1. **Effects of Neglecting Clinopyroxene or Plagioclase fractionation**

The thermobarometric formulations in Lee et al. (2009) require knowledge regarding the primary magma composition, i.e., the composition of the magma when it was last in equilibrium with the mantle to calculate the average magma generation pressure (Pg) and temperature (Tg). As erupted magmas undergo some degree of mineral fractionation at crustal level, the primary magma composition has been inferred by reversing the fractionation process (Lee et al. 2009). Sometimes, the evolved magma is saturated with clinopyroxene and plagioclase along with olivine, and reversing the fractional crystallization of such magma is much difficult. This is because the exact proportion of each fractionating mineral is not known. To estimate the percentage of fractionation, the entire differentiation suite is necessary. To avoid this problem, Lee et al chose the most primitive magmas, similar to few previous workers (Putirka 2005; Herzberg et al. 2007; Herzberg and Asimow 2008, 2015), that have undergone olivine fractionation only. By negating plagioclase fractionation, the SiO2 and MgO are overestimated. This results in somewhat higher T and P. Similarly, overlooking clinopyroxene fractionation underestimates SiO2 and overestimates MgO, resulting in lower P and higher T.

1. **Anhydrous source of origin for Tp calculation**

Lee et al’s thermobarometry can be applied for both hydrous and anhydrous magma. However, their formulations are calibrated to a minimum water content of 2 wt%, and considering lower water content than that suppresses the pressure estimation. Such high-water content magmas are characteristics of arc environment, where basalts generate through partial melting of a wet peridotite source. On the other hand, the ambient mantle derived basalts are originated from decompression melting of a dry peridotite source. Studies show that ambient mantle derived basalts (MORBs) contain a maximum up to 0.5 wt% of H2O (Michael 1995; Sobolev and Chaussidon 1996; Danyushevsky 2001), and are dry magmas in nature. The Tp calculations from this study is based upon the ambient mantle derived basalts from Archean to Proterozoic. As discussed earlier, basalts derived from the ambient mantle are considered to be dry in nature. Therefore, all our calculations are conducted by assuming an anhydrous source of origin. Previous studies have also adopted a similar approach, considering an anhydrous source, to calculate the Tp of the ambient mantle (Komiya et al. 2002; Putirka 2005; Herzberg et al. 2010; Ganne and Feng 2017; Aulbach and Arndt 2019).

1. **Assumptions regarding the final Mg# of olivine**

To calculate Pg, and Tg, for input basalt, Lee et al. (2009) applied a polybaric decompression melting process. Polybaric decompression melting initiated by solid-state upwelling, promotes melting along a path of changing pressure and temperature. The calculated primary melt composition in this process represents the weighted average aggregate melt composition. Lee et al. (2009) used a polybaric batch melting model to calculate the primary magma composition of a primitive basalt that has experienced only olivine fractionation. Batch melting refers to a process where the partial melt remains in equilibrium with its mantle residue at various melt fractions. Consequently, the authors have taken into account an average value of olivine Mg# to represent the mantle residuum. They first estimated an equilibrium olivine composition to the input basalt and added the olivine back into the magma until the magma equilibrates with olivine having an Mg# equivalent to the average mantle residuum. Varying the residuum Mg# to 1 unit can increase or decrease the temperature upto 50-100℃.

We acknowledge that considering a final forsterite content might cause some uncertainties to our calculation. For example, the approach over-estimates temperatures if melting degrees are lower and under-estimates if melting degrees are higher. To reduce the inconsistency in assuming the final forsterite content, Herzberg and co-workers (Herzberg et al. 2007; Herzberg and Asimow 2008, 2015) simultaneously calculated the Tp and olivine Mg#. In other words, their approach is self-consistent and does not need a final olivine forsterite number to be fixed to calculate the Tp.

Note that the physical meaning of olivine Mg# in Herzberg’s and Lee’s methods differ. While the iteratively calculated olivine Mg# in Herzberg’s method represents the Mg# of olivine to be crystallized from primary magma at 1 atmospheric pressure, the olivine Mg# required as input in Lee’s method represents the Mg# of residual mantle source. This is because Herzberg’s methodology to calculate primary magma composition is based on fractional melting equations, where the accumulated fractional melt is never in equilibrium with its residue except the final drop of liquid. Previous studies have shown that primary magmas produced by fractional melting have slightly higher FeO and lower SiO2 content than batch melts at constant MgO content (Langmuir et al. 1992; Herzberg 2004). Later, Asimow and Longhi (2004) showed that primary melts, produced via accumulated fractional melting of fertile upper mantle peridotites can be very similar to that of batch melts in terms of MgO and FeO content.

Polybaric melting, resulting from the adiabatic decompression melting of mantle would leave a residue where the degree of depletion decreases with depth. This is apparent from the xenolithic evidence for polybaric melt extracts (Xu et al. 2002), where the Mg# of residual olivine show a negative relation with depth. As the calculated primary melt composition represents weighted average aggregate melt composition produced via polybaric decompression, the residual olivine composition in the mantle must also represent an average Mg# value, produced during this process. In this context we have utilized a mean value of residual olivine Mg# derived from the polybaric fractional melting, using the parameterization of Herzberg (2004) and Herzberg and Rudnick (2012). For a hot-ridge melting during the Archean, the mean value of residual olivine Mg# is 0.92, whereas this value can be 2 units higher during a hot plume melting event during the Archean (fig. 5 in main text). During Proterozoic to Phanerozoic the Olivine Mg# decreases from 0.912 to 0.908 for ridge melting (Herzberg 2004; Herzberg and Rudnick 2012).

The Archean mantle xenoliths from cratonic lithosphere show an average Olivine Mg# (Fo) of 0.92 (Servali and Korenaga 2018), supporting the recent idea that depleted peridotites from the Archean cratonic lithospheric mantle are the residual product of basaltic primary melt extraction in a typical hot mid-ocean ridge (MOR) setting, rather than in a plume setting (Rollinson 2010; Herzberg and Rudnick 2012; Pearson and Wittig 2014; Herzberg 2018; Servali and Korenaga 2018). These peridotites later became part of the continental lithospheric mantle through processes such as orogenesis or underthrusting events. The basaltic crust was subsequently recycled to the mantle due to density inversion during subduction. Few of these Archean MOR basalts are preserved as non-arc basalts in Archean Greenstone belts. If this holds true, then using an average residuum olivine Mg# of 0.92 to calculate Tp for our study should align with previous Tp estimations for ambient mantle, based on both petrological and modeled values. Table R1T1 presents a comparison of mantle potential temperature (Tp) values for Archean basalts originally employed by Herzberg et al. (2010). The Tp values were re-calculated using their updated PRIMELT3 (Herzberg and Asimow 2015) algorithm and, concurrently, determined through the FRACTIONATE-PT software, incorporating an olivine Mg# of 0.92. Additionally, in both cases, the Fe+2/Fe total ratio was maintained at a constant value of 0.9.

**Table R1T1: Comparison between the Tp values for Archean basalts from PRIMELT3 and FRACTIONATE-PT**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Sample No** | **Location** | **Age (Ma)** | **Tp (℃) from PRIMELT3** | **Tp (℃) by considering residuum Ol Mg# = 0.92 (FRACTIONATE-PT)**  | **∆Tp (Tp PRIMELT3 - Tp FRACTIONATE-PT) (unitless)** |
| gc010697 | Coonterunah Gp, Pilbara | 3520 | 1448.916963 | 1455.66282 | -6.74585763 |
| 02MB256 | Warrawoona  | 3450 | 1536.99506 | 1566.212117 | -29.21705694 |
| M-14-16 | Minnesota, U.S.A. | 3255 | 1624.858428 | 1641.846865 | -16.98843743 |
| 96048540D | Sulfur Sprgs Gp, Pilbara | 3246 | 1626.892503 | NA | NA |
| 485418 | Ivisaartoq 1, Greenland | 3075 | 1549.062115 | 1575.90257 | -26.8404557 |
| 485420 | Ivisaartoq 1, Greenland | 3075 | 1514.470098 | 1491.262457 | 23.20764123 |
| I-417 | Iringora 'ophiolite' Finland  | 2800 | 1587.219972 | NA | NA |
| I-417/2 | Iringora 'ophiolite' Finland  | 2800 | 1602.476172 | NA | NA |
| RKY-17 | Kushtagi-Hungund, India | 2746 | 1612.46851 | 1560.290334 | 52.17817645 |
| RKY-18 | Kushtagi-Hungund, India | 2746 | 1523.325625 | 1535.92639 | -12.6007648 |
| s MU96-20 | Superior, Canada | 2700 | 1488.887087 | 1496.591921 | -7.704833696 |
| s DH95-3 | Superior, Canada | 2700 | 1550.861812 | 1557.537682 | -6.675869591 |
| s T-7 | Superior, Canada | 2700 | 1545.850084 | 1553.893266 | -8.043182132 |
| 2 | Aravalli Supergroup, India | 2550 | 1653.687403 | 1648.235736 | 5.451666394 |

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**Repository Fig R1S1.** Mantle potential temperature (Tp) variation with age calculated from the magma generation temperature (Tg) and pressure (Pg) from Lee et al. (2009), utilizing an average olivine Mg# of 0.92 for Archean and 0.912 for Proterozoic samples. The redox condition is considered as Fe+3/Fe Total = 0.1. Three values of Urey ratio (0.23, 0.38, 0.08) (Korenaga 2008) are shown. As a function of age, also shown are the TP based on liquidus temperatures of suggested MORB-like mafic suites (Abbott et al. 1994), MORB source mantle from (D09) (Davies 2009) based on parameterised convection models with conventional heat-flow scaling, mantle Tp from Herzberg and Asimow (Herzberg and Asimow 2015) from Archean and Proterozoic DM, and EM derived basalts, Tp minima and maxima from Ganne and Feng (2017) calculated from non-arc basalts, TP range for a pressure of 2.2 to 3.2 GPa based on the chemical composition of continental basalts e.g., condition in the arc mantle wedge from Keller and Schoene (2018). Mantle potential temperature observed from mantle eclogite xenoliths (Aulbach and Arndt 2019) are shown in olive green hexagons. 1: Siberian Craton, 2: Kaapvaal Craton, 3: Karelia Province, 4: North-Atlantic craton, 5: Superior Craton, 6: Dharwar Craton 7: Flin Flon 8: Zambia 9: Balkan-Carpat. For comparison, Tp values from Komatiites and Phanerozoic Plume are shown (Herzberg 2022). M.L.: Magmatic Lull from 2300 Ma to 2200 Ma (Spencer et al. 2018). Boring Billion from 1800Ma to 800Ma (Roberts 2013).

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