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Partial melting of eclogite in Central Himalaya and its contribution to Miocene climate change

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The presence of eclogite is a widely accepted indicator of the onset of modern-style plate tectonics. However, eclogite is rarely preserved in many heavily granulite-overprinted orogens, which are particularly common across ancient metamorphic terranes (i.e., Archean and Paleoproterozoic terranes). Here, we show that eclogite melting processes may be principally responsible for the poor preservation of high-pressure records. We demonstrate eclogite melting via detailed petrological, geochronological, and geochemical analyses on eclogites and separated centimetric leucosomes from the central Himalaya. The central Himalayan eclogites were overprinted by strong granulite-facies metamorphism, such that omphacite is only sparsely preserved. Thermodynamic modeling results indicate the eclogite experienced two types of anatectic reactions: phengite dehydration melting at high pressure in the presence of omphacite, and subsequent omphacite-dominated melting during exhumation. Omphacite-dominated melting is characterized by the jadeite breakdown, releasing Na and Al into the melts. This melting mechanism subsequently forms a less sodic clinopyroxene and high Na_2O/K_2O melts. These Himalayan findings appear relevant to early Earth explorations because of the high thermal gradients and intense granulite-facies overprints, implying that partial melting of eclogite dominated by omphacite breakdown could have erased early high-pressure records of modern-style plate tectonics.

Furthermore, we found calc-silicate zones produced from eclogite melt−carbonate interactions that resulted in significant CO_2emissions from the same area. The interactions occurred at high temperatures (685−828°C) in the lower crust (1.2−1.4 GPa) during the middle Miocene (ca. 17−14 Ma). Decoupled Sr−O isotope ratios suggest that calc-silicate zones were produced by eclogite-derived granitic melts infiltrated carbonates during exhumation. Estimates of the C budget indicate that 1.27 tons of CO_2 was liberated during the formation of each cubic meter of calc-silicates, and <4% of the C remained at the reaction site. Map analysis suggests granite pluton areas vary from <10−1705 km^2 in the Himalaya and each pluton contributed to carbon outfluxes of up to 1361 tons/yr. In this collisional orogeny, deep Earth degassing due to melt−carbonate interactions released 0.14−0.18 Pg/yr CO_2during the middle Miocene. The release of such a large CO_2 reservoir into the atmosphere ultimately enhanced the global Miocene climate warming event.