# Paleoatmospheric Consequences of $CO_2$ Released During Tertiary Regional Metamorphism in the Himalayan Orogen

TALK

**D.M. KERRICK*, K. CALDEIRA* & L.R. KUMP***

Fluxes of metamorphic $CO_2$ to the atmosphere have been suggested to be climatically important (Fyfe, 1986; Varekamp et al., 1992; Touret, 1992). Using an overly simplified model of decarbonation of a 1 km-thick carbonate layer, Fyfe (1986) concluded that atmospheric $CO_2$ content could have been significantly affected by the Tertiary Himalayan orogenesis. However, the validity of the suggestion that metamorphic $CO_2$ has significantly affected the atmosphere critically depends upon a number of factors; i.e., duration of prograde metamorphism, abundance and composition of $CO_2$ source rocks, and escape of $CO_2$ to the Earth's surface. The Himalayan orogenic belt affords an excellent case study for analysis of these variables in determining the quantities and fluxes of $CO_2$ released by metamorphic decarbonation and graphitization.

The Eocene was the warmest epoch of the Cenozoic, with published estimates of Eocene atmospheric $CO_2$ content ranging from two to six times the current value. The Early Eocene (50–55 Ma) global warming may have been produced by the greenhouse effect arising from elevated $CO_2$ contents. Our calculations of $CO_2$ consumption by silicate weathering show that metamorphic $CO_2$ releases of ca. $10^{18}$/Ma could readily account for inferred Eocene atmospheric $CO_2$ contents and, consequently, Eocene warming.

Because of the lack of evidence for Eocene metamorphism in the central and eastern portions of the orogen, we focused on Eocene metamorphism in the western portion of the orogen (i.e., Zanskar and westward). Duration of prograde metamorphism was constrained by the timing of the India-Tibet collision (50–65 Ma) and the peak of prograde regional metamorphism (ca. 40 Ma). Due to lack of published estimates of the proportions and bulk compositions of metacarbonate and graphitic lithologies in the western Himalayan orogen, we coerced selected colleagues (J.A. DiPietro, M.S. Hubbard, K.P. Hodges, and M.P. Searle) into providing "guesstimates" of the proportions of such lithologies. In our computations we assumed marl as the model metacarbonate source rock and that 5 wt % of $CO_2$ was released during prograde metamorphism (Ferry, 1982). With a conservative assumption that carbonate rocks constitute ca. 10% (by volume) of the western Himalayan orogen (J.A. DiPietro, M.P. Searle), and that $CO_2$ was generated at a constant rate during the prograde event, we estimate that ca. $10^{19}$ moles/Ma of metamorphic $CO_2$ were produced at depth. Assuming 0.5% (by volume) of carbonaceous lithologies, $CO_2$ released from the graphitization of carbonaceous material is estimated to be ca. $10^{18}$ moles/Ma. These calculations assumed that $CO_2$ was linearly released during prograde metamorphism; however, because extensive devolatilization of marls and carbonaceous lithologies occurs during progradation through the lower greenschist facies (Ferry, 1982; Labotka et al., 1988), $CO_2$ production may have been two to four times more rapid than these estimates.

*) Earth Science Center and Geosciences Department, Penn State University, University Park, PA 16802, USA

The possibility of escape of metamorphic $CO_2$ to the atmosphere is indicated by the global correlation between the distribution of major zones of seismicity and carbon dioxide discharged from hot springs (Barnes et al., 1978). Release of metamorphic $CO_2$ to the atmosphere would have been impeded by retrograde carbonation and carbonate vein formation in the shallower (lower grade) portions of the orogens. However, in light of large fluid/rock ratios, significant expulsion of $CO_2$ to the atmosphere may have occurred by focused fluid flow along the Main Central Thrust (MCT) in the Himalayan orogen. Transient expulsion of large amounts of metamorphic volatiles is expected to have accompanied seismic activity along the MCT.

Geochronologic analyses reveal a remarkable similarity in peak metamorphic ages (40–50 Ma) for many areas within the Tethys and Circum-Pacific orogens, thus supporting the concept of a major, world-wide Eocene regional metamorphism. This metamorphic culmination was contemporaneous with increased Eocene atmospheric $CO_2$ and associated global warming. World-wide Eocene regional metamorphism could well have generated $\geq 10^{20}$ moles $CO_2$ /Ma at depth. Even if only 1% of the total metamorphic $CO_2$ produced escaped to the Earth's surface, there would have been significant paleoclimatic consequences.

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