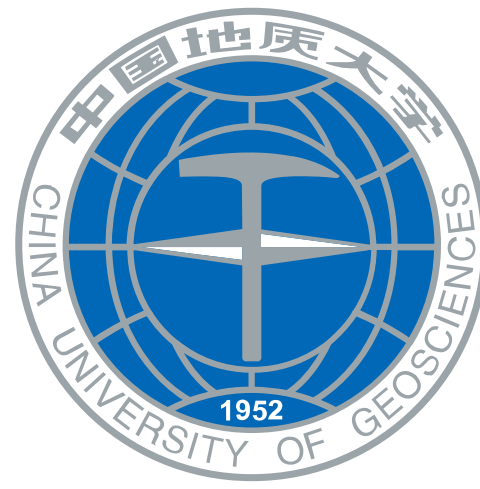




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Metamorphism and the tectonic evolution of the Archean

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Introduction

- What is the tectonic style on the Archean Earth is a hot and controversial topic. Plate tectonics, stagnant-lid, heat pipe, drip tectonics, sluggish plates, and other planetary modes of heat loss have been used to explain part of the geological records.

Methodology

- Each mode is associated with distinct metamorphic characters, highlighting the utility of metamorphic proxies in testing and refining our understanding of Archean tectonics.

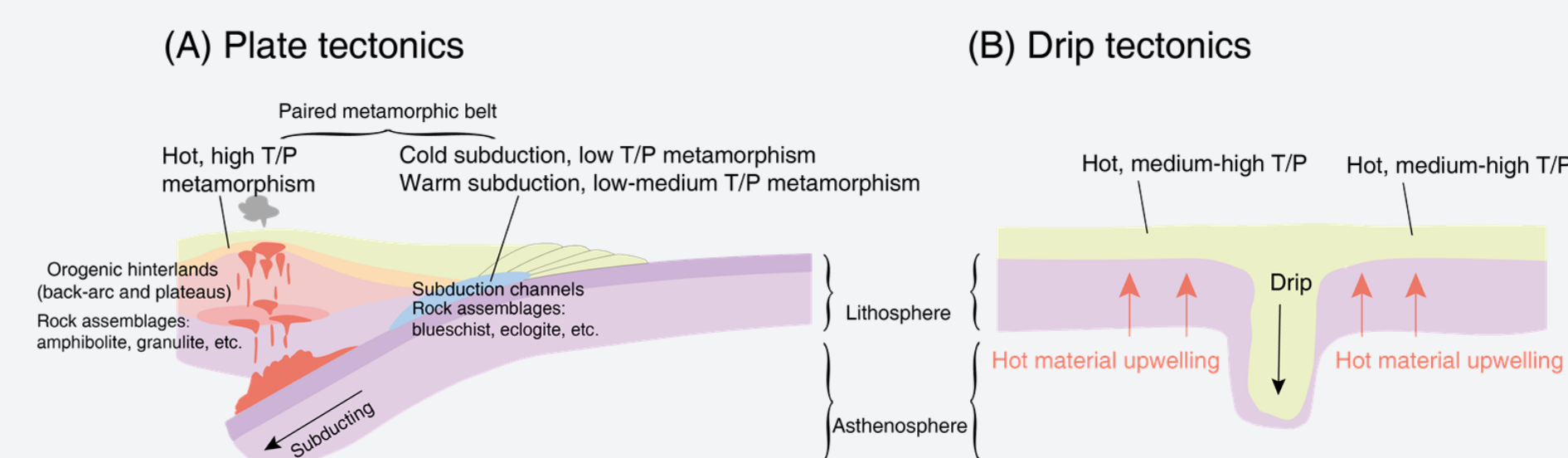


Fig. 1 P-T condition of plate tectonics and drip tectonics

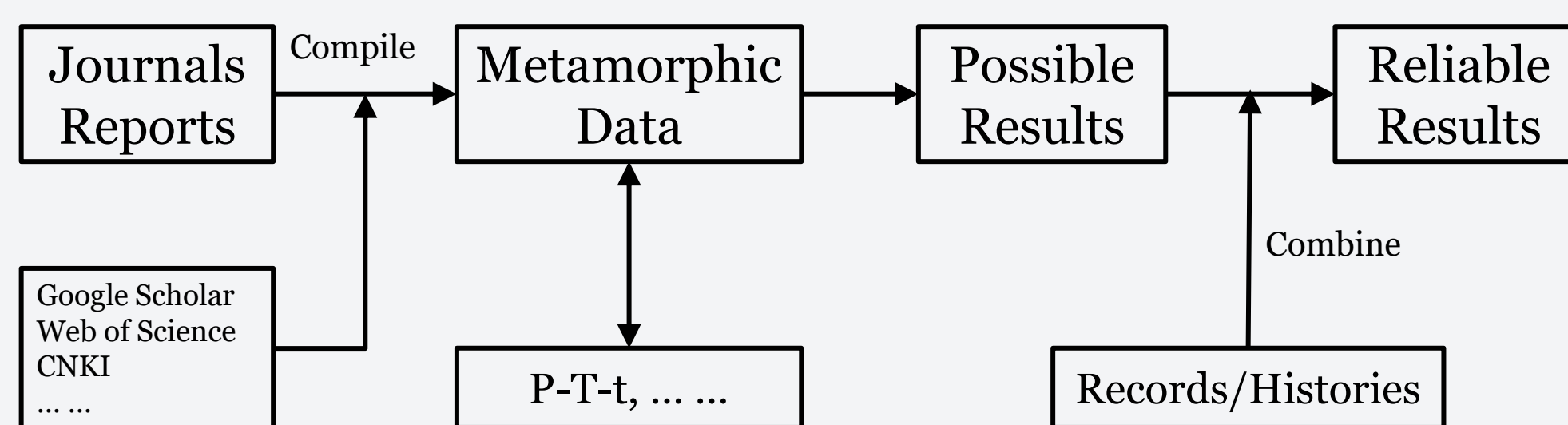


Fig. 2 Flow chart of the methodology

Results-part 1

- 141 data points in total, excluding several controversial data
- Wyoming, Superior, Rae, Slave, North Atlantic, Kaapvaal, Tanzania, Dharwar, Pilbara, Yilgarn, North China, Siberian craton, etc.

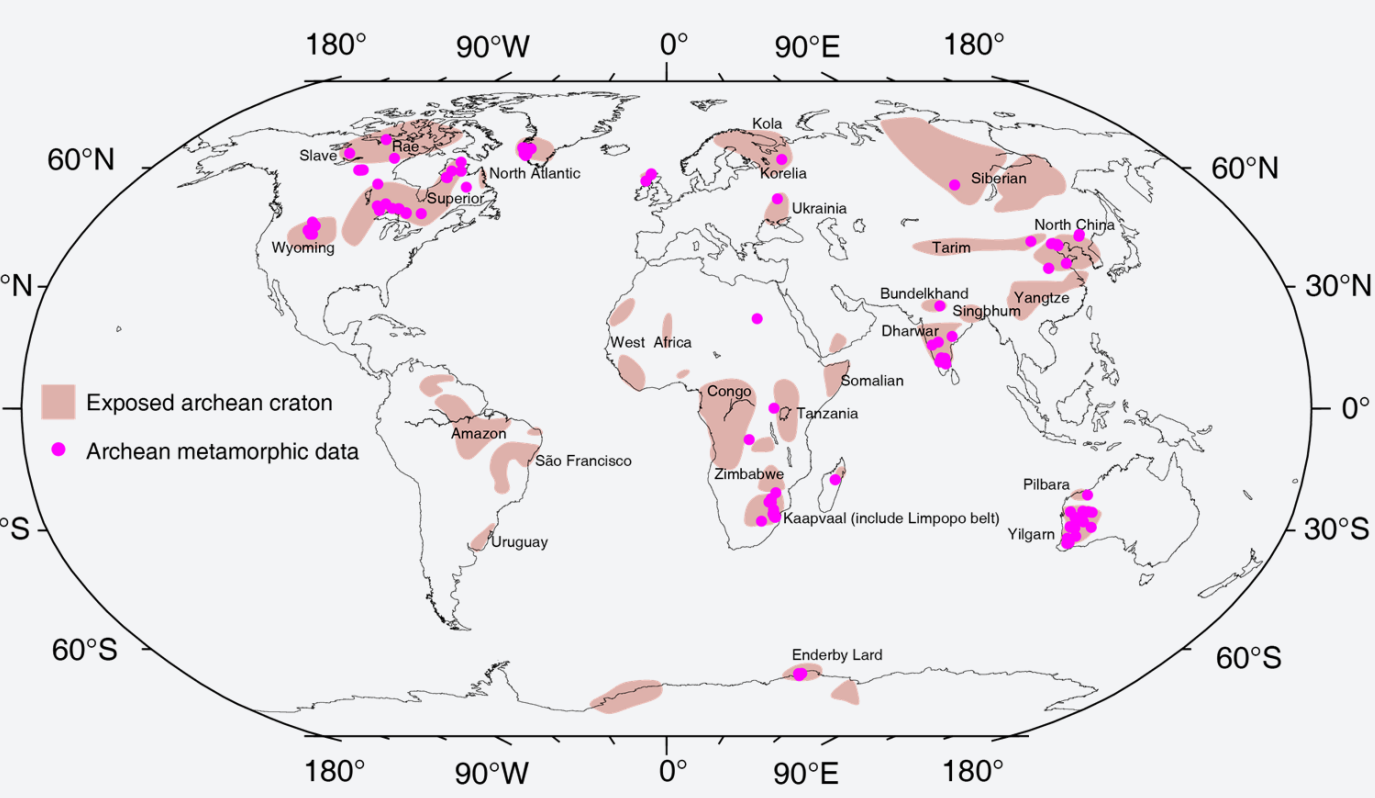


Fig. 3 Distribution characteristics of metamorphic data points. The exposed Archean craton area is modified from Condie et al. (2009).

Results-part 2

- Archean metamorphic data possible could link to subduction and pre-subduction tectonics (e.g., drip tectonics).
- Conditions: the specific location and the effect of rock preservation biases.

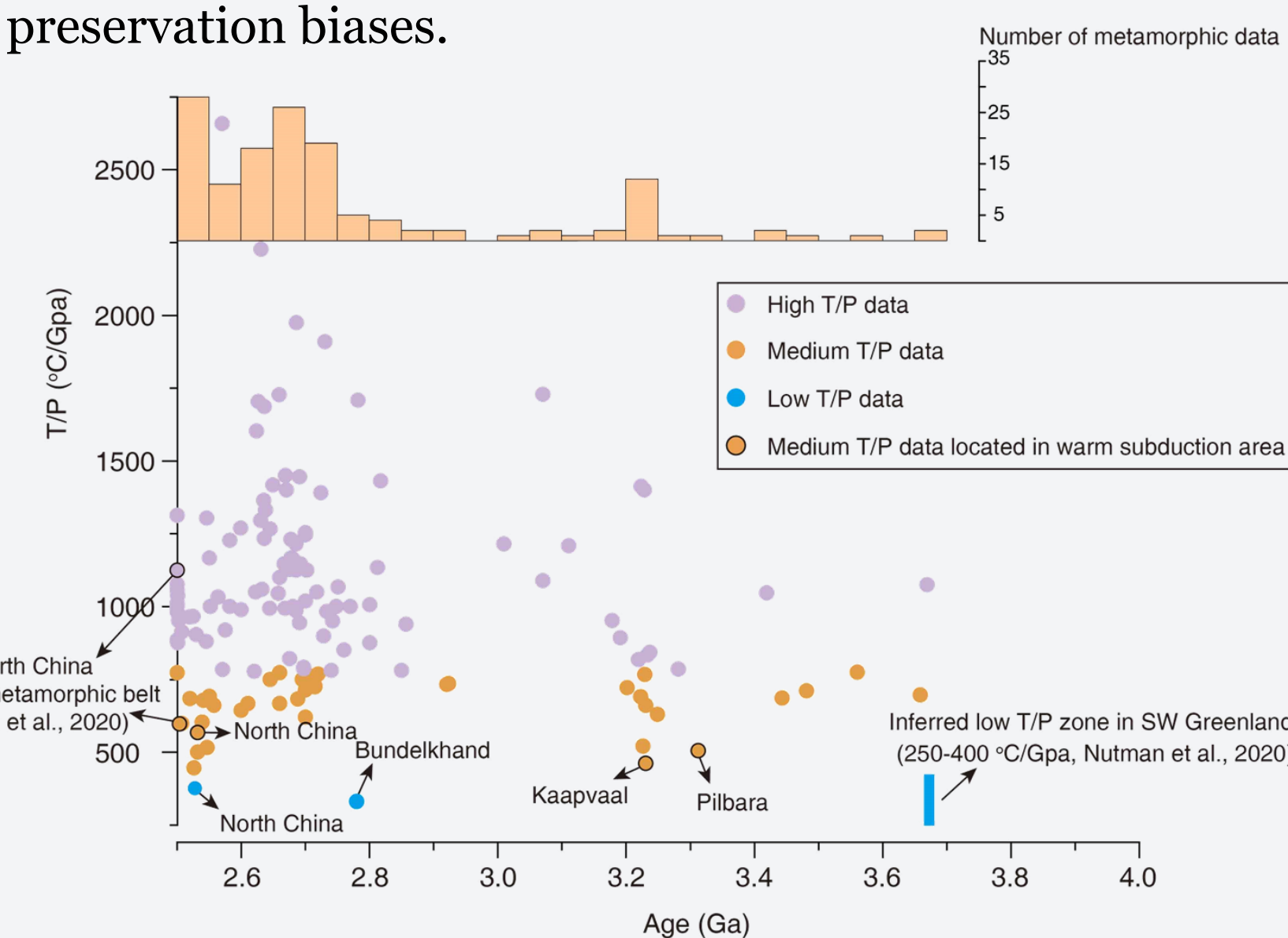


Fig. 4 Archean metamorphic data against age

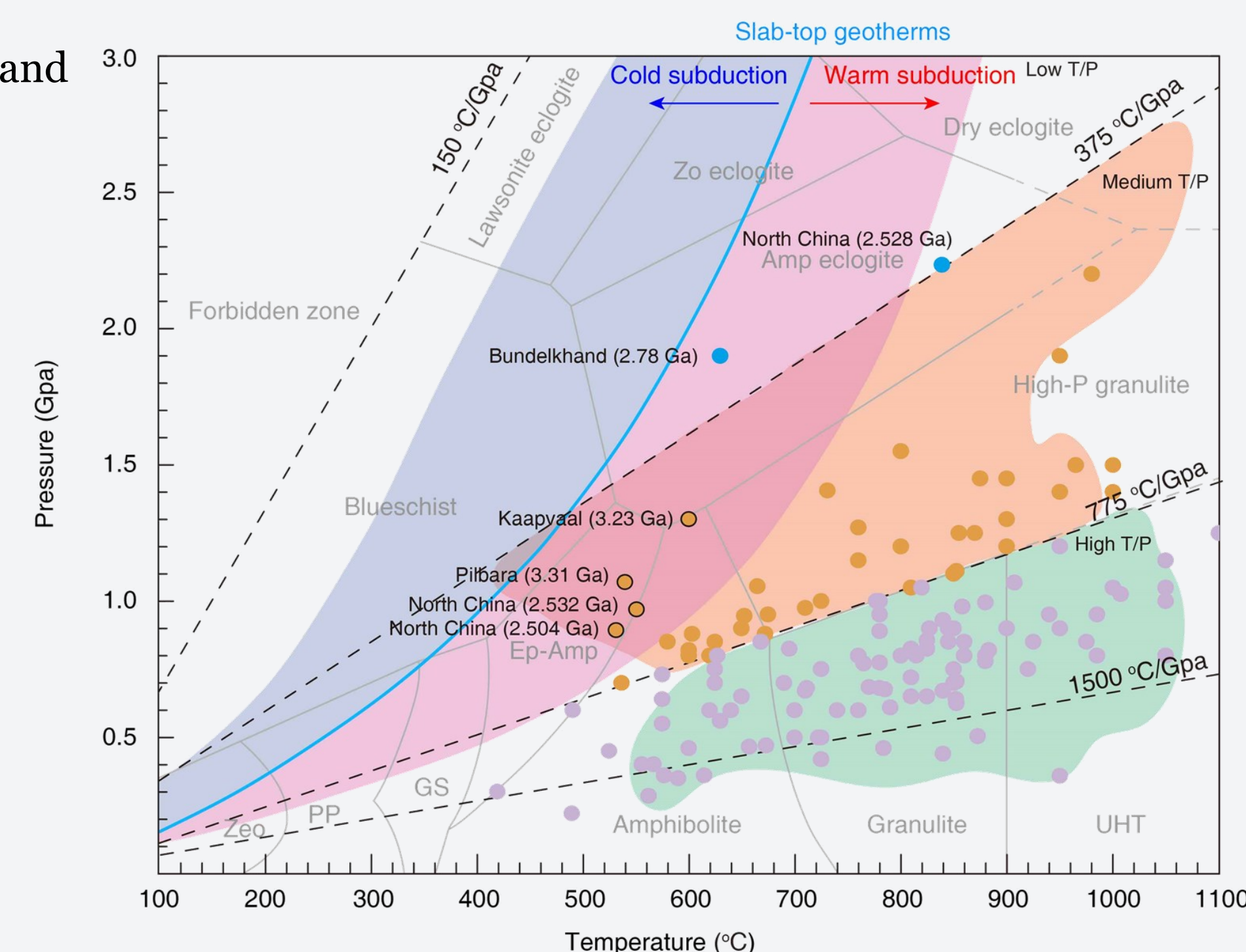
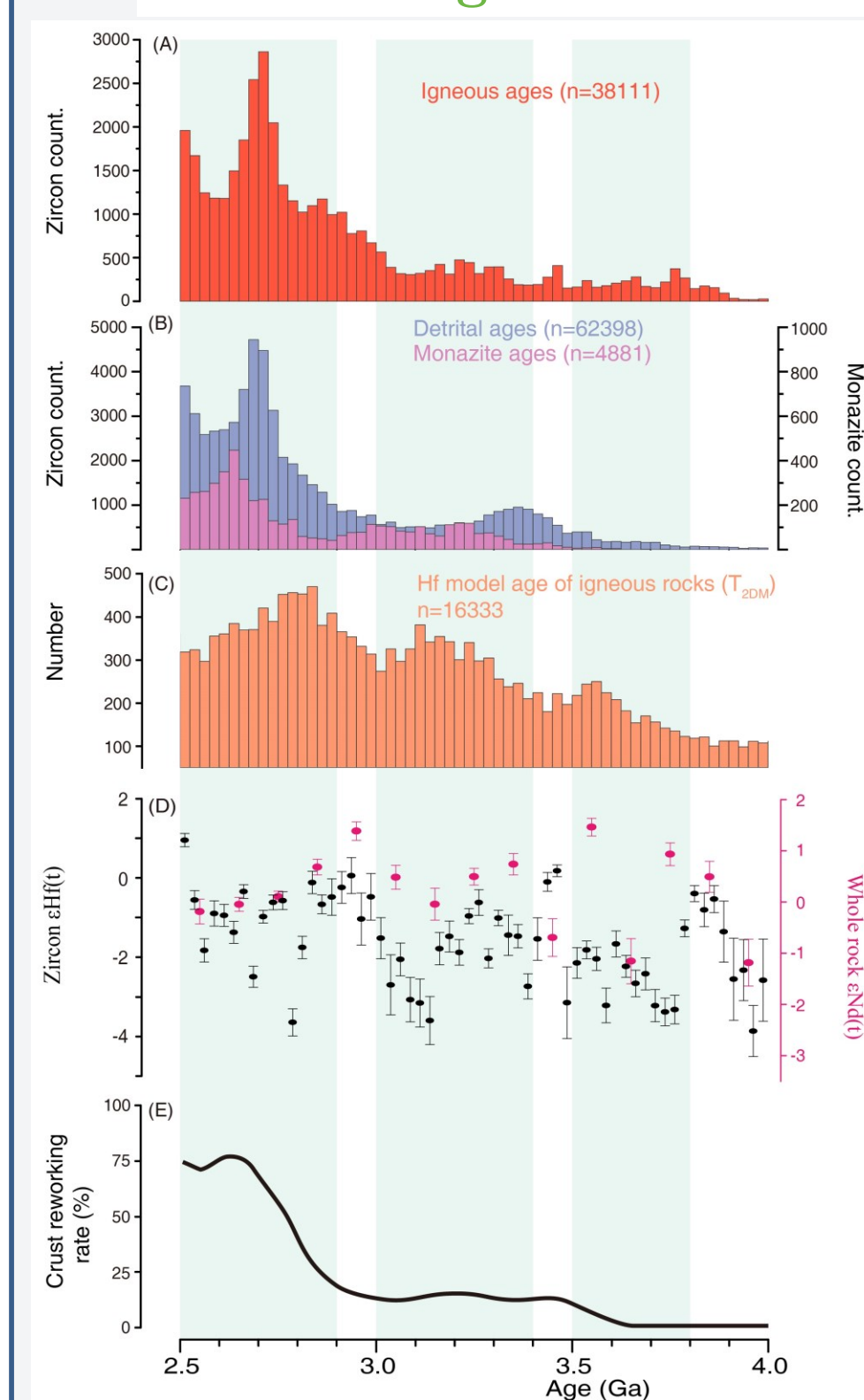


Fig. 5 Metamorphic P-T diagram (After Huang et al. (2020)). The intermediate T/P area (brown) and high T/P area (cyan) were based on the global metamorphic database through deep-time (Brown and Johnson, 2018). Blue and pink areas are slab-top geotherms of Neoproterozoic to Phanerozoic subduction zones (Penniston-Dorland et al., 2015). Blue solid line is the mean slab-top geotherms.

Combining the records/histories



- Archean Earth underwent three distinct phases of tectonic processes, (i) at 3.8-3.5 Ga; (ii) at 3.4-3.0 Ga; (iii) at 2.8-2.5 Ga
- Supercontinent/supercraton assembly in subduction-like tectonic setting, approximately 2.8 Ga
- The onset of subduction-like tectonics may presumably be dated to at least circa 3.4-3.0 Ga, without considering the effect of rock preservation biases.
- Subduction and non-subduction tectonic processes were likely operating at least back to 3.7 Ga

Fig. 5 Records linked to continental growth and crustal reworking event over Archean history. (A) Global Archean igneous zircon age distribution histograms. Bin width is 25 Ma. Age data from Puetz (2018). (B) Global Archean monazite and detrital zircon age distribution histograms. Bin width is 25 Ma. Age data from Mulder and Cawood (2021). (C) Two stage of Hf model age of globe Archean igneous rocks. Bin width is 25 Ma. Age data from Puetz and Condie (2019). (D) The zircon $\epsilon Hf(t)$ and whole-rock $\epsilon Nd(t)$ of Archean igneous rocks against age plot. $\epsilon Hf(t)$ has a bin width of 25 Ma, while $\epsilon Nd(t)$ has a bin width of 100 Ma. Data from Puetz and Condie (2019). (E) Crust reworked rate against age (modified from Dhuime et al. (2012)).

Conclusion

- Three active periods of Archean tectonics: 3.8-3.5 Ga, 3.4-3.0 Ga, and 2.8-2.5 Ga
- Period from 3.8 to 3.5 Ga, short-lived subduction, drip tectonics, and heat-pipe lid processes.
- During 3.4 to 3.0 Ga, subduction appears.
- From 2.8 to 2.5 Ga, plate tectonics assumes its modern form.
- Earth evolution in the Archean exhibits a progression from craton formation during the Eoarchean, to continental formation between 3.4 and 3.0 Ga, and ultimately, towards the end of the Archean, to assembly of supercontinents/supercratons.

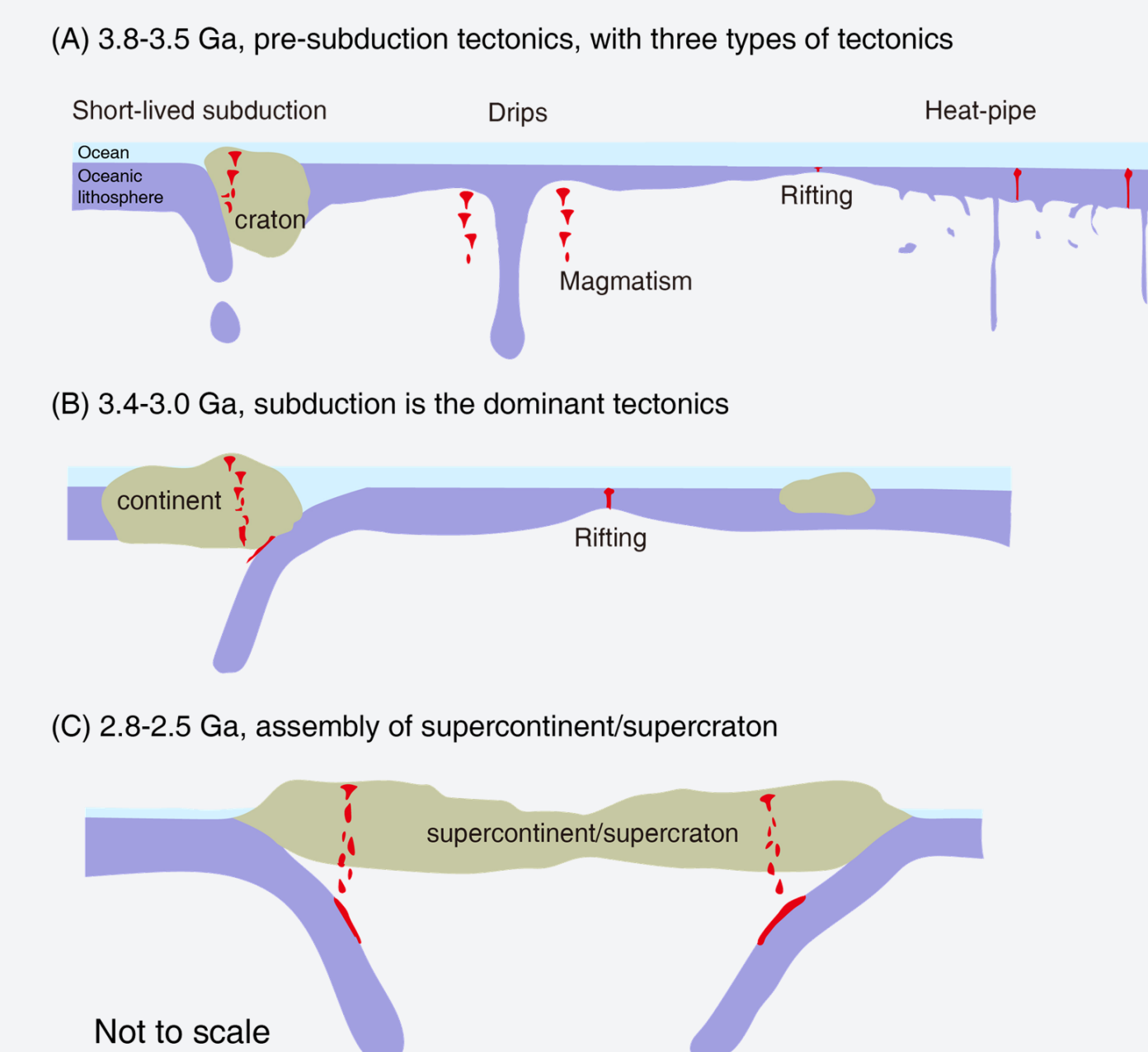


Fig. 7 A cartoon model for the styles and evolution of Archean tectonics.

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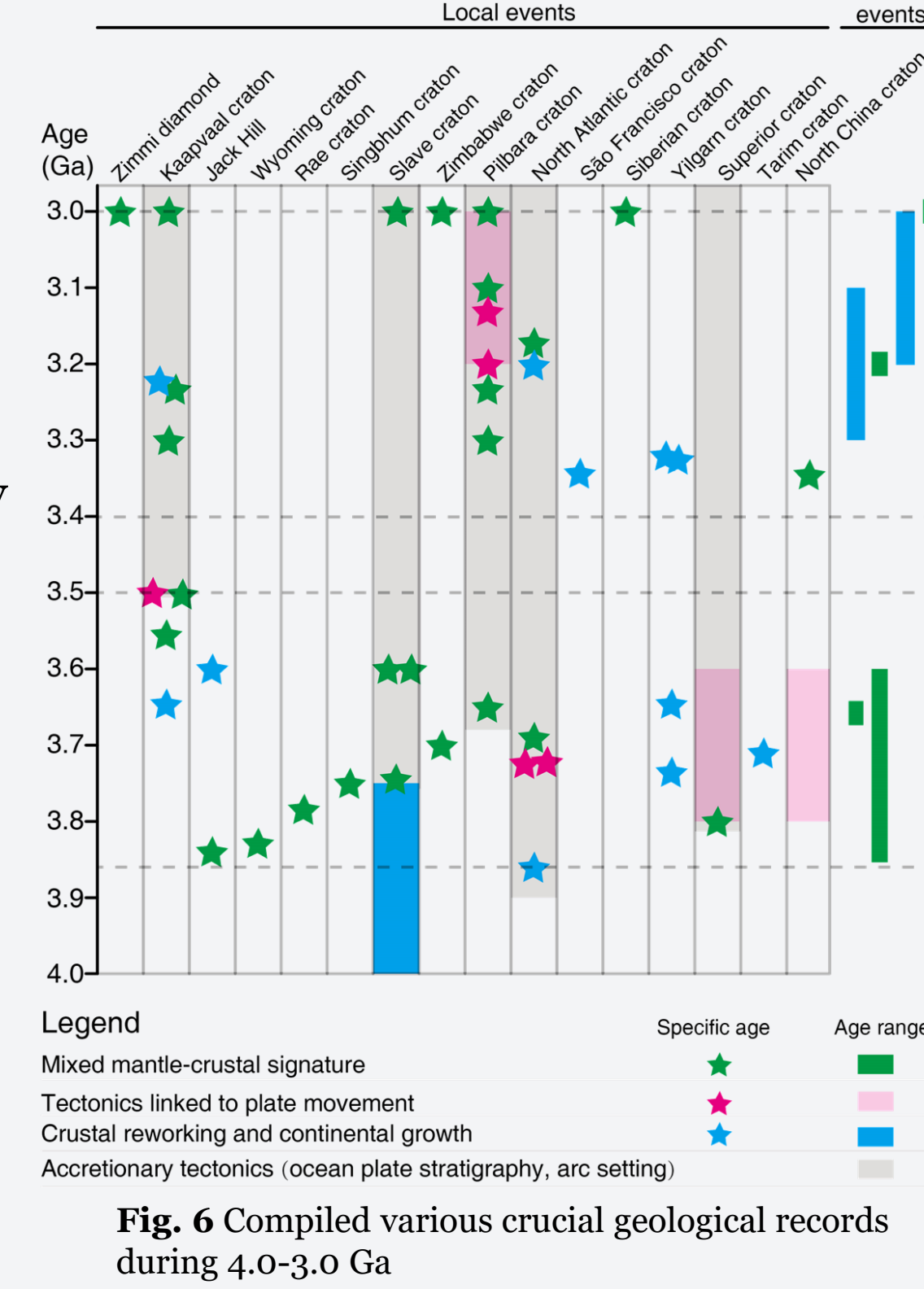


Fig. 6 Compiled various crucial geological records during 4.0-3.0 Ga