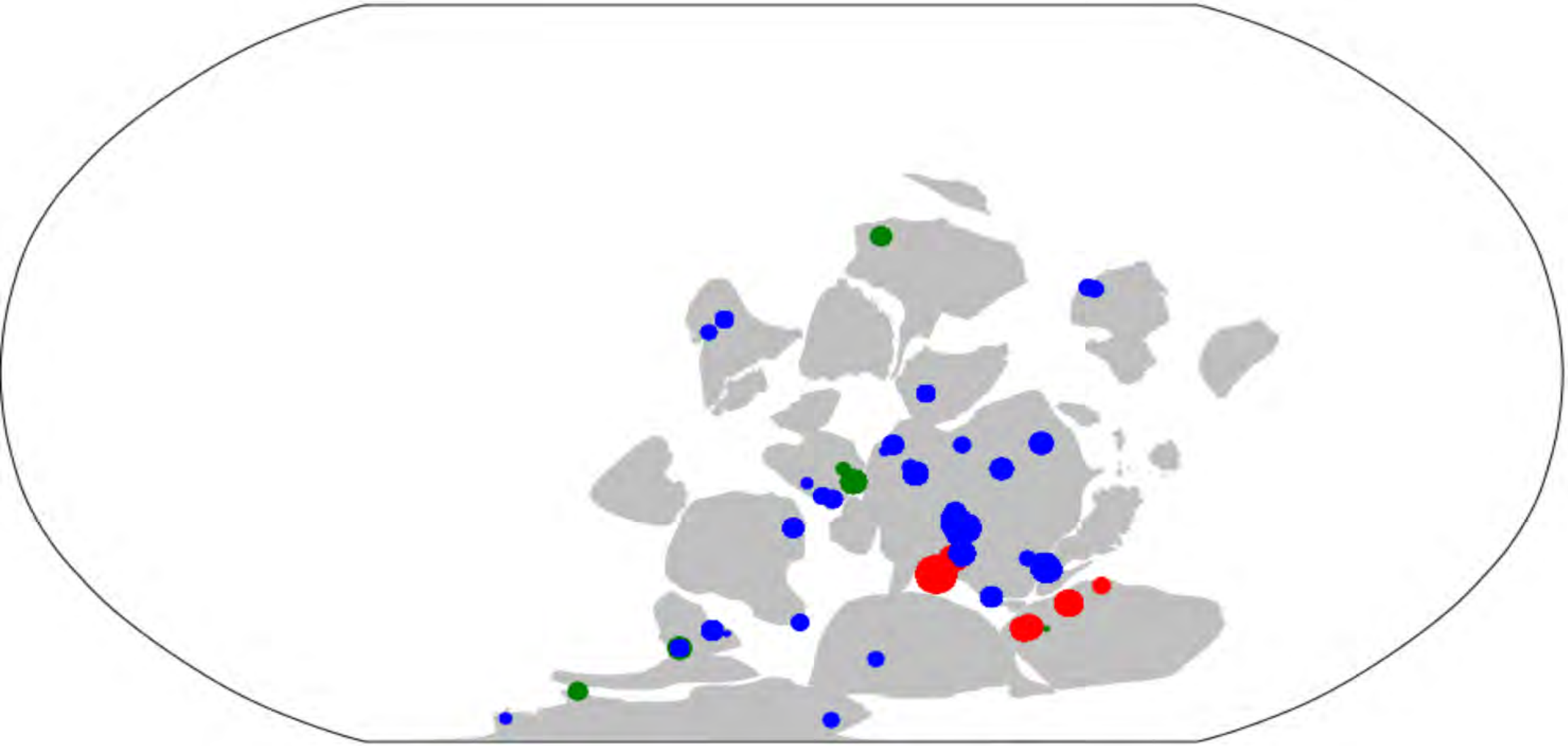
Ore fluids oxidized in a relatively high f_{o2} atmosphere (Large et al., 2017) ???





Lyons et al. (2013)

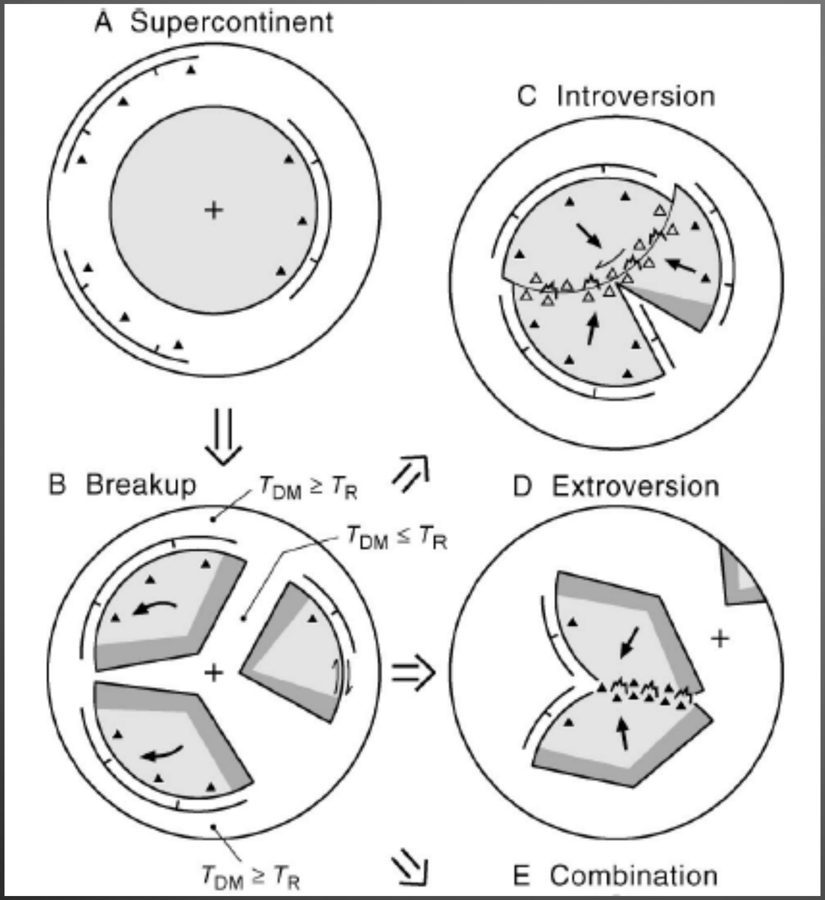
Lack of Collisional Settings



Green: Collisional Settings

Preservational: Enhanced erosion

1. Enhanced pre-collisional erosion was proposed since Rodinia was probably assembled extrovertly (Pehrsson et al., 2013**)**

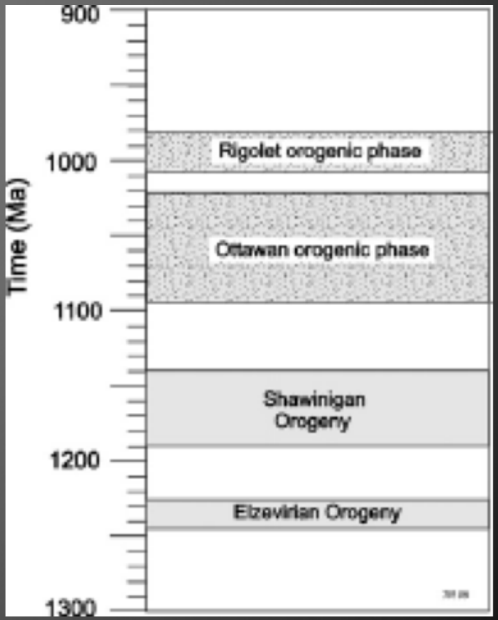


Murphy and Nance, 2003

Preservational: Enhanced erosion

2. Enhanced collisional erosion was discovered for most major Rodinian mountain belts (e.g., Hoffman and Grotzinger, 1993; Bingen et al., 2006**).**

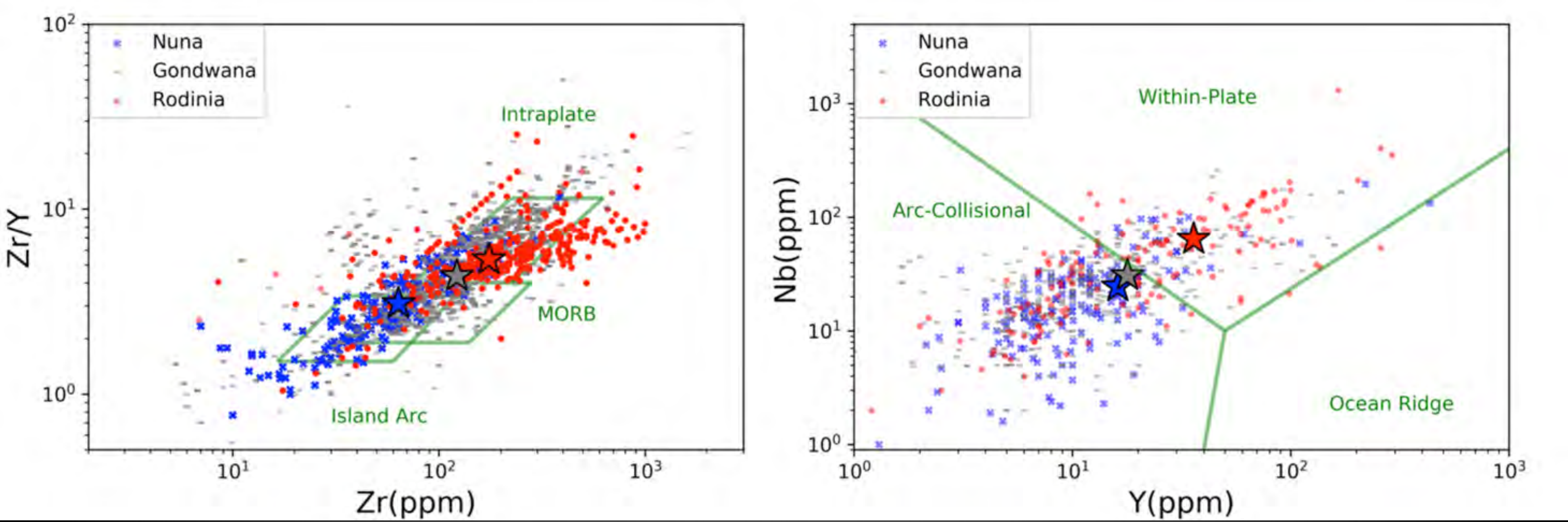
This is supported by discovery of Grenville-derived sediments in mid-west US and West Africa (Bradley et al., 2018).



Rivers, 2008

Preservational: Enhanced erosion

3. Enhanced erosion is consistent with our observation of dearth in arc magmatism during Rodinian assembly.



Questions and Answers

1. **Why is the formation of high-T Nb and Y minerals as pronounced as, or even more prominent than zircons during Rodinia assembly?**

Unique tectonic settings: Prevalence of intraplate magmatism.

2. Why are many other high-T minerals, especially Ni, Co, PGE minerals, much less abundant during Rodinia assembly?

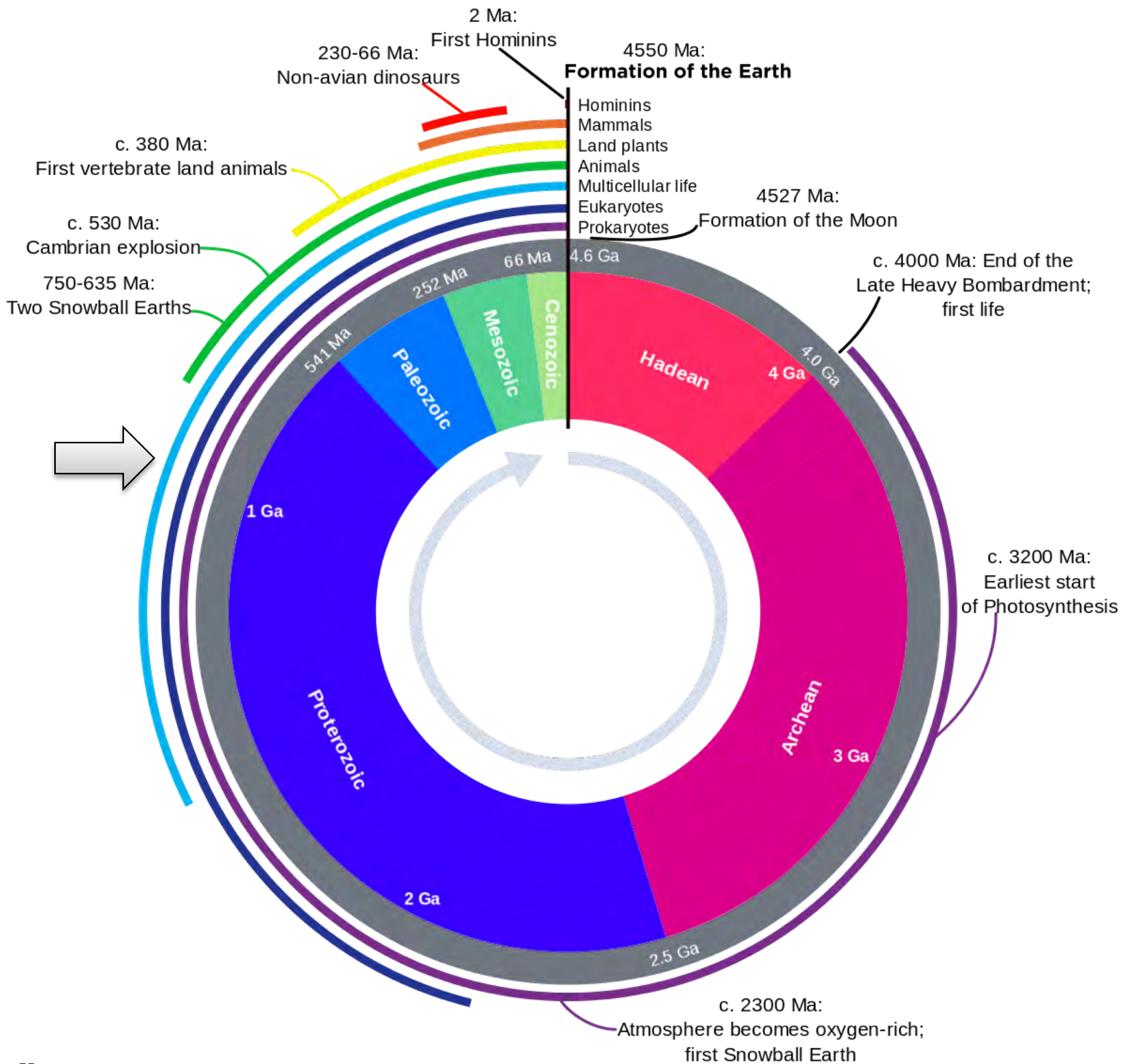
Poor preservation due to enhanced erosion.

Implications and Future Studies

1. **The 'boring billion' (1.7-0.7 Ga) of the Earth is not boring at all! Significant within-plate magmatism and orogenic erosion.**

2. **Tectonics: prolonged, extrovert assembly (**Pehrsson et al., 2013**) from thickend continental crust (**Dhuime et al., 2015**) via two-sided subduction (**Cawood et al., 2016**)**

3. **Geodynamic modeling? Paleoclimate? Earth's biosphere?**



Credit: Woudloper

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Robert Hazen

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