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Recycled sedimentary carbonate can not oxidize mantle directly

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Carbon predominantly occurs as C^{4+} in subduction systems, where recycled sedimentary carbonates are hypothesized to act as oxidizing agents for enhancing mantle oxygen fugacity (fO_2). However, the broad fO_2 variations recorded in natural carbonatites, even with their carbonate-dominated mineralogy, reveal substantial complexities in carbonate-mediated redox processes. Here we demonstrate that deep subduction of carbonates may not directly oxidize the mantle with high efficiency. We present petrogenetic evidence challenging the paradigm of direct mantle oxidation through deep carbonate subduction. We investigate Dalihu basalts hosting carbonatitic xenoliths derived from recycled sedimentary carbonate. These lavas exhibit geochemical imprints of carbonate recycling: (1) radiogenic $^{87}Sr/^{86}Sr$ ratios (0.7058–0.7063) showing positive covariation with Sr/Nd; (2) lower $\delta^{44/40}Ca$ (0.51-0.70‰) coupled with higher $\delta^{66}Zn$ (0.35-0.45‰) relative to mantle reservoirs. Nevertheless, the oxygen fugacity (fO_2) of Dalihu basalts, as constrained by vanadium partitioning coefficients between olivine phenocrysts and whole-rock matrices (ΔQFM = -2 to 0.4), aligns with typical upper mantle oxygen fugacity. Additionally, these basalts exhibit homogeneous iron isotopic compositions ($\delta^{56}Fe$ = +0.08 to +0.15‰), consistent with values reported for mantle-derived basalts globally. This geochemical coherence—both in redox state and Fe isotope signatures—provides robust evidence against substantial oxidation of the mantle source by recycled sedimentary carbonates. Our findings suggest that sedimentary carbonate recycling does not necessarily oxidize the mantle, but geological processes such as decarbonation reactions should be taken into account.