Olivines from Archean Komatiites

William F McDonough[1] and Emilie LaVoie-Ingram[2]

[1]Advanced Institute for Marine Ecosystem Change, Tohoku University, Sendai, Miyagi 980-8578, Japan
[2]Department of Physics, University of Michigan, Ann Arbor, MI 48103 USA

Topics
1. Komatiitic olivines
2. Melt inclusions
3. Crustal residence
4. Hanging around for billions of years
5. Earth’s exposure to SN flux

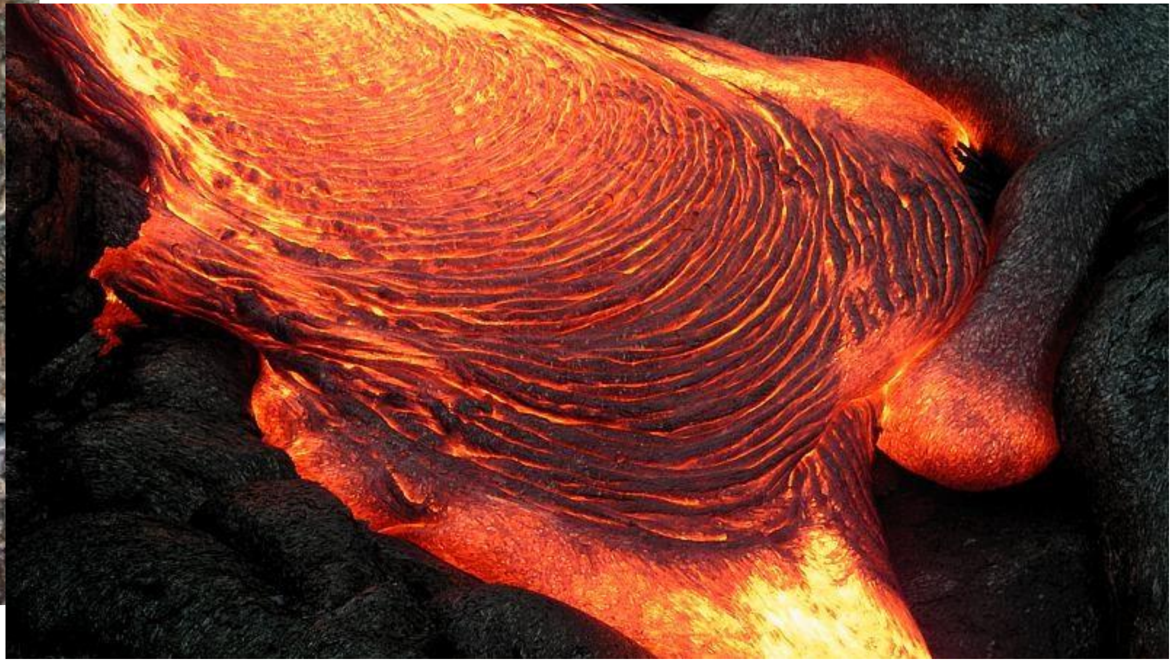
Hotest lavas ever to erupt on Earth's surface!

Komatiite ~25 wt% MgO

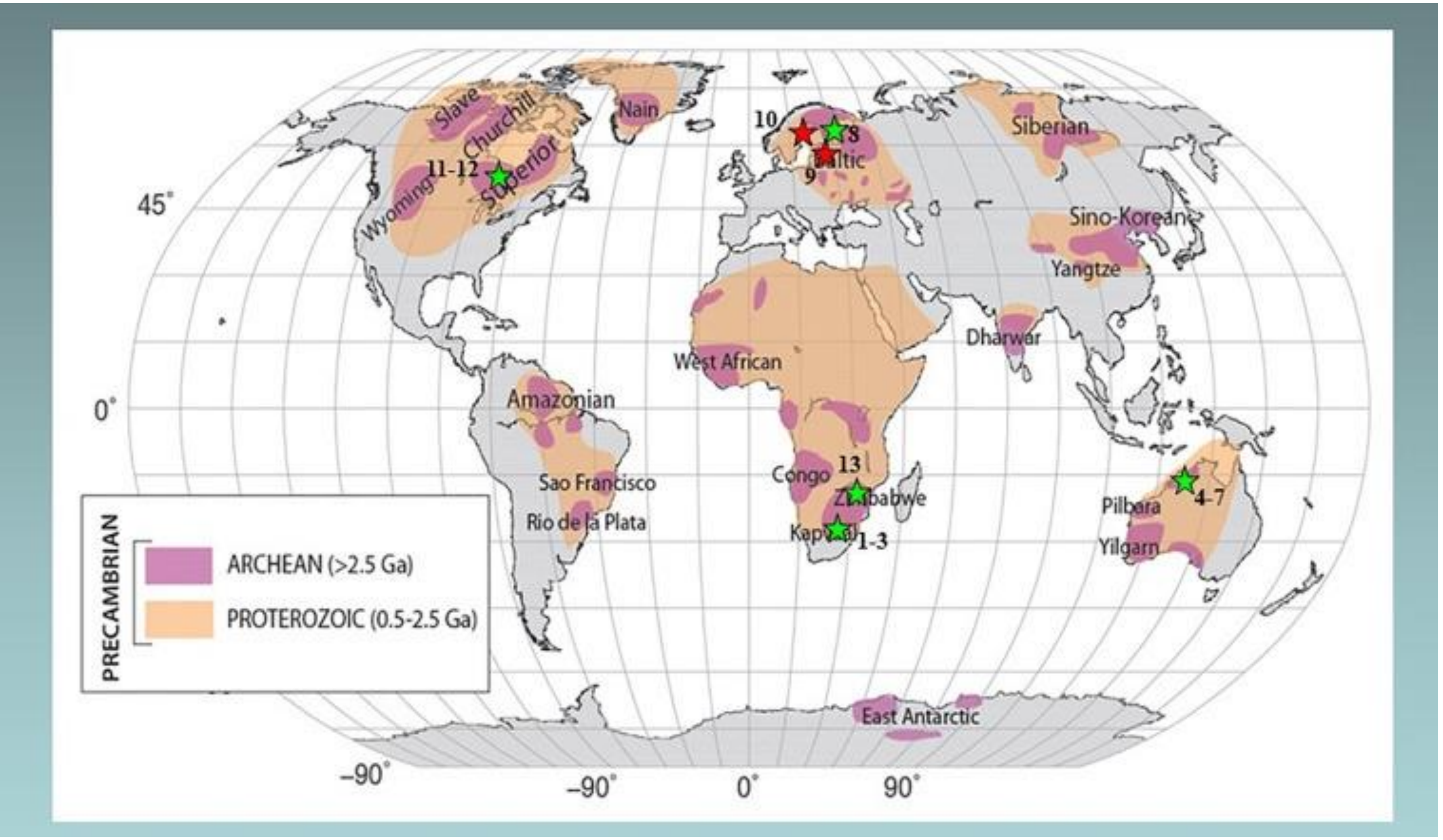
~1700°C

vs ~1250°C

Basalt ~10 wt% MgO



Komatiites, erupted 4.0 to 2.5 billion years ago, with a few younger examples (last ~90 Myrs ago)

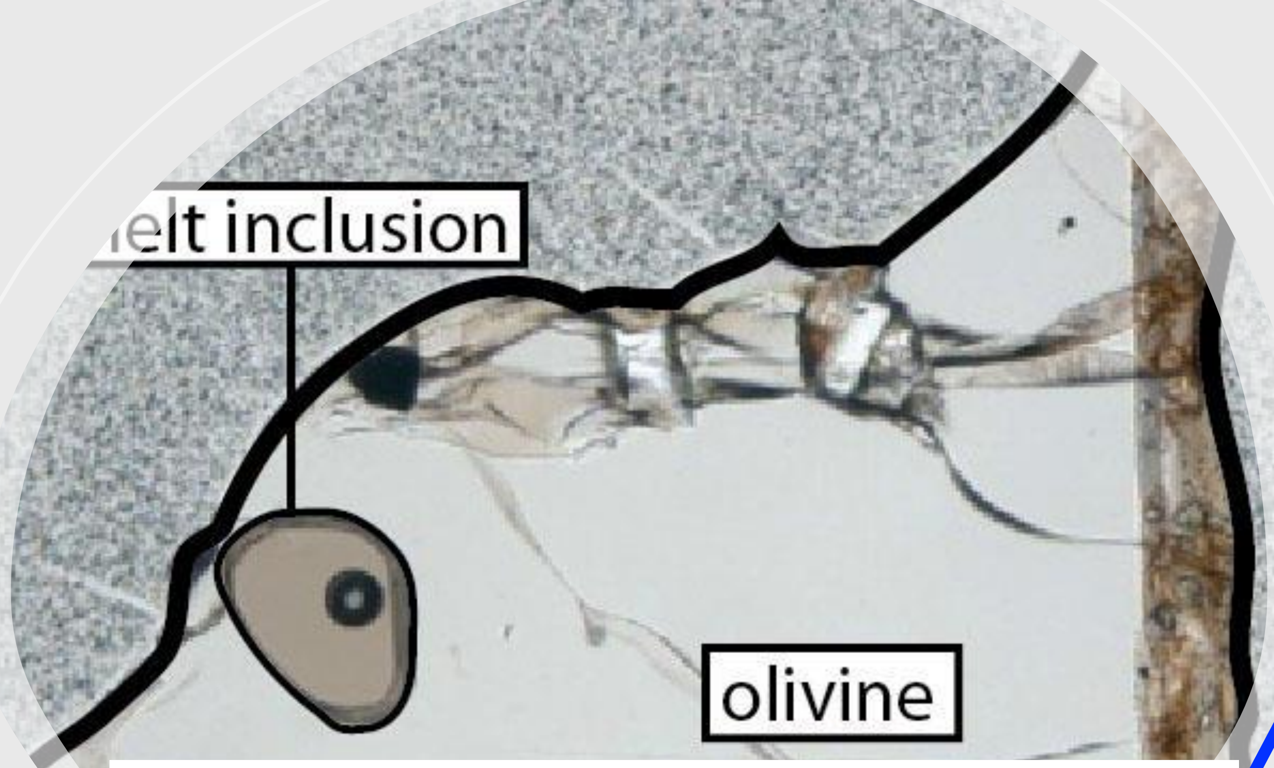


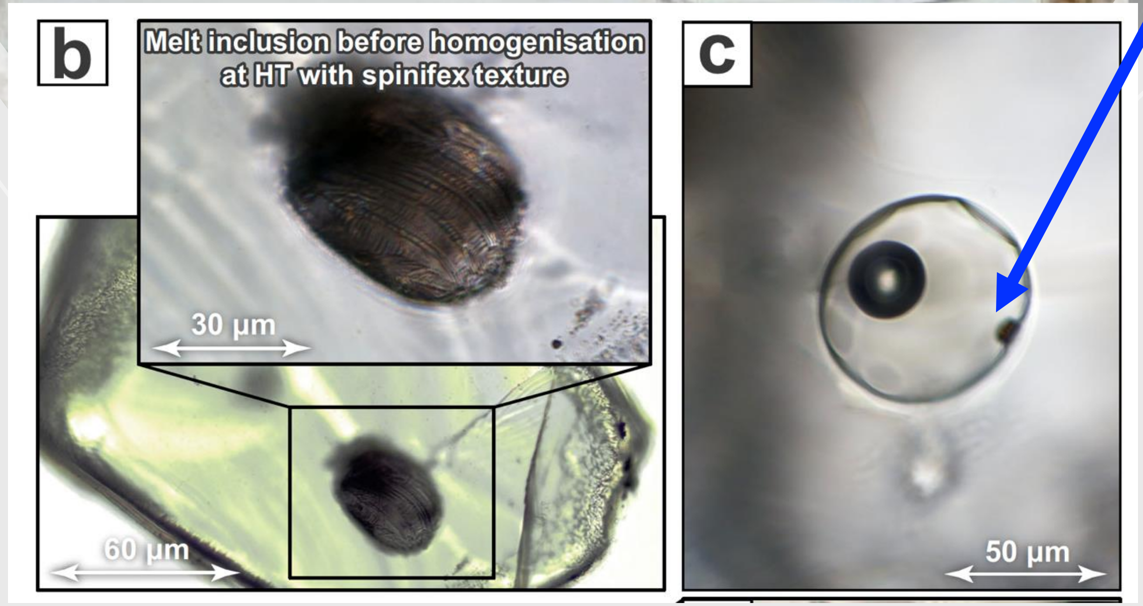
Strongest evidence for a cooling Earth

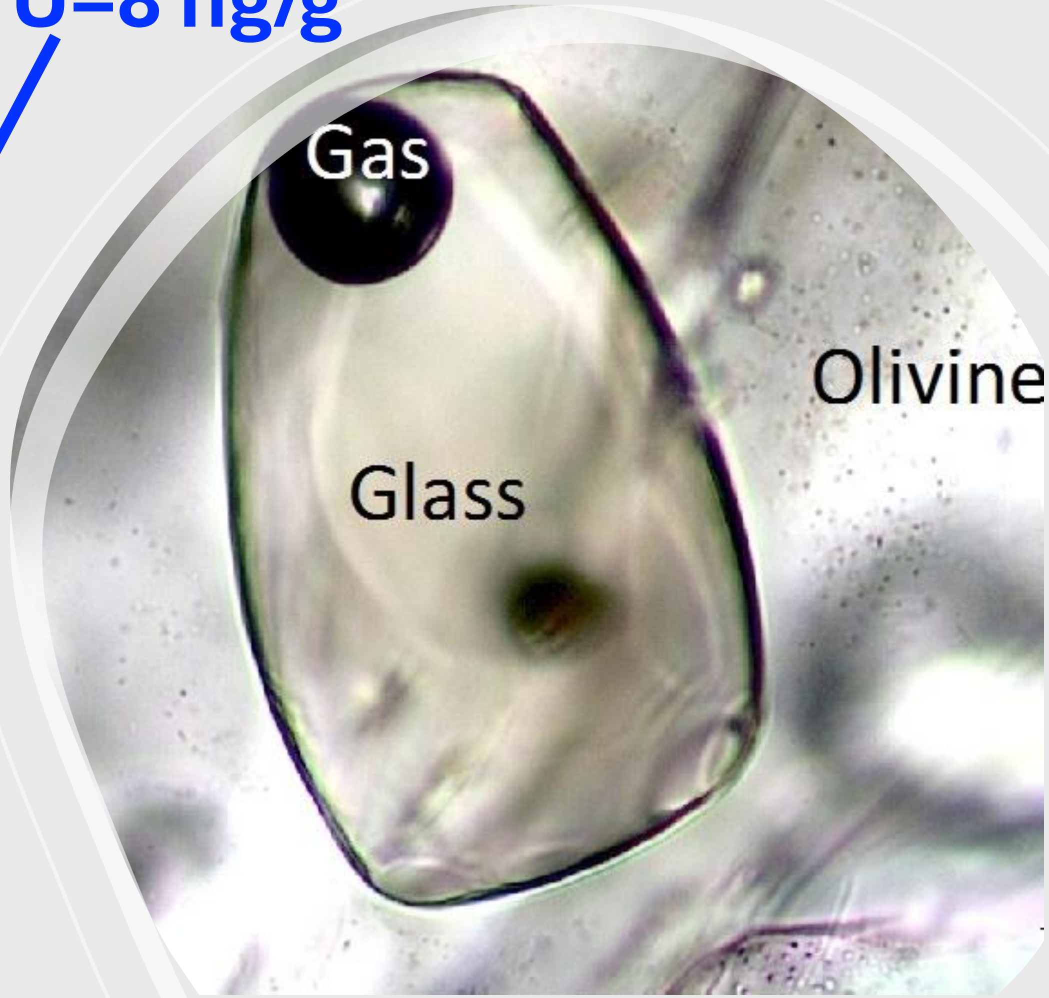
~100 ± 50 K/Ga

Olivine
U< 0.08 ng/g!

Melt inclusion
U=8 ng/g



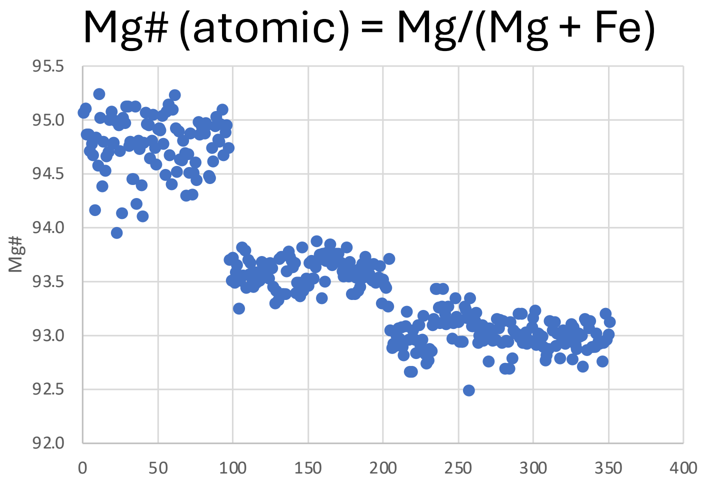




What do melt inclusions tell us?

- Fresh unaltered rock
- Rock has been isolated for its history
- Unlikely to be at the Earth’s surface
- How much overburden????

Olivine $(Mg,Fe)_2SiO_4$: komatiitic Mg# 92-95



~4 atoms of U & Th/micron^3


Olivine is the most common mineral in Earth's upper.
Credit: Smithsonian National Museum of Natural History, CC0 1.0

Given

$U \leq 10^{-10}$ g/g,

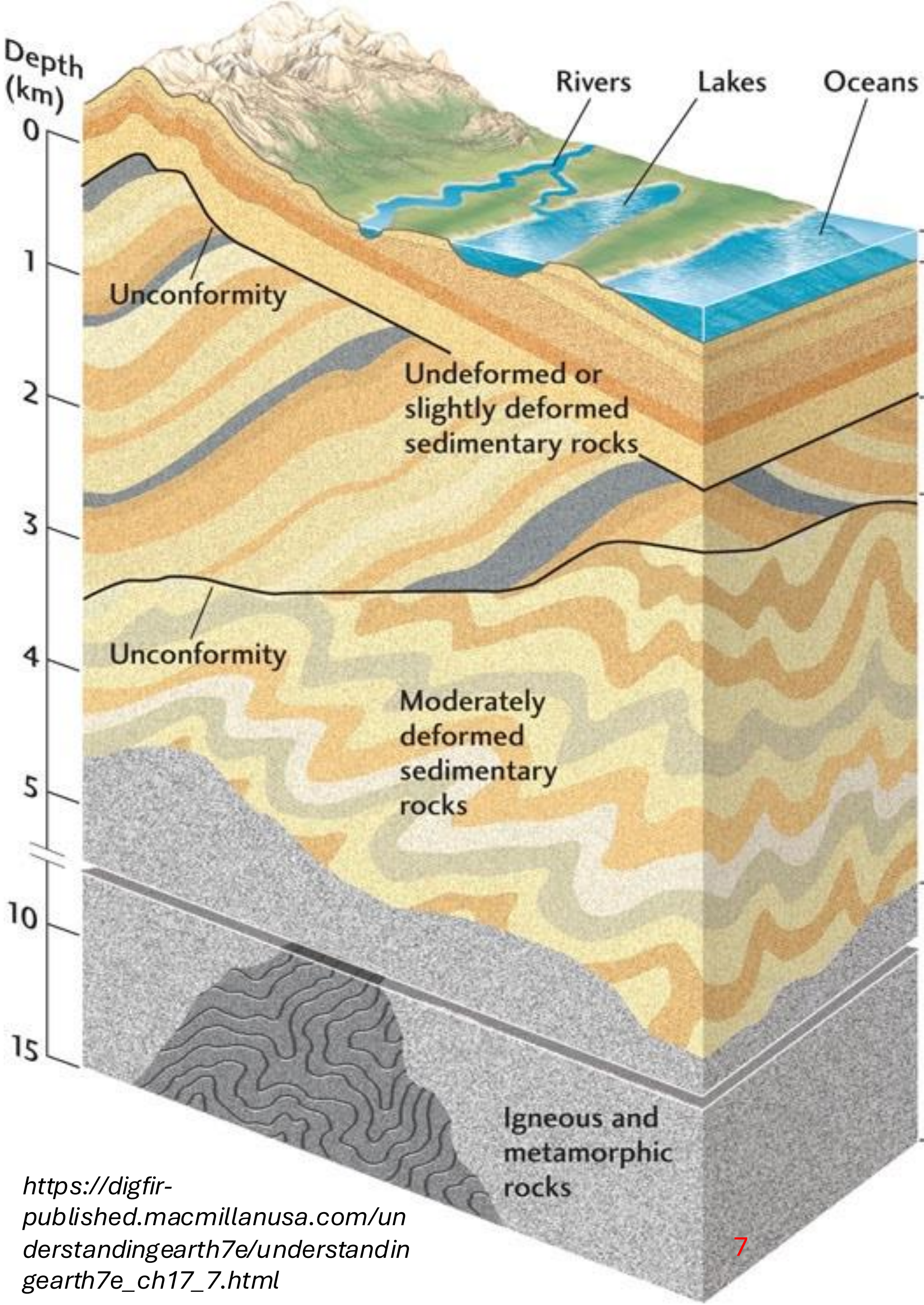
Th/U ~ 4, and

$\rho_{olivine} = 3$ g/cm^3

Water drives the weathering of rocks and minerals

Groundwater penetration depth is generally down to 2 to 3 km depth, but is known to reach 10 km depth

Note: Earth is not a simple layered structure



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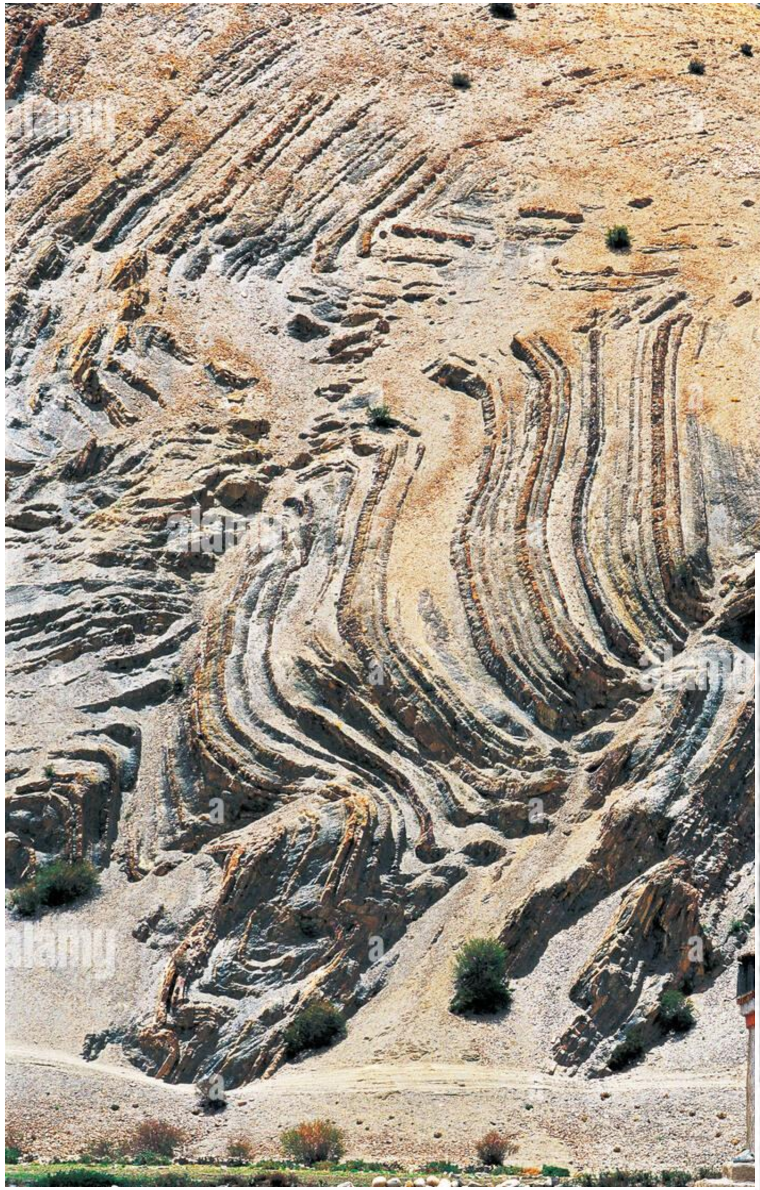
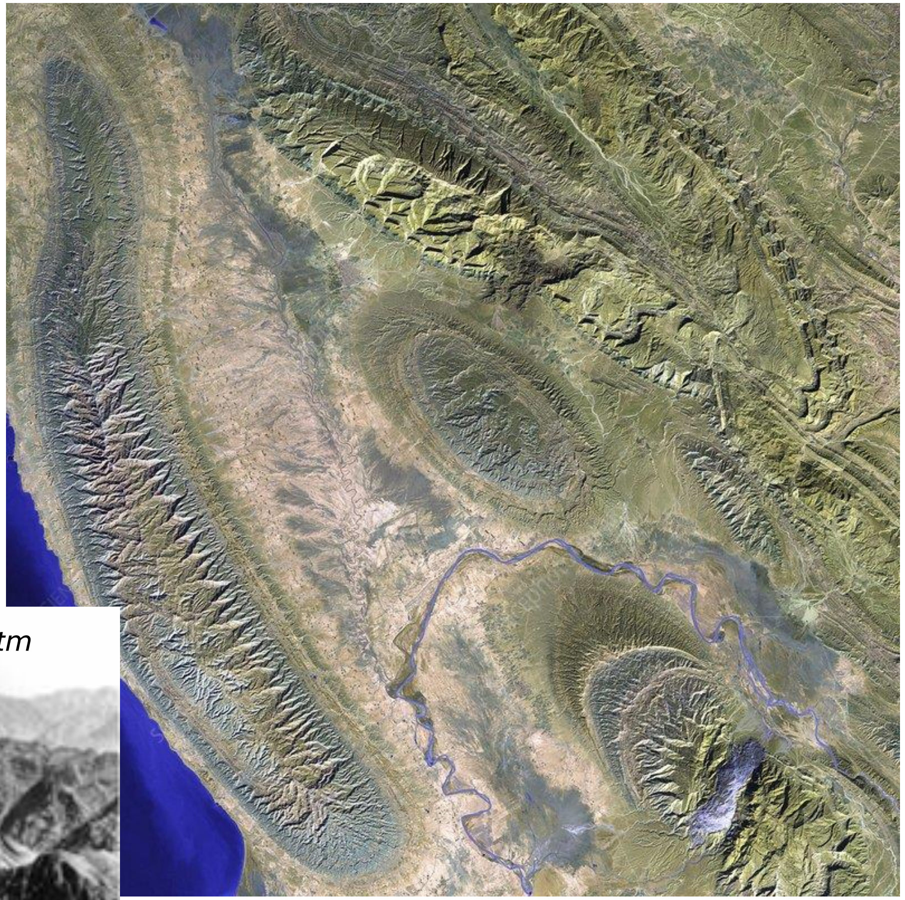


https://wgbis.ces.iisc.ac.in/envis/Remote/section226.htm



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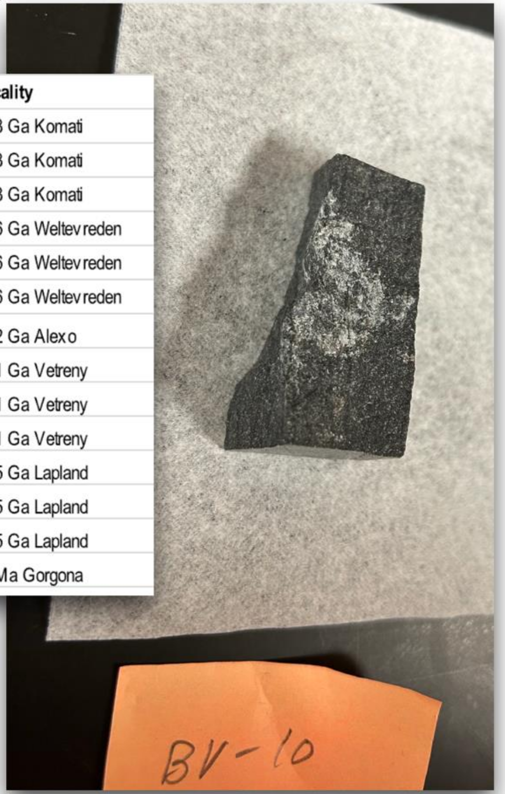
Burial is not simple

Atmospheric Neutrino Detection with South African Komatiite Olivine

- Mainly forsterite (Mg_2SiO_4), from ancient lava flows, ejected and quickly buried
- The burial rate and depth transient is **unknown** after eruption
- However, **everything else -** the rock's composition, radioactive concentration, location, and age **-** ***is very well-constrained,*** with an abundance of literature published!

Note - there are more of these in the 200-300 Myr range that we can get!

Sample#	Locality
BV-10	3.48 Ga Komati
BV-15	3.48 Ga Komati
BV-16	3.48 Ga Komati
501-8	3.26 Ga Weltevreden
501-9	3.26 Ga Weltevreden
564-1	3.26 Ga Weltevreden
ALX-26	2.72 Ga Alexo
121001	2.41 Ga Vetreny
12105	2.41 Ga Vetreny
12117	2.41 Ga Vetreny
KD-06	2.05 Ga Lapland
KD-09	2.05 Ga Lapland
KD-10	2.05 Ga Lapland
GOR 1901	89 Ma Gorgona



Could we reconstruct an average depth history based on the amount of cosmogenic neutron tracks we detect + simulation estimates with best known history?

Lithophile and siderophile element systematics of Earth's mantle at the Archean–Proterozoic boundary: Evidence from 2.4 Ga komatiites

Ultra-depleted 2.05 Ga komatiites of Finnish Lapland: Products of grainy late accretion or core-mantle interaction?

Pt–Re–Os and Sm–Nd isotope and HSE and REE systematics of the 2.7 Ga Belingwe and Abitibi komatiites

Insights into early Earth from Barberton komatiites: Evidence from lithophile isotope and trace element systematics

Insights into early Earth from the Pt–Re–Os isotope and highly siderophile element abundance systematics of Barberton komatiites

Igor S. Puchtel[a,*], Richard J. Walker[a], Mathieu Touboul[a], Euan G. Nisbet[b], Gary R. Byerly[c]

We have several > 20 gram samples from the same host rock, of a variety of ages — **a great sample set for atmospheric neutrino searches!**

UNIVERSITY OF MICHIGAN NSF GORDON AND BETTY MOORE FOUNDATION

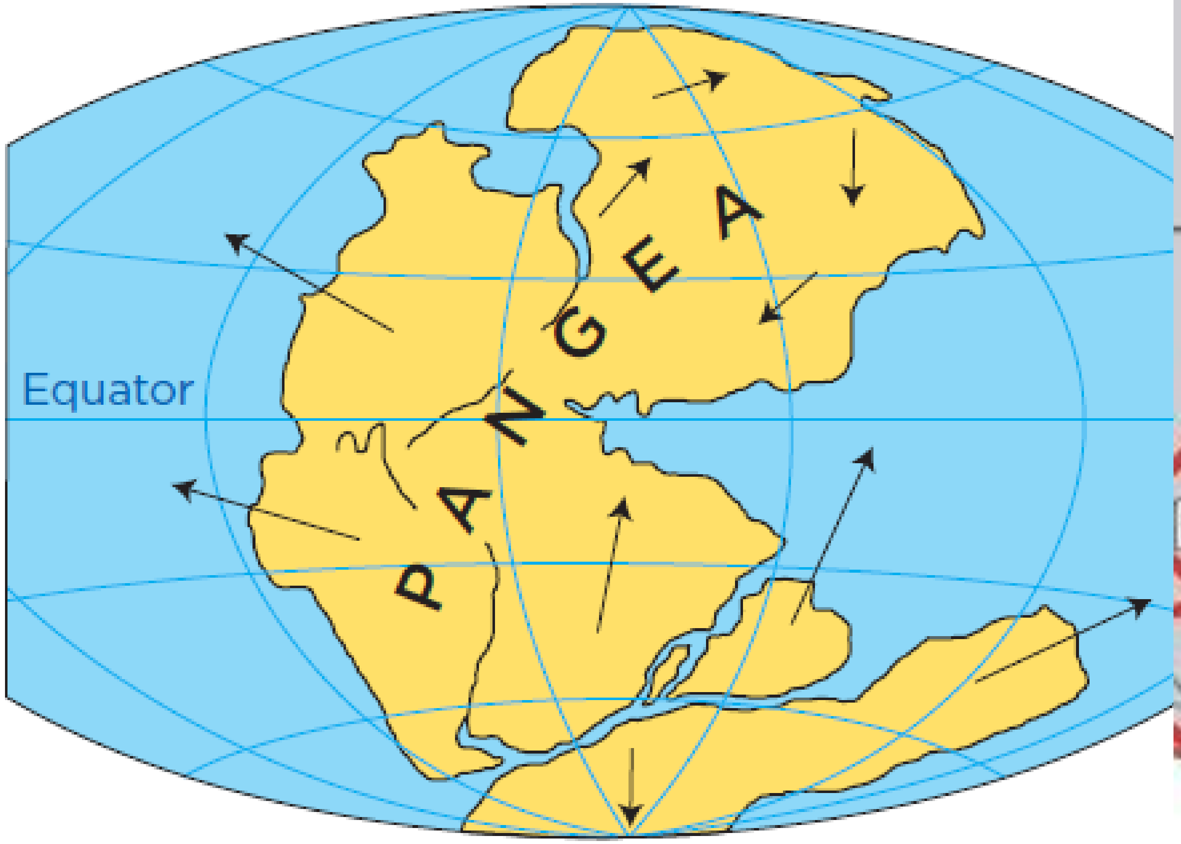
Sample exposure: muon flux

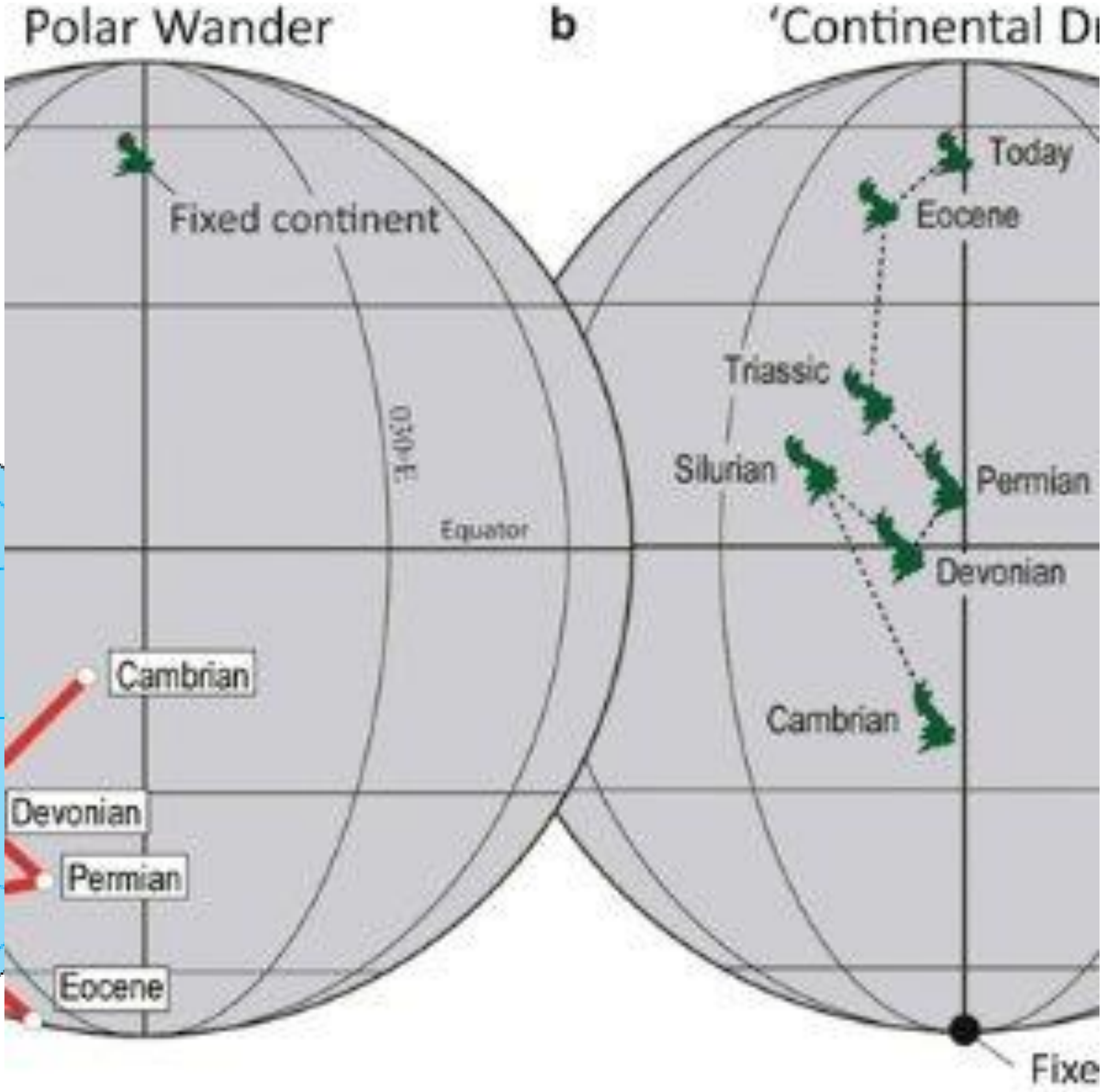
Accurate cosmogenic background modeling of sample?

<u>Considerations</u>:

1. Depth of burial
2. Paleopole position
3. Variation in magnetic field intensity

Moving continents means magnetosphere not constant shape.





Moving magnetic north pole position

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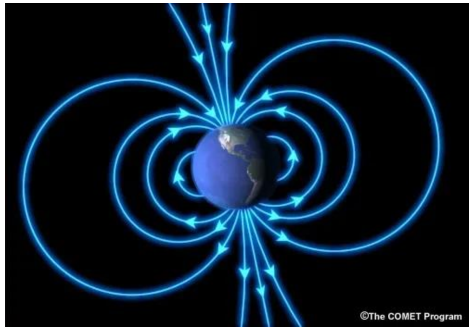
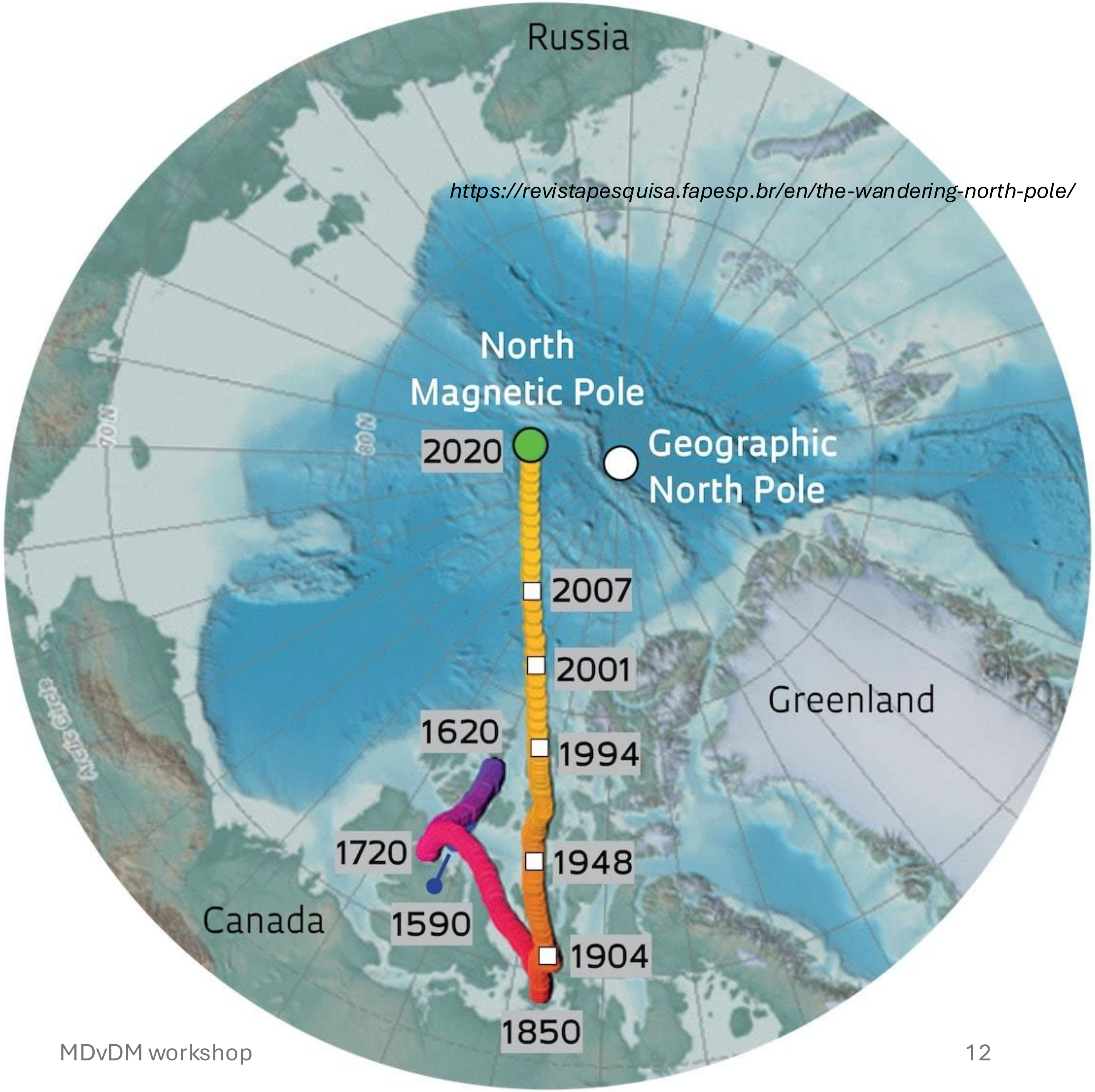
Moving continents

Shape of magnetosphere

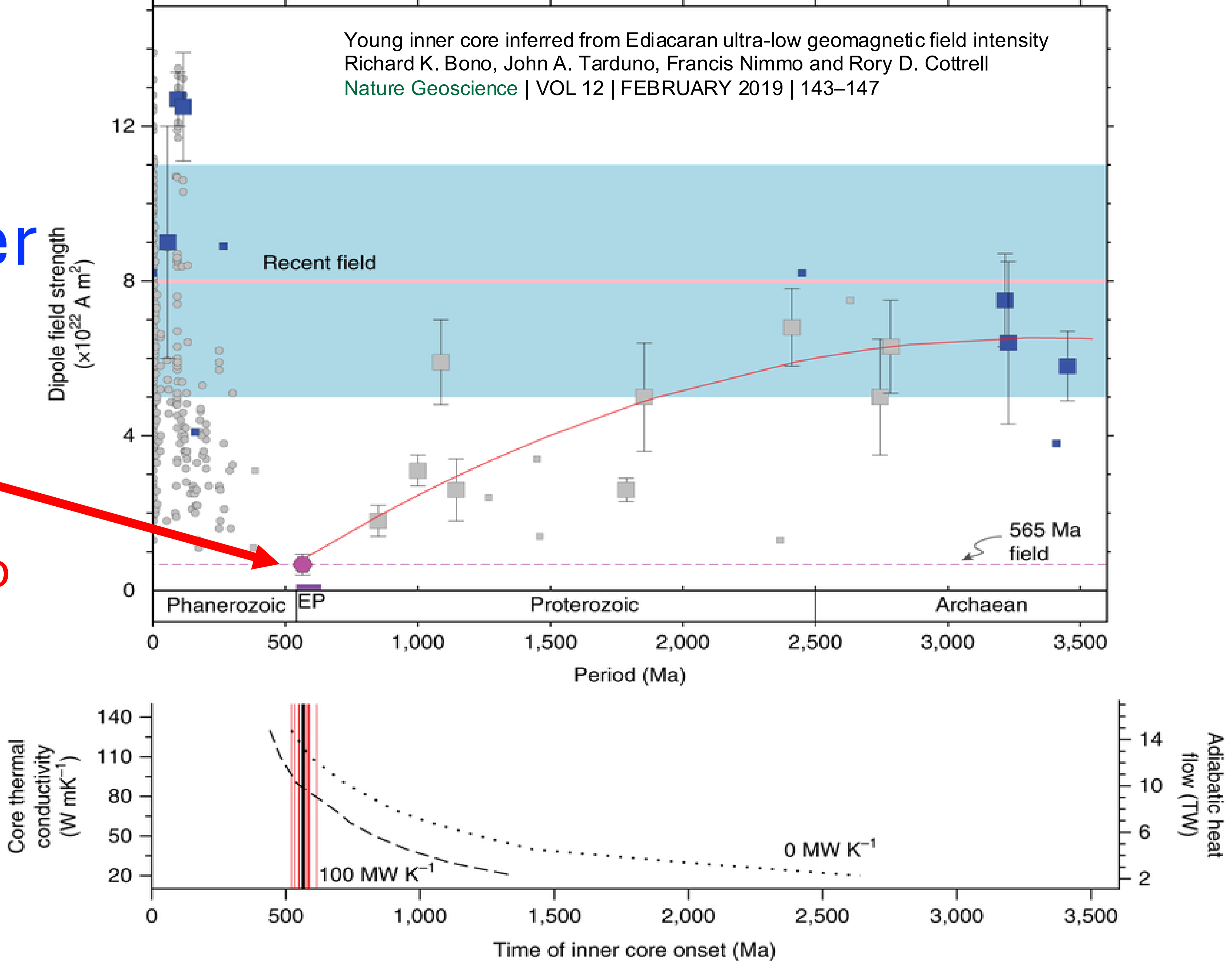




What is the level of effect on modeling the muon flux??

Magnetic field intensity varied considerably over Earth's history

Field dropped to near 0 intensity 0.5 billion yrs ago



Initiaition of inner core crystallization??

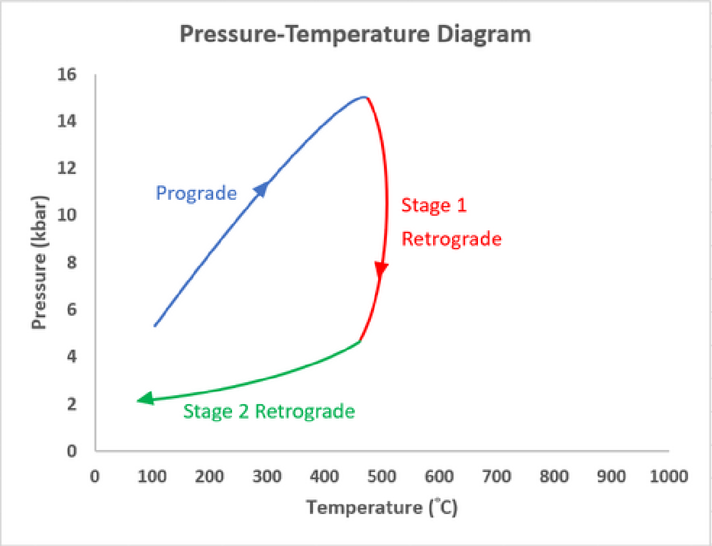
Residence in the crust?

1. Depth: 0 to 5 km not well constrained

2. Temperature: typically <500°C

3. TTP path: time-temperature-pressure

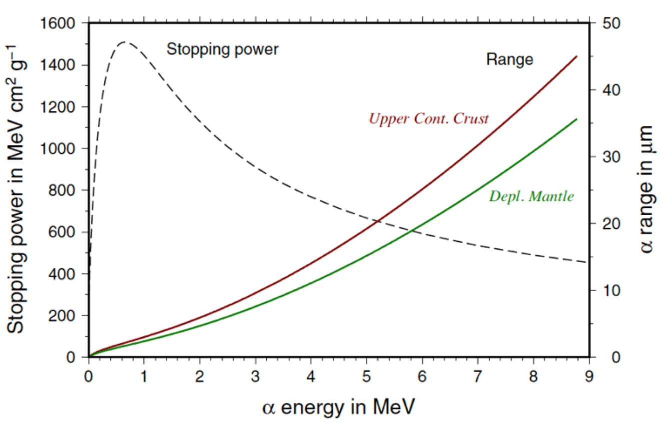
Typical geotherm is between 10 and 20°C/km

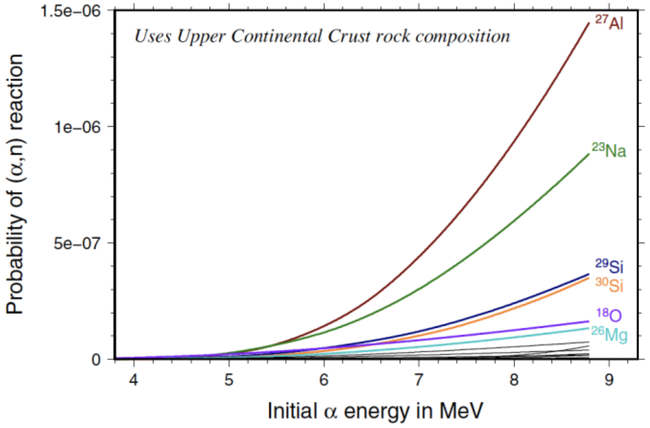


Tracks: background signal and preservation

Considerations:

1. Radiogenic contribution: Few atoms/micron^3
2. Neutron flux: lots of fast neutrons, 10^4 n/kg/yr
3. Nucleogenic vs Cosmogenic neutrons: ?
4. Weathering: free from water
5. Annealing: <500°C

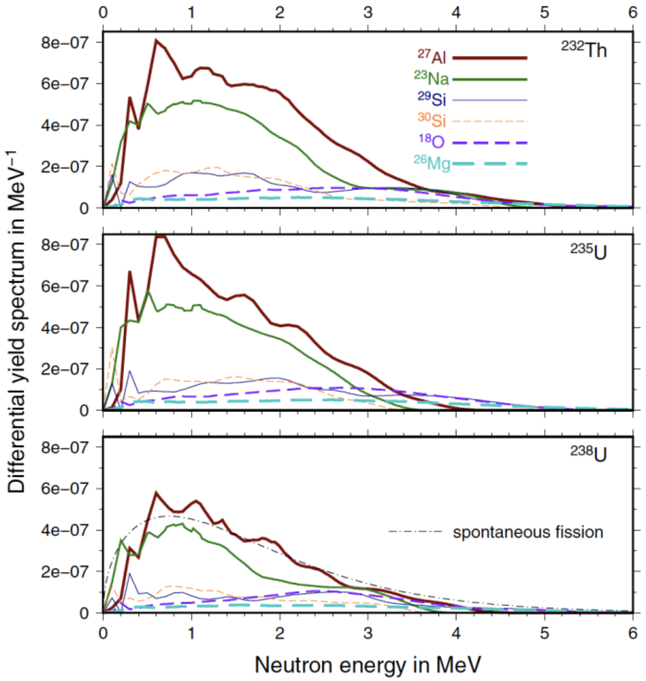




Avg. Upper Crustal rock

Target	Neutron production rate (S_n) ^{232}Th	^{235}U	^{238}U	Sum
Upper (				
^{27}Al	2265.0	72.8	1107.0	3445.0
^{23}Na	1547.0	52.5	805.6	2405.0
^{29}Si	636.9	21.2	328.7	986.9
^{30}Si	549.2	17.2	266.0	832.4
^{18}O	441.4	17.2	294.2	752.8
^{26}Mg	270.0	9.8	150.1	429.8
^{25}Mg	158.1	5.8	89.8	253.7
^{19}F	93.4	3.5	56.4	153.3
^{17}O	47.9	1.8	31.9	81.6
^{56}Fe	51.9	0.3	9.9	62.1
^{41}K	26.7	0.6	10.3	37.6
^{48}Ti	17.5	0.2	5.2	22.9
^{13}C	5.2	0.2	3.7	9.0
^{44}Ca	8.0	0.2	3.0	11.2
SF	0.0	0.0	1198.0	1198.0
Total	6119	203	4360	10 680

neutrons/kg/yr



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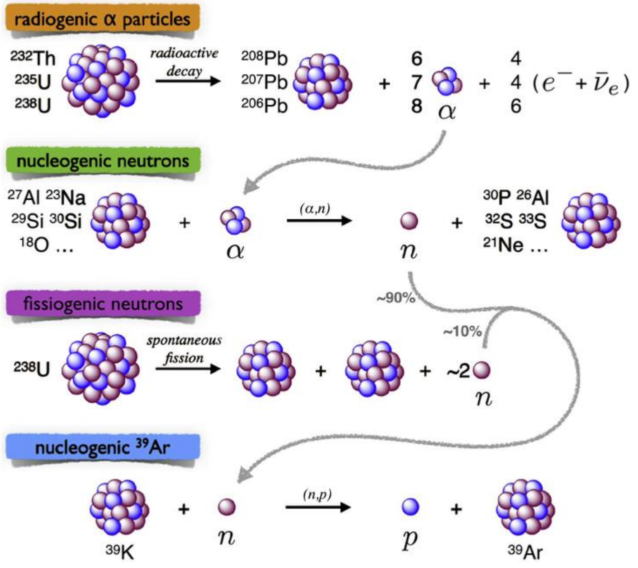
Subterranean production of neutrons, ^{39}Ar and ^{21}Ne: Rates and uncertainties

Ondřej Šrámek [a,*], Lauren Stevens [b], William F. McDonough [b,c,*], Sujoy Mukhopadhyay [d], R.J. Peterson [e]

crustal layers and from PREM (Dziewons
abundances not provided in a particular

Z	symbol	Upper CC
3	Li	–
6	C	1.36E–03
7	N	8.30E–05
8	O	0.480
9	F	5.57E–04
11	Na	0.0243
12	Mg	0.0150
13	Al	0.0815
14	Si	0.311
15	P	6.55E–04
16	S	–
17	Cl	3.70E–04
19	K	0.0232
20	Ca	0.0257
22	Ti	3.84E–03
24	Cr	–
25	Mn	7.74E–04
26	Fe	0.0385
28	Ni	–
38	Sr	–
56	Ba	–
90	Th	1.05E–05
92	U	2.7E–06



Neutron Production by rocks

Upper crust 10^4 n/kg/yr (~10^{-8} cm²/s)

Supernovae: extra bright neutrino source

Considerations:

1. emits >10^{50} ν & $\bar{\nu}$ in all lepton flavors
2. SN 1987A : 51 kiloparsecs (170,000 ly)
3. SN Neutrino luminosity: 10^{45} W
4. Neutrino energies: up to a few tens of MeV

Local Galaxy:

1. A few % of fresh ^{60}Fe was captured in dust and deposited on Earth 1.5–3.2 million years and 6.5–8.7 million years ago.

2. Multiple supernova and massive-star events have occurred during the last 10 million years at up to 100 parsecs.

Thoughts from Mark Vagins

- "typical" distance for a Milky Way supernova is 10 kpc
- Super-K expects to observe about 5000 neutrino events
- SK 22.5 ktons 1 ν interaction per 4500 kg of target mass
- 10^4 SN/Myrs, or **20 million SN/billion years**
- local Galactic ($\lesssim$100 pc) 1/every 2–4 million years
- total rate in the Milky Way (2.0 ± 0.7 per century).