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Archaean tectonic systems: a naive geochemist's view

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On a global scale, the geochemistry of common igneous rocks reflects the dominant processes operating on Earth. Therefore, any change in global tectonic patterns should reflect on global geochemical patterns. This work examines the global distribution of Archaean and modern igneous rock's compositions, without relying on preconceptions about the link between rock compositions and tectonic sites (as in "geotectonic" diagrams). Rather, geochemical patterns are interpreted in terms of source and melting conditions; Archaean and modern patterns are compared.

The dataset used is extracted from web databases (georoc and petDB), supplemented with the author's own compilation (for granitoids). The igneous rock record for both Archaean and Phanerozoic systems is bimodal, with mafic/ultramafic rocks on one hand (mantle source) and granitic rocks on the other hand (crustal recycling). Ultramafic rocks are rare in modern systems, but common in the Archaean – this is classically interpreted as reflecting a higher degree of melting in a hotter Archaean mantle.

Mafic rocks on the modern Earth show a clear separation between "arc" and "non-arc" rocks, depicting for instance two clearly separated, parallel arrays in a Th/Yb vs. Nb/Yb diagram. This points to the first order difference between "wet" (arc) and "dry" (mid-ocean ridges and hotspots) melting of the mantle. Dry melts are further separated in depleted (MORB, high Zr/Nb) and enriched (OIB, low Zr/Nb) sources. This three-fold pattern is a clear image of the ridge/subduction/plume system that dominates modern tectonics. In contrast, Archaean mafic and ultramafic rocks are clustered in an "intermediate" position, between "arc" and non "arc" and between "enriched" and "depleted" components. The distribution is unimodal; Archaean rocks depict a single, oblique array in Th/Yb vs. Nb/Yb, and cluster between the three main modern types in e.g. Zr/Nb vs. Nb/Th. This suggests that the Archaean mantle had lesser amounts of clearly depleted or enriched portions; that true subductions were rare; and that the distinction between oceanic plateaux and ridges may have been less significant.

Modern granitic rocks are essentially metaluminous (subduction-related), plotting together with mafic "arc" rocks; or peraluminous (collision, plotting near the average continental crust), with rare "mantle-like" rocks plotting near MORBs or OIBs. Again, the Archaean granites show a different picture, with the near absence of peraluminous rocks; a group of low HFSE and HREE granites (the "high pressure" TTGs) that have no modern match; and the near-absence of "within plate" or "oceanic ridge" granites. This points to the absence of large sedimentary accumulations, and the presence of uniquely Archaean petrogenetic processes (high pressure melting of basalts).

Collectively, the geochemical evidence suggests an Archaean Earth with somewhat different tectonic systems. In particular, the familiar distinction between collision, arcs, ridges and hotspots seems to blur in the Archaean, where "hybrid" tectonic sites may have existed.