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Carbonate subduction drives gold metallogenesis in convergent margins

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The exchange of carbon dioxide between Earth's surface and interior through the fluids and melts in convergent margin sustains planetary habitability[1-2]. Since the giant Mesoarchean crustal gold addition event[3], these CO_2-rich fluids and melts have repeatedly mobilized and redistributed crustal gold at the lithospheric scale, producing the current variety of gold deposit[4-5]. However, it remains elusive how carbonic-aqueous fluids control gold transfers and whether there is a fundamental link between gold metallogenesis and Earth's habitability evolution. Our novel numerical models reveal that subduction of carbonate sediments enhances gold mobility in aqueous fluids by stabilizing the $Au(HS)S_3^-$ complex, producing fluxes up to 6 kg Au m^{-2} Myr^{-1}—almost 10 times greater than those from reduced pellitic sediments. CO_2-rich fluids derived from subducting slab promote the fluid-present melting of mantle wedge and buffer a favorable acidity-redox-sulfur speciation environment, thereby opening a window for generating gold-enriched melts that are the primary source of porphyry gold deposits. Time-series analyses indicate that since 250 Ma, porphyry gold deposits are closely correlated with carbonate subduction, with mineralization occurring either synchronously or with a time lag depending on the depth of carbon release. Additionally, major gold-mineralization episodes coincide with rising atmospheric carbon influx and Earth surface cooling, indicating that intensified arc degassing and silicate weathering jointly promoted both habitability and crustal metal enrichment. These findings link gold metallogenesis to subduction carbon cycling and place crustal metal enrichment within the context of Earth's habitability evolution.

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