Early Earth Plate Tectonics; A Universal or Craton Specific Feature? Implication from Poisson's Ratio Calculation of the Primary Melts

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Abstract

Primary melt compositions and mantle potential temperature (Tp) was calculated for c.a. 3.4 Ga -2.21 Ga volcanic rocks e.g., Basalts, Dikes, Komatiites, Komatiitic-basalts from different Indian cratons, using the data sourced from previously published literature. The results are then compared with the previously published values of Tp from different cratons of the world. In addition, we have also calculated the Poisson's ratio value for the Primary melts from Indian cratons and other cratons of the world as well. A volume normative mineralogy was used for the input to calculate the Poisson's ratio. For temperature, we have used the Tp value of the corresponding Primary melts, and the pressure was kept constant at 1 bar. The measured values of Poisson's ratios are then plotted against their respective ages. Poisson's ratio estimates from different cratons range between 0.2764-0.2840 for 3.5 Ga to 2.6 Ga time window, and records a rise at 2.5 Ga, reaching 0.288 at 2 Ga. The average value of Poisson's ratio from 3.5 Ga to 2.6 Ga is 0.2791± 0.0021(SD), whereas it is 0.282923±0.00283 from 2.5 Ga to 1.3 Ga. However, the number of data points from 1.3 Ga to 500 Ma is very less, and the modern world (i.e., 500 Ma- Present) records an average Poisson's ratio of 0.285 ± 0.004. Nevertheless, the scenario flips around for a few cratons e.g., Superior craton of Canada, the Baltic shield of eastern Europe, and Bundelkhand craton of India; as these cratons are showing an extraordinarily high Poisson's ratio between 2.8 Ga-2.7 Ga. The average Poisson's ratio of 0.287±0.0021 with a high Tp value of 1550°C-1630°C is recorded from Superior craton and the Baltic shield. Tp value from the Bundelkhand craton, on the other hand, is low (1388°C). Similar to the present day, subduction dominated Poisson's ratio from Superior craton and Baltic shield with high Tp value at 2.7 Ga suggests a possibility of manifestation of subduction even at higher temperature conditions. These phenomena, however, appear to be craton-specific rather than a general approach, as no such values of Poisson's ratio have been documented from any other craton in the world between 3.5 Ga-2.7 Ga. The other way around for the above condition might be explained by a proto-tectonic activity such as drip-tectonics or sagduction. This is because, although the Poisson's ratio is high for these cratons during 2.8 Ga- 2.7 Ga, rigid plate subduction at such a high temperature seems to be a difficult task. On the other hand, multiple peaks in Tp values with a certain interval between 3.5 Ga-2.5 Ga indicate cyclic mantle overturn events, which might have terminated the possibility of subduction. However, a lower Tp with a high Poisson's ratio from Bundelkhand might suggest a very similar rigid plate motion during the end of Archaean. Key Word- Mantle Potential Temperature, Poisson's Ratio, Primary Melt

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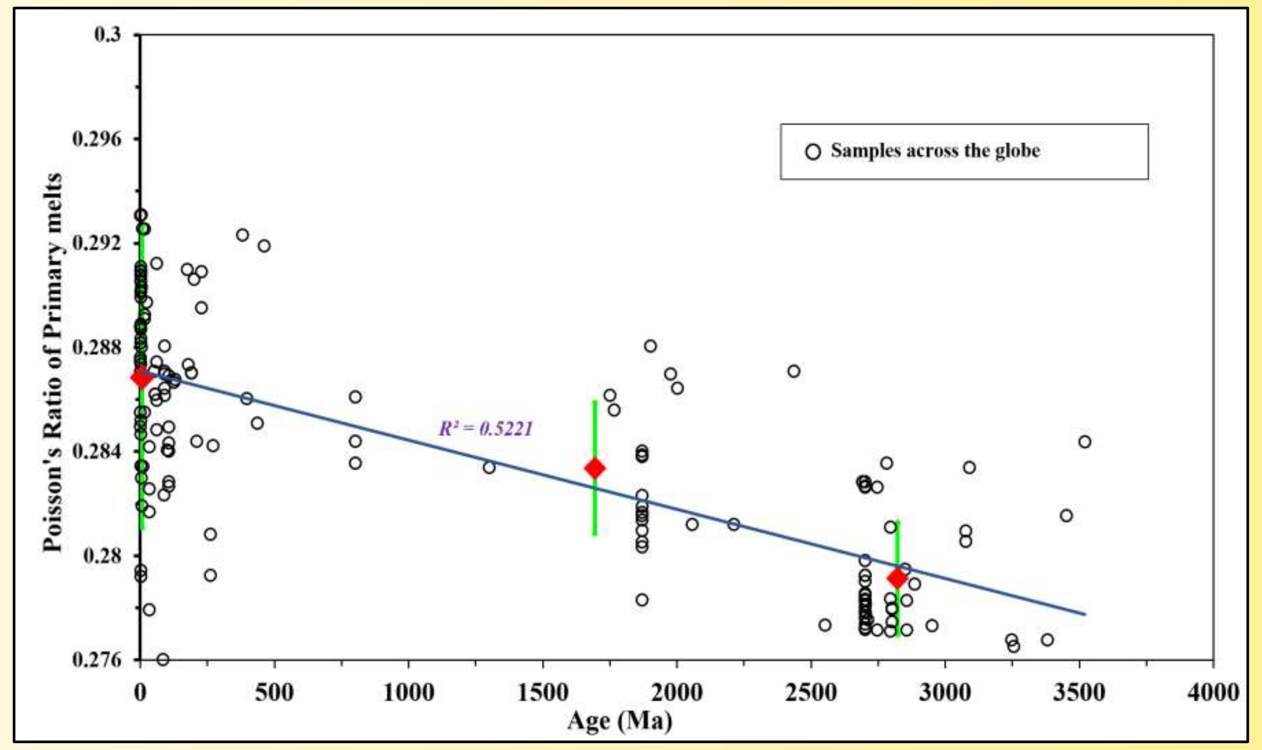
Materials and Methodology

1. Primary melt compositions and mantle potential temperatures (Tp) for mafic dikes, basalts across the globe ranging from Archean to present were calculated using PRIMELT3 of Herzberg and Asimow, (2015) considering a constant redox condition at the source (Fe_{+2}/Fe_{Total}=0.9). The final results of these calculations were checked geochemically and statistically to meet the program requirements.

2. Volume normative mineral% were calculated for these calculated primary melts.

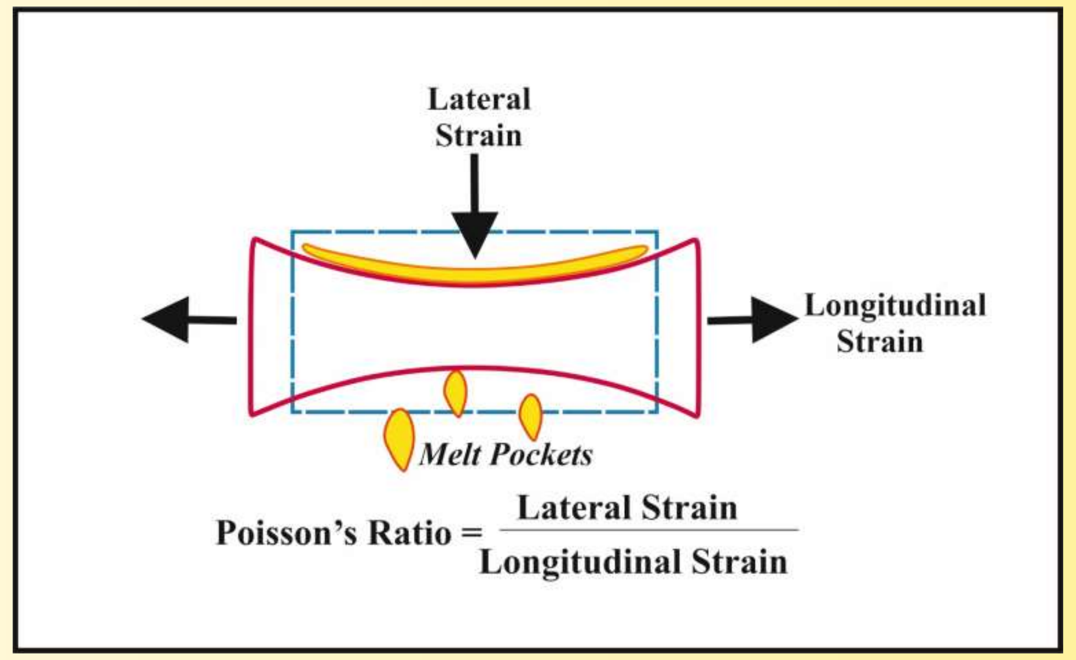
3. Physical properties of the primary melts were calculated using the volume normative mineral% utilizing the program by Abers&Hacker, (2016).

4. A comparison between Poisson's ratio of the primary melts with their ages is shown in the following figure.



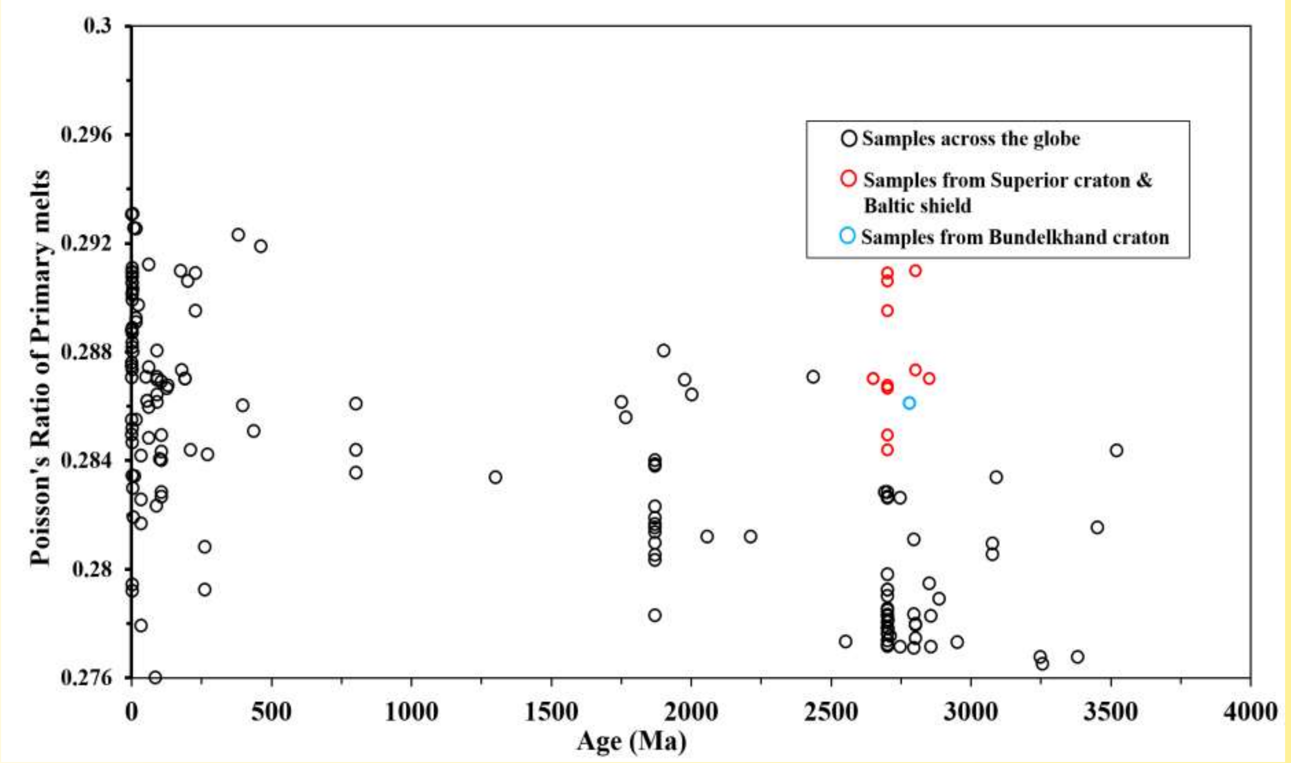
Rigid plate motion during Archean

1. Following is a figure illustrating Poisson's ratio



2. The Archean was characterized by high Tp values (>1500 degrees celsius) and low Poisson's ratio value. The minimum drop in Tp value was calculated to be 200 degrees celsius since the last 2.5 Ga.

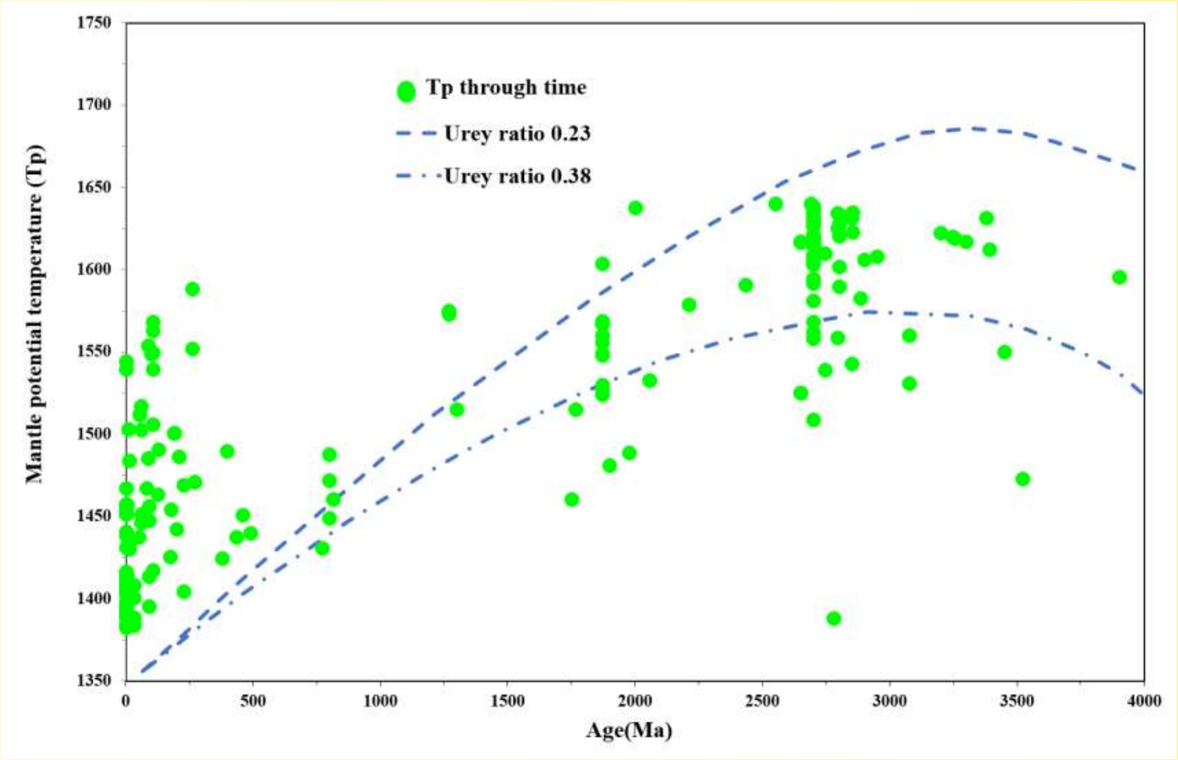
3. However, Archean samples from Superior craton and Baltic shield show high Poisson's ratio and high Tp values (1530-1638 degrees celsius).



High Tp and Mantle Overturn?

1. Sample from Bundelkhand Craton however shows low Tp and higher Poisson's ratio value during Archean.

2. Bédard, (2020, 2013); Stern, (2008) suggested intermittent mantle overturn periods during the Archean and showed the birth of subduction dominated plate motion at least during paleo-proterozoic.



3. The multiple peaks in Tp (data from this study and from Ganne and Feng, (2016))values around the globe, however, indicate a similar scenario for many of the cratons

Summary

- Archean was characterized by high Tp and low Poisson's ratio value for primary melts.
- Unlikely some cratons around the globe show a present-day-like Poisson's ratio value during Archean.
- Nevertheless, their high Tp is unlikely to represent a rigid present-day type tectonic activity.
- However, low Tp producing samples with a high Poisson's ratio during Archean seems to be a possible crustal composition that could have manifested subduction-related tectonic activity.

References

Abers, G.A., Hacker, B.R., 2016. A MATLAB toolbox and Excel workbook for calculating the densities, seismic wave speeds, and major element composition of minerals and rocks at pressure and temperature. Geochemistry Geophys. Geosystems 17, 616–624.

Bédard, J.H., 2020. From the LIPS of a serial killer: Endogenic retardation of biological evolution on unstable stagnant-lid planets. Planet. Space Sci. 192. https://doi.org/10.1016/j.pss.2020.105068

Bédard, J.H., 2013. How many arcs can dance on the head of a plume? A "comment" on: A critical assessment of neoarchean "plume only" geodynamics: Evidence from the superior province, by Derek Wyman, precambrian research, 2012. Precambrian Res. 229, 189–197. https://doi.org/10.1016/j.precamres.2012.05.004

Ganne, Jérôme, Feng, X., 2017. Primary magmas and mantle temperatures through time. Geochemistry, Geophys. Geosystems 18, 872–888. https://doi.org/10.1002/2016GC006787.Received

Herzberg, C., Asimow, P.D., 2015. PRIMELT3 MEGA.XLSM software for primary magma calculation: Peridotite primary magma MgO contents from the liquidus to the solidus. Geochemistry, Geophys. Geosystems 16, 563–578. https://doi.org/10.1002/2014GC005631.

Stern, R.J., 2008. Modern-style plate tectonics began in neoproterozoic time: An alternative interpretation of Earth's tectonic history. Spec. Pap. Geol. Soc. Am. 440, 265–280. https://doi.org/10.1130/2008.2440(13)

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