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Metamorphic decarbonation in the Proterozoic ultrahigh-temperature metamorphism and its environmental implication

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Metamorphic decarbonation reactions and volcanic degassing lead significant influx of CO_2, a major greenhouse gas, into the ocean-atmosphere system from the solid Earth. The anhydrous mineral assemblages that characterize the Proterozoic granulite facies rocks, including charnockites and ultrahigh-temperature (UHT) rocks, require that water activity was buffered to low levels during their formation. One of the popular models invokes the influx of CO_2-rich fluids from the tectosphere mantle to generate dry mineral assemblages. Here we present quantitative estimates on CO_2 derived through degassing during UHT metamorphism in the Proterozoic through the mineralogical and geological analyses. In an attempt to investigate the link between CO_2 liberation from the carbonated tectosphere, UHT metamorphism and major earth processes, we address some of the important issues such as: 1) how the tectosphere had become carbonated; 2) how and when the tectosphere degassed; and 3) what is the difference between Proterozoic orogens and those of the present day. Our computations show that an extra flux of CO_2 was added to the atmosphere through a Himalayan scale UHT metamorphism to the extent of $6x10^{16}$ to $3x10^{18}$ mol/my, for a duration of 10 my. A calculation of the impact of the extra CO_2 influx to the global mean temperature in the context of carbon cycle and greenhouse effect of CO_2 shows that at the peak influx stage, the steady state temperature would be raised significantly.

The fate of the Earth as a habitable planet was dictated by fundamental interaction processes between ocean-atmosphere and solid Earth: selective removal of CO_2 into mantle in the Hadean time, carbonation of the Archean mantle wedge, subsequent decarbonation of the carbonated mantle through divergent metamorphism during Proterozoic, and decarbonation by water infiltration since the late Proterozoic. Our results also have important bearing in evaluating the mechanism of melting and the duration of Snowball Earth. Our estimate of the maximum degassing rate during UHT metamorphism suggests that the duration of Snowball Earth in Marinoan was probably shorter, than previous estimates.