

## Constraining Hesperian martian $P_{\text{CO}_2}$ from mineral analysis at Gale crater

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Carbon dioxide is an essential atmospheric component in martian climate models that attempt to reconcile a faint young sun with planet-wide evidence of liquid water at the planets surface in the Noachian and Early Hesperian. Current estimates of ancient martian CO<sub>2</sub> levels, derived from global inventories of carbon, and orbital detections of Noachian and Early Hesperian clay mineral-bearing terrains indicate CO<sub>2</sub> levels that are unable to support warm and wet conditions. These estimates are subject to various sources of uncertainty however.

Mineral and contextual sedimentary environmental data collected by the Mars Science Laboratory rover *Curiosity* in Gale Crater provide a more direct means of estimating the atmospheric partial pressure of CO<sub>2</sub> ( $P_{\text{CO}_2}$ ) coinciding with a long-lived lake system in Gale crater at ~3.5 Ga. Results from a reaction-transport model, which simulates mineralogy observed within the Sheepbed member at Yellowknife Bay by coupling mineral equilibria with carbonate precipitation kinetics and rates of sedimentation, indicate atmospheric  $P_{\text{CO}_2}$  levels in the 10's mbar range. At such low  $P_{\text{CO}_2}$  levels, climate models are unable to warm Hesperian Mars anywhere near the freezing point of water and other gases are required to raise atmospheric pressure to prevent lakes from boiling away. Thus, lacustrine features of Gale formed in a cold environment by a mechanism yet to be determined, or the climate models still lack an essential component that would serve to elevate surface temperatures, at least temporally and/or locally, on Hesperian Mars. Our results also impose restrictions on the potential role of atmospheric CO<sub>2</sub> in inferred warmer conditions of the Noachian.