A new negative feedback mechanism for balancing Tibet uplift-driven CO$_2$ drop: Evidence from Paleogene chemical weathering records in the northern Tibetan Plateau

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BLAG model

Robert A. Berner

Frings, 2019

Berner, 1990
Uplift-Weathering Hypothesis

Maureen Raymo

Zachos et al., 2008

Uplift

Steep slopes

Mass wasting

Mountain glaciers

Slope precipitation

Increased rock fragmentation

Increased weathering and CO₂ removal

Global cooling

Ruddiman, 2008
Negative Feedbacks to maintain geological carbon cycle

The imbalance resulting from accelerated CO$_2$ consumption and a relatively stable CO$_2$ input from volcanic degassing during the Cenozoic should have depleted atmospheric CO$_2$ within a few million years.

Therefore, a negative feedback mechanism must have stabilised the carbon cycle.

1 Reduce organic carbon burial (Raymo and Ruddiman, 1992)
2 Enhance reversal weathering and CO$_2$ release (Raymo and Ruddiman, 1992)
3 Enhance metamorphism degassing (Bickle, 1996)
4 Enhance sulfide weathering and CO$_2$ release (Torres et al., 2014)
5 Reduce Temperature-regulated weathering (Kump and Arthur, 1997)
   5.1 Ocean crust basalt (Coogan and Dosso, 2015)
   5.2 Ocean island basalt (Li et al., 2013)
   5.3 Continental arc (Lee et al., 2015)
   5.4 Weatherability (Caves et al., 2016)
   5.5 Weathering in other regions (Kump and Arthur, 1997)
CO₂ consumption increase in tectonically active region (e.g., Himalayas, where erosion rate increases)

CO₂ decline reduced the degree of silicate alternation in tectonically less active region (where erosion rate is stable)

Decrease in silicate weathering flux and CO₂ consumption in tectonically less active region

Carbon cycle balanced!!
1) During the Paleogene, the northern Tibetan Plateau was a tectonically less active area;
2) The Asian summer monsoon did not reach this region until the beginning of the Neogene.
Lithology and Age control

Qaidam Basin

Xining Basin
Clay mineral records in Qaidam Basin
Clay mineral records in Xining Basin
Global cooling regulate silicate weathering intensity in the northern Tibetan Plateau
In scenario (A), any increase in degassing flux will lead to an increase in temperature and ultimately will be balanced by nearly the same amount of increase in CO₂ uptake flux through increases in the silicate weathering intensity and thus in the silicate weathering flux.

In scenario (B), given a constant degassing flux, any increase in erosion in orogenic belts will result in an overall increase in the CO₂ uptake flux in orogenic belts. This will be quasi balanced by nearly the same amount of decrease in CO₂ uptake flux in flat tectonically inactive regions through decreases in in the silicate weathering intensity and the silicate weathering flux.
Model test

\[ \ln\left( \frac{k_{\text{post-uplift}}}{k_{\text{pre-uplift}}} \right) = -\frac{Ea}{R}\left( \frac{1}{T_{\text{post-uplift}}} - \frac{1}{T_{\text{pre-uplift}}} \right) \]

52-36 Ma Temperature drop 7-8 °C, ~0.44 °C/Myr

Silicate weathering rate drop 4%/Myr

Zachos et al., 2008
Model test

Pre-uplift:
Area of tectonically inactive region: 99.6%
Area of tectonically active region: 0.4%
Uniform erosion flux everywhere,
Weathering flux in proportion to area

Post-uplift:
Weathering flux drop in tectonically inactive area would be balanced by erosion-induced weathering flux increase in tectonically active region

Result:
Erosion increase in tectonically active region should be >100-fold
Modern observations

West et al., 2005
Paleogene global cooling–induced temperature feedback on chemical weathering, as recorded in the northern Tibetan Plateau

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