Oxidized carbon species in the Early Archean mantle: Clues to the evolution of plate tectonics and terrestrial magmatism

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The redox history of Earth's mantle is controversial with arguments suggesting near-constant or increasing mantle redox through time [e.g., 1, 2]. The mobility of carbon between Earth's interior and its outer life-supporting reservoirs is controlled by the redox state of mantle lithologies. Although our understanding of mantle redox across the tectonic environments on modern Earth has improved dramatically, the redox state of the Archean mantle remains enigmatic, where limited fO_2 estimates have been determined on products of major melting such as komatiites.

We measured the C- and N-isotope compositions of the oldest confirmed Archean diamonds, which were recovered as placer stones from the 3.1-2.7 Ga Witwatersrand Supergroup, Kaapvaal craton. Utilizing N-aggregation and C- isotope systematics, we obtained firm evidence that the Wits diamonds formed between 3.5 and 3.1 Ga within Earth's upper mantle. However, the N-isotope compositions suggest that recycled sedimentary components contributed to the diamond-forming fluids/melts. Importantly, detailed high-precision SIMS C-isotope profiles across the Wits diamonds reveal that the growth medium contained oxidized carbon species in the form of CO_3^{2-} and/or CO_2 (as opposed to CH_4). These findings are among the most robust and direct evidence for the presence of highly oxidized and recycled components within Earth's mantle near a subduction zone by 3.5 Ga, and possibly before [3]. As a corollary of our Early Archean diamond results, the 'delayed' appearance of CO_2-rich surface magmatism (such as kimberlites and carbonatites) during Earth's evolution after 3 Ga, and more notably after 2 Ga [4], does not appear to be an important function of increased mantle redox through time. Rather, onset of mantle cooling at 3.0-2.5 Ga [5] enabled CHO-volatile driven incipient melting regimes beneath the stabilizing continents, which gave rise to this new form of terrestrial magmatism.

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[5] Korenaga (2008), Rev Geophysics 46: 1-32.