

Geodynamic implications of the change in basalt petrology across deep time and space

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The secular chemical evolutions of the continental crust and upper mantle are heavily informed by basalt composition and isotope data. As products of mantle melting, basalt compositions are initially controlled by source characteristics and melting *PT* but strongly modified by assimilation and fractional crystallization during ascent. A comprehensive understanding of basalt evolution therefore requires an integrated petrological and geochemical approach. Despite extensive studies, the interpretation of basalt geochemistry from the Archaean to the present remains contentious, including concerning major oxides such as MgO and inferred mantle potential temperatures.

Motivated by emerging agreement that Archaean basalts are dominantly quartz-normative, contrasting with the olivine- and nepheline-normative nature of modern basalts, we here move beyond study of individual element trends to investigate the petrogenetic implications of normative basalt mineralogy through time.

A curated deep-time geochemical dataset ($5 \leq \text{MgO wt.\%} \leq 18$) was compiled from published academic and governmental sources, as well as precompiled databases (GEOROC, EarthChem) and industry records ($n = 93,294$). To limit alteration effects, data were filtered based on loss on ignition ($\text{LOI} < 5 \text{ wt.\%}$) and chemical index of alteration ($\text{CIA} < 60$). Our results imply a strong secular shift in normative basalt mineralogy: quartz-normative basalts constituted $>50\%$ of Archaean samples, progressively declining to $\sim 20\%$ in the Phanerozoic, while nepheline-normative basalts increased from $\sim 4\%$ in the Archaean to $\sim 15\%$ in the Neoproterozoic and $\sim 40\%$ in the Phanerozoic. This trend reflects two unrelated processes: (i) preservation bias and (ii) secular source evolution.

Analysis of the tectonic setting of Phanerozoic basalts reveals that nepheline-normative compositions ($\sim 60\%$) dominate rift-related and other intra-plate basalts, whereas continental flood basalts (CFB) exhibit normative characteristics indistinguishable from Archaean greenstone belt basalts. This adds to growing evidence that most Archaean greenstone belts are not accreted oceanic terranes but CFBs erupted on evolving proto-cratonic lithosphere. Melt-solid interaction during passage through thick cratonic lithosphere offers many petrological ways of driving compositions to quartz-normativity^[1]. Because most nepheline-normative Phanerozoic basalts are continental, their paucity in the older rock record is unlikely a preservation bias but suggests a genuine secular increase in enriched mantle source melting.

[1] Tomlinson and Kamber (2021) *Nature Communications*, 12(1), 1082